FINAL
8/16/2021

2021

HRTPO Regional Connectors Study, Phase II, Technical Guide

Documentation of Phase II Scenario Planning

Table of Contents

Phase II Technical Guide

The Technical Guide for the Phase II scenario planning under the Hampton Roads Transportation Planning Organization's (HRTPO) Regional Connectors Study (RCS) is intended to document Phase II scenario planning activities, explaining the overall scenario planning and modeling process. The Technical Guide is also intended to serve as a resource for further scenario analysis, allowing users to understand how the scenarios were developed and the underlying assumptions in the modeling.

Throughout the Phase II process, the consultant team generated several technical memos and white papers on various elements of the modeling process. Content from those documents has been incorporated into the Technical Guide. Part II of the Technical Guide provides further technical documentation of each of the computer models used in the scenario planning effort.

Part I. Documenting the Phase II Scenario Planning Process

The first part of the Technical Guide is intended to document the planning and modeling process for the scenarios conducted as part of the Phase II RCS. This part of the Technical Guide includes a general background of the planning effort, to inform any readers that are less familiar with the scope and timeline of the scenario planning process. The chapters in this part explain the process of building the scenarios and the overall Phase II modeling process.

Part II. Documenting Modeling Data and Assumptions

Part II of the Technical Guide consists of a detailed documentation of the data and methodology used in each of the models used in the scenario planning process. This part includes content from technical documentation prepared during Phase II. While Part I will help the reader understand the scenario planning process, assumptions and modeling process, Part II is the technical documentation of the assumptions and inner workings of the models.

Part III. Appendices

The appendices include other resources, such as a technical memoranda developed early in the process to document the project Goals and Objectives as well as analyses that were used to build the final drivers and performance measures. The Appendices also contain a glossary of terms and other references that may be helpful to anyone operating the models in the future.

Acronyms

The following are common acronyms used throughout the Technical Guide. A full Glossary of Terms is included at the end of this document.

CTB: Commonwealth Transportation Board
FEIS: Final Environmental Impact Statement
FHWA: Federal Highway Administration
GIS: Geographic Information Systems
HRCS: Hampton Roads Crossing Study
HREDA: Hampton Roads Economic Development Alliance
HRPDC: Hampton Roads Planning District Commission
HRTAC: Hampton Roads Transportation Accountability Commission
HRTF: Hampton Roads Transportation Fund
HRTPO: Hampton Roads Transportation Planning Organization
MMMBT: Monitor–Merrimac Memorial Bridge–Tunnel
REMI: Regional Economic Models, Inc.
RCS: Hampton Roads Regional Connectors Study
SEIS: Supplemental Environmental Impact Statement
TAZ: Transportation Analysis Zones
TEU: Twenty-Foot Equivalent Unit
TREDIS: Transportation Economic Development Impact System
TDM: Travel Demand Model
USACE: United States Army Corps of Engineers
VDOT: Virginia Department of Transportation

Part I. Documenting the Phase II Scenario Planning Process

In Phase I and II of the RCS, a consulting team worked with the Hampton Roads Transportation Planning Organization (HRTPO) to develop a series of models:

- A land use model that would interface with the region's Travel Demand Model (TDM),
- A series of refinements to the regional TDM to allow modeling of a suite of land use scenarios
- An economic analysis model, called TREDIS that would use the TDM results to generate economic data

In Phase III of the RCS, the consultant team will use the three models to evaluate different transportation investments for new or expanded facilities across Hampton Roads.

This Technical Guide focuses on the scenario planning and modeling process. The following chapters provide an overview of:

- The development of the goals and objectives and performance measures for the project
- The analysis of regional growth and drivers of change that resulted in three future scenarios for the Hampton Roads region,

  The development of the land use model, and the technical process and assumptions used for the Travel Demand and Economic models for Phase II

Overview of Part I

Part I is intended to accomplish two broad objectives: 1.) Document the development of the scenario planning and modeling under Phase II; and, 2.) Serve as a resource for the modeling analysis work in Phase III and any subsequent modeling done for the region. The RCS consultant team prepared technical memos and white papers throughout the Phase II process, regarding scenario planning and modeling. Part I of this document consolidates content from these memos and white papers and assembles them into a more comprehensive narrative of the whole process, thus creating a logical and user-friendly narrative of the Phase II scenario planning process. Part II of the Technical Guide also includes additional information, not included in previous documents to give a more detailed understanding of the model assumptions. Generally, this Guide also roughly follows the tasks in the Phase II Scope of Work for the RCS.

Chapter I: Background

In 2015, the Virginia Department of Transportation (VDOT), in coordination with the Federal Highway Administration (FHWA), initiated the preparation of a Supplemental Environmental Impact Statement (SEIS) for the March 2001 Hampton Roads Crossing Study (HRCS) Final Environmental Impact Statement (FEIS).

On July 25, 2016, the FHWA and Commonwealth Transportation Board (CTB) approved the Hampton Roads Crossing Study Draft Supplemental Impact Statement (HRCS SEIS). At its September 2016 meeting, the Hampton Roads Transportation Planning Organization (HRTPO) unanimously approved the HRCS SEIS Alternative A, "modified" to include the Bowers Hill Interchange, as the region's Preferred Alternative. On October 20, 2016, the Hampton Roads Transportation Accountability Commission (HRTAC) also unanimously supported the HRTPO's selection of Alternative A-modified, and allocated up to $7 million of Hampton Roads Transportation Fund (HRTF) for further study of the HRCS SEIS components not included in the selected Alternative A.

On December 7, 2016, the CTB approved Alternative A and instructed VDOT to continue to work with HRTPO, HRTAC, USACE, Navy, the Port of Virginia, and others to advance separate studies to identify appropriate access options around Craney Island to include I-564/I-664 Connectors, I-664/MMMBT and 164/164 Connector. The resolution also directed VDOT to continue to work with HRTPO, HRTAC, USACE, and other parties to advance a separate study of the Bowers Hill Interchange in Chesapeake.

In January 2017, the HRTPO Board directed staff to work with VDOT, HRTAC, and other partners to develop a Memorandum of Understanding (MOU) for supporting studies on how to move forward with the remaining segments of the SEIS and the Bowers Hill Interchange. The May 1, 2017 MOU was signed among the HRTPO, VDOT, and HRTAC to advance two separate components:

- $4 million for study of the Bowers Hill Interchange following the NEPA process, to be managed by VDOT.
- $3 million for Additional Feasibility Studies of the remaining components of the HRCS SEIS not included in the approved Alternative A, to be managed by the HRTPO. In March 2017, HRTAC approved a contingency of $4 million to be available if additional funding is required for the completion of the HRTPO Feasibility Studies.

Regional Connectors Study

HRTPO kicked-off the Regional Connectors Study in June 2018 with funding from HRTAC. The study focuses on Hampton Roads connectivity through the lenses of congestion relief, economic vitality, resiliency, accessibility, and quality of life.

The HRTPO Regional Connectors Study reexamines projects previously studied in the HRCS SEIS, seen in Figure 1, including:

- VA 164
- I-564 Connector
- VA 164 Connector
- I-664 Connector
- I-664 widening (from I-64 in Hampton to US 460/58/13 in Chesapeake)

In addition to these projects, HRTPO may also study other feasible projects that could improve Hampton Roads connectivity. The completed study will provide a long-term vision for improved connectivity between the Peninsula and Southside, with recommendations for project phasing.

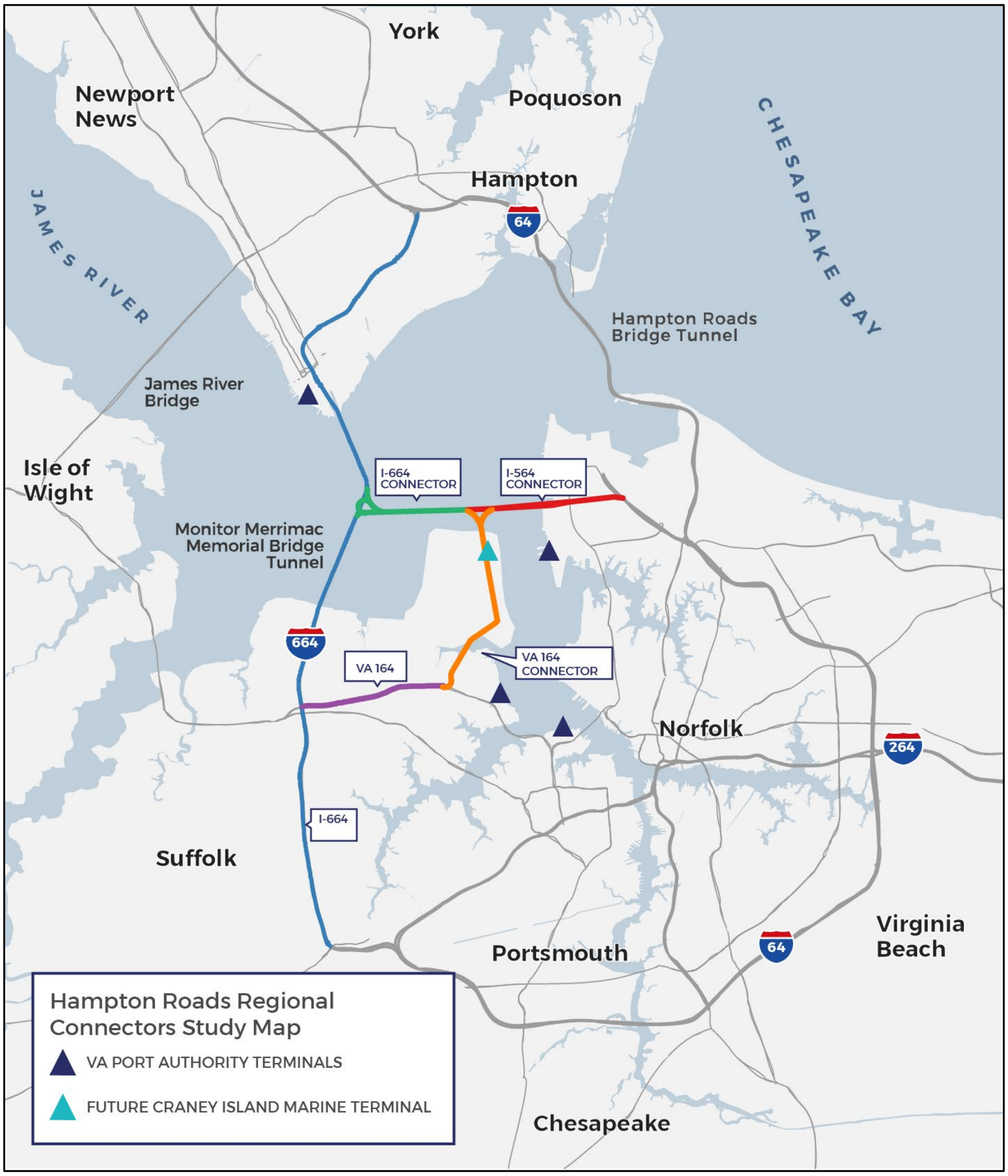


Figure 1. *Hampton Roads Regional Connectors Study map*

Phase I

HRTPO determined that the Regional Connectors' Study would best be conducted through a multi-phased approach. Phase I resulted in the establishment of goals and objectives for the remainder of the study and included the development of a draft scope for Phase II. Phase I entailed the following five tasks:

- Task 1: Develop and initiate an engagement program
- Task 2: Evaluate the regional travel demand model
- Task 3: Define the scenario planning effort
- Task 4: Update existing conditions information
- Task 5: Present findings at Working Group meetings

Chapter II: Phase II Process

The RCS Phase II process entailed development of the models and scenarios for the technical analysis required to identify, assess, and prioritize potential transportation improvements to enhance connectivity between the Peninsula and the Southside of Hampton Roads. Following is an overall summary of the Phase II process as detailed in the following chapters. This chapter can be used a s a quick reference for the overall process but greater detail is provided in chapters 3 through 8, below.

The major tasks in Phase II are summarized below and form a good summary of the entire Phase II process detailed in the subsequent chapters of this Technical Guide.

Scenario Planning

The RCS Regional Scenario Planning process provides insight to decisionmakers regarding the need for and the benefits of alternative transportation investments considering potential alternative future trends. The scenario planning process considered a baseline 2045 scenario and three alternative 2045 scenarios (also called greater growth scenarios) that presented plausible futures with respect to economic, demographic and technology drivers. The scenarios developed in Phase II will be analyzed in Phase III.

Base Geography

The consultant team's land use modeling staff built the GIS base for the scenario planning effort. The Consultant Team built a layered base, using GIS data, of the entire region to be used as the platform for spatial allocations in the land use model, using CommunityViz software. Data collection in this task included collecting information on demographics, housing, transportation, environment, infrastructure, governance, employment, education, finance and a host of other measures.

Place Types

The land use allocation aspect of the scenario planning process is conducted through a "Place Type" approach. The regional land use categories used in the HRTPO's regional land use map were converted into a series of typical community or "place" types such as low density residential, agricultural, or mixed-use community with a commercial or residential focus. These Place Types were used both to profile the existing land use pattern in the region and to construct each of the future land use scenarios.

The process of building the Place Types for use in the land use model involved several steps, including:

1. Profiling existing and future land uses in the region to calibrate the Place Type capacities to typical existing residential densities and nonresidential intensities
2. Developing quantitative summaries of each Place Type that summarizes land uses, developed areas, and environmental data for each to build into the land use model
3. Developing summary visualizations of the Place Types, to clearly explain them to stakeholders and the public.

Virtual Present

The current population, employment and land uses in the region were assembled for modeling purposes into a map dataset called the "Virtual Present". Building the Virtual Present involved allocating population and employment to the Place Types in the GIS base map of the region to match the existing pattern of population and employment as contained in the regional TDM for the year 2015. This involved breaking down the data contained in each Transportation Analysis Zone (TAZ) in the TDM to the Place Type-level geography of the land use model.

The output was a GIS map of the region that converts the existing land uses to Place Types, with socioeconomic data that exactly matches the data that is in the TDM for the year 2015.

No Build Analysis

The No Build Analysis was a necessary step to build future scenarios and land use allocations. To be able to allocate *new* development based on growth scenarios, it was necessary to understand which lands are suitable for development from a regulatory, environmental and existing conditions standpoint. In this task, a series of new data layers were added to the regional GIS base that describe the feasibility of the land for development or redevelopment based on:

- Federal, state or local government-owned lands
- Environmental constraints
- Utilities, infrastructure, and easements
- Zoning and other regulatory constraints
- Flood and inundation zones
- Value of land and improvements (used to determine potential for redevelopment of built out parcels)
- Other constraints or factors influencing development potential

Together, the Virtual Present map and the No Build overlays defined where new growth is feasible which could be used for allocating growth in the future scenarios.

Calibrating "Virtual Present" to TAZs

Calibration was an important aspect of this process, allocating land use to the control totals for socioeconomic data in the TDM for each TAZ. This task involved modifying the Place Type allocation in the Virtual Present so that the population and industry employment totals match the controls in each TAZ according to the TDM. This ensures that the Virtual Present map exactly matches the spatial distribution of population and employment data that is used in the TDM so that the land use scenario planning model (CommunityViz) and the TDM are in synch. This highlights any significant differences between the 2015 land use data and the socioeconomic data in the TDM.

Alternative Future Scenarios

This task was crucial to the overall process as it defined the set of alternative future scenarios that served as the basis for all the subsequent analysis and modeling in the project. In this task, the Consultant Team collaborated with the Working Group to define and affirm three draft "framework" scenarios. The framework scenarios are simplified narrative descriptions of each scenario in plain language that describe the storyline for each alternative future. Through a series of work sessions with the Working Group and HRTPO staff, a set of draft frameworks were developed, each of which profiles a different economic and growth future for the region.

Once the framework scenarios were defined and vetted, the Consultant Team conducted research and applied technical expertise to propose a set of draft trend drivers to develop the future scenarios. These drivers were major change parameters in basic categories such as:

- Demographics and location choice
- Economy
- Technology

Each category has a set of quantitative drivers associated with it, used to construct the alternative future scenarios.

Scenario Performance Measures

In this task, a set of scenario performance measures were applied to the specific modeling methodology used in the land use model and related GIS data, the TDM, and the economic models (including TREDIS, REMI, and spreadsheet “models”).

The remaining chapters explore these tasks in greater detail, with Part II documenting the technical elements of the land use model.

Chapter III: Goals, Objectives & Performance Measures

The Regional Connectors Study scope of work includes a vision statement and a task to develop goals, objectives, and performance measures for the project. This work was carried out in the spring and early summer of 2019 through a series of meetings with the RCS Working Group and stakeholders from the region. All jurisdictions within the HRTPO region as well as other stakeholders in the region were invited to share their input as part of the development of the goals and objectives for the process. The study performance measures were approved by the RCS Steering Committee on July 9, 2019. This chapter documents the development process and approved performance measures for the RCS scenario planning. These performance measures were reported for the scenario-based analyses, and a subset of the measures will be selected in Phase 3 for evaluating the performance of the Regional Connector alternatives in the process of selecting candidate alternatives.

Vision and Goals

At the RCS Working Group meeting on March 28, 2019, the study team kicked off the development of project Vision and Goals (see Appendix B). The Working Group affirmed the project Vision as stated in the "Guidance for Scope of Work" of the RCS Request for Proposals. The Vision states that the RCS study will:

> *Establish a regional long-term vision that investigates 21st century transportation options that connect the Peninsula and the Southside across the Hampton Roads Harbor that enhance economic vitality and improve the quality of life in the region.*

The input that had been received in the project from regional stakeholders was summarized and, through a series of discussions in the March 28th and April 11th, 2019 RCS Working Group meetings, a set of themes was established to shape the project goals and objectives, and these were combined into a final draft set of goals and objectives that were presented in the RCS Working Group Webinar #5 on May 2, 2019, along with a draft set of performance measures. With input from stakeholders and the Working Group, the goals and objectives were refined and approved for referral to the Steering Committee in June. The approved goals and objectives for the RCS are shown in Figure 2. The detail of the initial study themes that were synthesized into the final goals and objectives is provided in Appendix B.

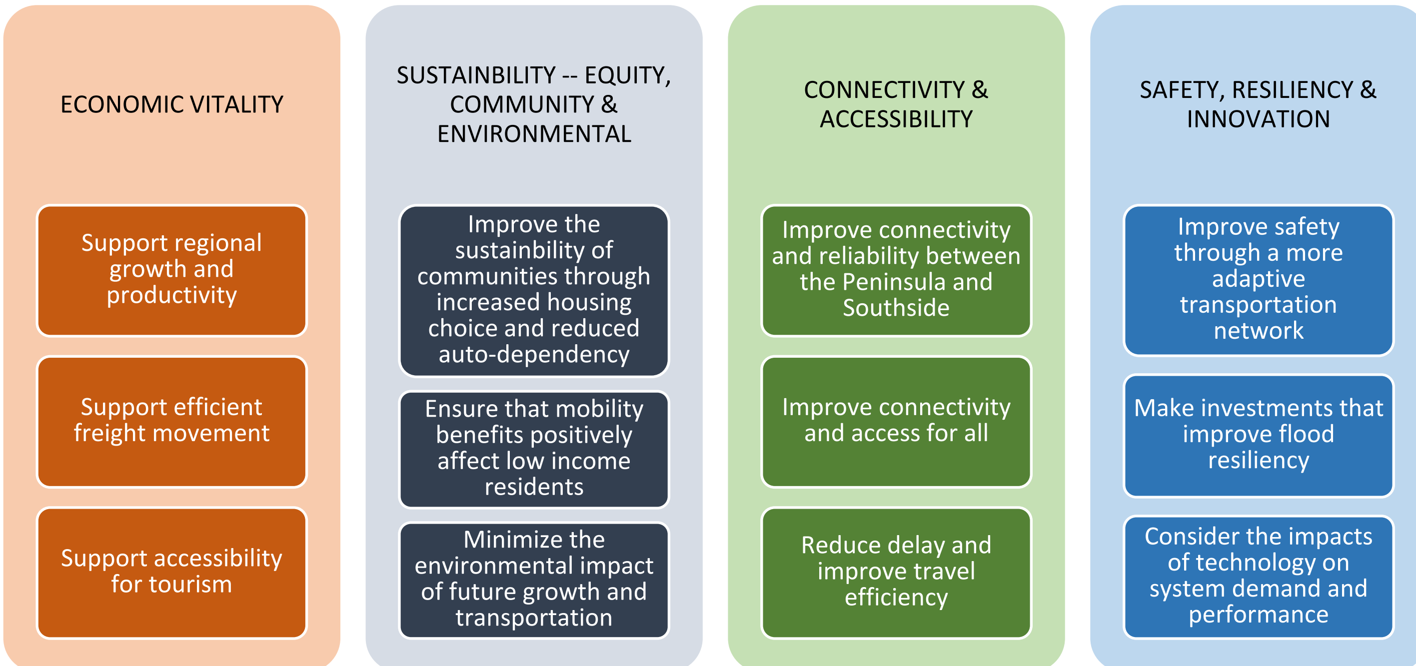


Figure 2. *Regional Connector Study goals and objectives*

Performance Measures

The RCS Working Group discussed concepts and priorities for the performance measures in their April 11, 2019 meeting, after which they requested the consultant team to develop a recommended set of performance measures. The framework provided in the Working Group meetings shaped the content of the draft performance measures. The performance measures also were shaped by the following guiding principles for developing strong performance measures:

- It is specific and clear about what is being measured.
- It accurately reflects the goal/objective that you are trying to accomplish
- The units make sense (dollars, hours, jobs, etc.)
- Only add complexity if it adds meaning (ex: Vehicle Miles Traveled (VMT) per capita is meaningful)
- Spatial: Some measures can be both summarized regionally and shown spatially, and both have value
    - Example: Congestion can be summarized (regional hours of delay) but also mapped on the network
- Comparative: It focuses on a meaningful comparison
    - Example: Compared to 2045 baseline, compared to the same scenario with other RCS alternatives, etc.

The draft performance measures were initially developed in relation to the objectives – each began as a specific measure grounded in one objective. However, the Working Group noted that, once defined, many performance measures add insight to multiple objectives. Therefore, the draft performance measures were ultimately presented in a matrix format, denoting the relevant objectives for each measure. The full set of draft performance measures is shown in Figure 3. As indicated in the second and third columns of Figure 3, some of the measures focus primarily on the scenario land use outcomes, and others focus primarily on the transportation network outcomes. The first set of measures ("scenario measures") were only analyzed for the four land use scenarios: 2045 Baseline ("Baseline"), Greater Growth on the Water, Greater Growth in Urban Centers, and Greater Suburban/Greenfield Growth. As mentioned above, the final set of performance measures included some adjustments and additions based on the final model runs to be able to highlight the most meaningful measures that show clear differences between the scenarios based on each model's outputs. When the scenario model runs are performed with the RCS Alternatives, the results will focus on the "Candidate Project Measures." Note that many measures, particularly those with accessibility and/or economic components, fall in both categories.

Several terms used in the performance measures reflect important transportation and regional planning concepts. These terms are explained below and in the Glossary in Appendix E.

- **Accessibility** – the collective ability of travelers to access specified types of destinations (such as jobs) within a reasonable travel time by the specified mode of travel (automobile, transit, etc.) on the transportation network
- **Reliability** – the predictability of travel times; for example, the amount of extra time that must be allowed for a certain trip to accommodate the worst level of recurring congestion
- **Productivity** – the economic value of time lost or gained through travel, such as time spent in traffic congestion or time gained in higher-speed travel or shorter commutes
- **Mode Share Index** – the profile of the share of travel for each mode (automobile, transit, bike, etc.) for a particular area such as a traffic analysis zone (TAZ).
- **Place Types** – land use categories that describe distinctly different development patterns such as "mixed use residential" and "neighborhood commercial"
- **Delay** – the difference between congested and uncongested travel times
- **Circuity** – the difference between the distance of a route traveled on the network and the straight-line distance between origin and destination
- **Bottlenecks** – congestion hot-spots that create upstream congestion, such as lane reductions or busy interchange weaving areas

Several measures begin with "change in" in parentheses – this indicates that the baseline metric was reported for the 2045 Baseline scenario and the greater growth scenario performance was reported as the change in that metric relative to the 2045 Baseline. The performance measures were provided in a dashboard format to facilitate understanding and comparisons of the data by the RCS Working Group, RCS Steering Committee, stakeholders, and the public.

June 21, 2019

GOALS →			ECONOMIC VITALITY			SUSTAINBILITY -- EQUITY, COMMUNITY & ENVIRONMENTAL			CONNECTIVITY & ACCESSIBILITY			SAFETY, RESILIENCY & INNOVATION		
OBJECTIVES →			Support regional growth and productivity	Support efficient freight movement	Support accessibility for tourism	Improve the sustainbility of communities through increased housing choice and reduced auto-dependency	Ensure that mobility benefits positively affect low income residents	Minimize the environmental impact of future growth and transportation	Improve connectivity and reliability between the Peninsula and Southside	Improve connectivity and access for all	Reduce delay and improve travel efficiency	Improve safety through a more adaptive transportation network	Make investments that improve flood resiliency	Consider the impacts of technology on system demand and performance
Performance Measures ↓	Scenario Measure	Candidate Project Measure												
(Change in) Lost productivity from delay	■	■	✓							✓	✓			
(Economic impact of change in) Labor market accessibility	■	■	✓						✓	✓	✓			
Performance on the freight network - total delay + spatial results	■			✓					✓		✓			
Change in hours of delay on freight network		■		✓					✓		✓			
Economic impact of change in delay and reliability on the freight network		■		✓										
(Change in) Percent of freight traffic on secondary streets - total + spatial	■	■		✓				✓				✓		
Traffic volumes at at-grade rail crossings		■						✓			✓	✓		
(Change in) Accessibility to major tourist attractions	■	■			✓									
Percent of population in multi-family housing	■					✓								
(Change in) Mode share index	■	■				✓								
(Change in) Transit ridership	■	■				✓								
Percent of growth near key destinations	■					✓								
Average trip length by purpose		■				✓				✓	✓			
Percent of jobs/pop within (15 min) drive time to airport or Amtrak station	■	■			✓					✓				
Ratio of user costs for low income travelers to all user costs (ratio of savings)	■	■					✓							
Low income household access to employment	■	■					✓							
Percent of growth near transit stops	■					✓	✓	✓						
Percent of growth in urban place types	■							✓						
(Change in) cost of emissions	■	■						✓						
Percent of growth on formerly undeveloped land (per 2016 Land Cover Data)	■							✓						

June 21, 2019

GOALS →			ECONOMIC VITALITY			SUSTAINBILITY -- EQUITY, COMMUNITY & ENVIRONMENTAL			CONNECTIVITY & ACCESSIBILITY			SAFETY, RESILIENCY & INNOVATION		
OBJECTIVES →			Support regional growth and productivity	Support efficient freight movement	Support accessibility for tourism	Improve the sustainability of communities through increased housing choice and reduced auto-dependency	Ensure that mobility benefits positively affect low income residents	Minimize the environmental impact of future growth and transportation	Improve connectivity and reliability between the Peninsula and Southside	Improve connectivity and access for all	Reduce delay and improve travel efficiency	Improve safety through a more adaptive transportation network	Make investments that improve flood resiliency	Consider the impacts of technology on system demand and performance
Performance Measures ↓	Scenario Measure	Candidate Project Measure												
(Change in) Delay on cross-harbor trips [time and dollar value]	■	■							✓		✓			
(Change in) Circuity of cross-harbor trips	■	■							✓		✓			
(Change in) Reliability for cross-harbor trips [time and dollar value]	■	■							✓					
(Change in) Cross-harbor accessibility									✓	✓				
(Change in) Multimodal accessibility to jobs	■	■								✓				
(Change in) Accessibility index by mode	■	■								✓				
Performance of the transit-serving roadway network [i.e., average speed]	■	■								✓				
(Change in) Regional delay [total + spatial]	■	■									✓			
System reliability	■										✓			
Reliability cost savings		■									✓			
(Change in) User cost	■	■					✓				✓			
Bottlenecks on identified priority military routes		■	✓								✓			
Bottlenecks on identified evacuation routes (daily peak conditions)		■									✓			
Cost of forecasted crashes	■	■										✓		
Percent of trips by automated vehicles	■											✓		
(Change in) Percent of travel using facilities wth adaptive technologies [e.g., V2I, ITS]	■	■										✓		
Percent of growth near flood-prone areas	■							✓					✓	
(Change in) Transportation network impact from flood-prone conditions [e.g., delay, trip length, and/or circuity]	■	■						✓					✓	
Reliability enhancement from technology	■													✓
Induced trip demand from technology	■													✓

Figure 3. *Regional Connector Study goals, objectives, and performance measures*

Chapter IV: Scenario Planning Framework

This chapter describes the approach to scenario planning to be applied in the RCS. It describes the overall framework for scenario planning and gives particular attention to the methods for analyzing and allocating regional land use for the scenarios.

Scenario planning can be defined as the process of planning for the future by analyzing existing trends and organizing them into a series of plausible future scenarios to explore their consequences. Scenario planning is useful in understanding the potential impacts of current and proposed policies in the face of these potential futures. With respect to land use planning, scenario planning provides a method for exploring potential future land development patterns and alternative forecasts of population and jobs in a locality or region. This exploration is done through the development of multiple future land use scenarios in which growth is driven by distinct sets of trend "drivers." The drivers represent forces such as demographic change, economic trends or technological advances, which can all affect land use patterns in different ways. After the scenarios are developed, their impacts can be quantified and used as evaluation measures against which to test the viability of policies and investments in the long-term.

Figure 3. *Conceptual diagram of scenario planning approach*

Scenario Planning in the Regional Connectors Study

For the Hampton Roads Regional Connectors Study (RCS), scenario planning was used to test potential future land use and growth scenarios as a basis for further analyzing potential future transportation alternatives. Normally, transportation alternative testing is done against a single future land use scenario that is built into the regional transportation planning assumptions, typically within a regional TDM. This land use scenario is usually developed in consultation with each locality and represents their collective vision for how much population and employment growth will be distributed across their jurisdictions and where that growth will be located.

In the Regional Connectors Study, however, a series of land use scenarios was developed for the Hampton Roads region, and the regional transportation alternatives will then be tested against each of these potential future land use patterns. This approach provided a more sophisticated "resilience test" of each of the transportation alternatives. It will yield information about how each transportation improvement package would perform under very different future land use conditions. As an example, proposed improvements that rely on transit investments require compatible and supportive densities of land uses to make extensive transit mode share viable. Alternately, future expansion of marine-related employment growth may show better performance for some types of transportation investments that support freight movement near the water. Therefore, the exploration of different land use growth patterns will allow for a much deeper analysis of the resilience of future transportation investments in the face of uncertainty. Using scenario analysis to test the outcomes of investments helps reveal how beneficial and robust potential transportation investments are; in other words, how resilient the investments are. The ultimate goal is to make the wisest possible transportation investments, ones that can stand up optimally in light of several potential growth futures and that will be most resilient to change and uncertainty.

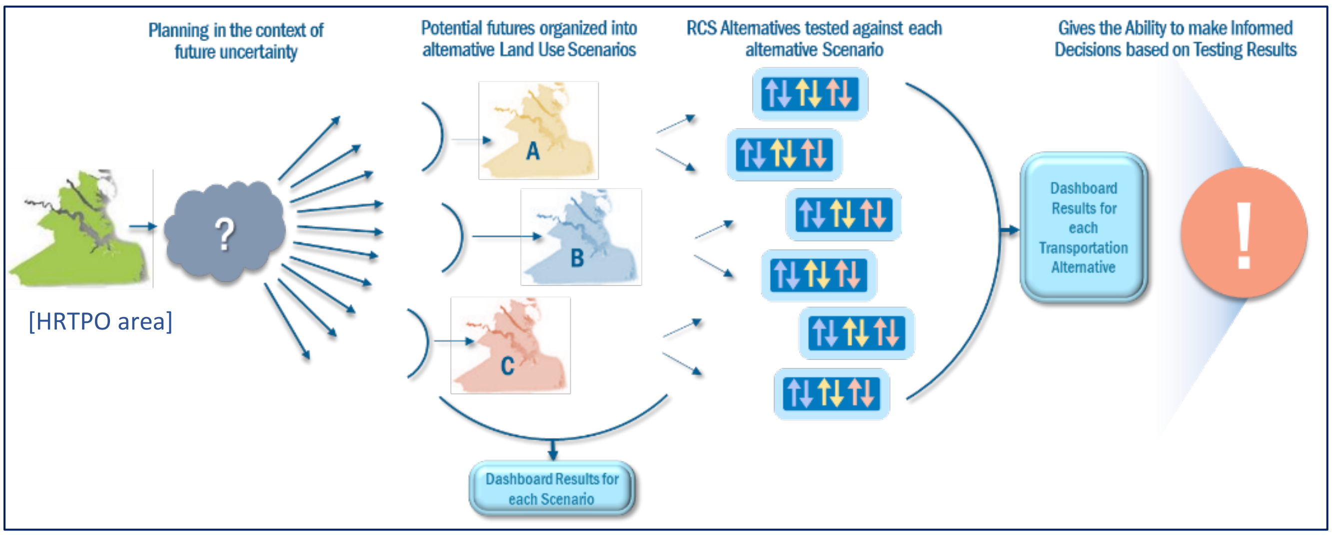


Figure 4. *Diagram of the process of testing transportation alternatives against potential future land use scenarios used in the regional connectors study process*

Scenario Development

The regional scenario planning process was conducted through 2019 and the beginning of 2020 by the study team, working with the RCS Working Group and with input from regional stakeholders. All information in the process was posted on the project website which was linked from the general HRTPO website and there were opportunities for public review and input through the HRTPO comment portal (see Appendix F for survey results). In addition, the study team conducted a series of 7 public webinars, from February 2019 to January 2020 to walk through each step in the development of the scenarios and data assumptions to ensure that the complex modeling process had good understanding and vetting by the public and stakeholders. The overall scenario planning framework for this project had approval from the RCS Working Group and Steering Committee, as well as from the HRTPO Policy Board.

Baseline Growth Assumptions

Through an interactive process with the RCS Working Group and input from regional stakeholders, the study team began by developing assumptions about the amount of population and employment growth that would be used as the basis for the development of the land use scenarios. The starting point for these assumptions is the growth totals that were approved by the HRTPO Policy Board and built into the 2045 Regional Travel Demand Model (TDM). These totals and the 2015 base year totals (the latest approved for the HRTPO TDM) are summarized in Table 1.

Table 1. *Approved 2015 and 2045 Regional Control Totals*

Year	Employment	Population
2015	1,027,006	1,725,777
2045	1,108,274	2,024,085

The RCS Working Group, with approval by the RCS Steering Committee, decided to use these assumptions as the "2045 Baseline" scenario and to develop three other scenarios that would assume an additional amount of "greater growth" above the 2045 baseline level. The 2045 employment growth represents an increase of 8 percent over the 2015 employment total. The RCS Working Group, including regional stakeholders, and the study team reviewed alternative forecasting assumptions and related trends and scenarios, as documented in Appendix A: *Economic Trends and Opportunities in the Hampton Roads Region - Technical Memo* to develop a recommended change in employment growth control total for the three greater growth scenarios. The RCS Working Group recommended, and RCS Steering Committee approved, an employment increase of 16 percent over the 2015 employment total. The Steering Committee's approval allows up to 21 percent growth to be modeled if the initial modeling of 16 percent growth does not produce adequate differentiation between scenarios. The HRPDC staff used their REMI© regional economic model to derive population growth totals from the 16 percent employment growth assumption. The scenario planning control totals for population and employment for the three "greater growth" scenarios are as follows:

Table 2. *Control Totals for the "greater growth" scenarios using 16 percent employment growth 2015-2045*

	Greater Growth Total	2015 – 2045 Growth	Greater Growth Amount over 2045 Baseline
Employment	1,187,532	163,798	82,972
Population	2,127,172	408,214	110,460

The population growth in the greater growth scenarios is driven by the increased workforce needs of the growth in employment and related effects as processed by the REMI© model. Note that while jobs are added at approximately twice the rate in the greater growth scenario between 2015 and 2045 as in the baseline (16% compared to an 8% increase), the incremental population increase is lower (23% compared to 17%). This occurs because the baseline forecast includes demographic trends for all people in the region including retiring populations/older non-working adults, whereas the employment growth increment in the greater growth scenarios drives additional economic migration to the region of people and their families to meet the additional job growth.

The three greater growth land use scenarios use the specified growth control totals. The amount of growth to be allocated by the land use model is the increment of employment and population growth *over the 2045 Baseline* (i.e., 83,053 jobs and 110,569 population). The land use model does not re-allocate any of the 2015 to 2045 Baseline forecast growth. The land use scenario testing also uses the existing plus committed project (E+C) transportation network from the regional TDM as an assumed transportation network in all scenarios.

Baseline Scenario

The 2045 Baseline Scenario uses the forecasted growth for the region in the 2045 Regional TDM. It consists of the 2045 socioeconomic forecast that was approved for the region by the HRTPO Board allocated into a total of over 1,500 TAZs. For the purposes of scenario planning, the 2045 Baseline is used to compare against the three greater growth scenarios.

Greater Growth Scenarios

The three greater growth scenarios are the alternative future land use scenarios that were developed interactively by the Working Group, reviewed by the public and stakeholders and approved by the Steering Committee. They represent the alternative future land use patterns against which the transportation investment alternatives will be tested. Figure 6 depicts the scenario narratives, including the key drivers for each scenario that were agreed upon for this study. Each scenario has a distinct set of trend drivers that inform different patterns of economic and population growth in the region as well as technology that will affect transportation demand and performance. The drivers represent external forces that can influence growth and transportation dynamics in the region. The scenario planning process uses a set of computer models to translate the drivers into variable input measures that yield variable outcomes to be studied under each scenario. Specifically, the Land Use Allocation model uses GIS data and the techniques described in the remainder of this chapter to modify the distribution of jobs and population in each scenario, and the TDM uses a combination of built-in levers and modified travel behavior and network performance assumptions to represent the impact of technology drivers. The scenario drivers are documented in detail in the *Technical Memorandum on Scenario Drivers*.

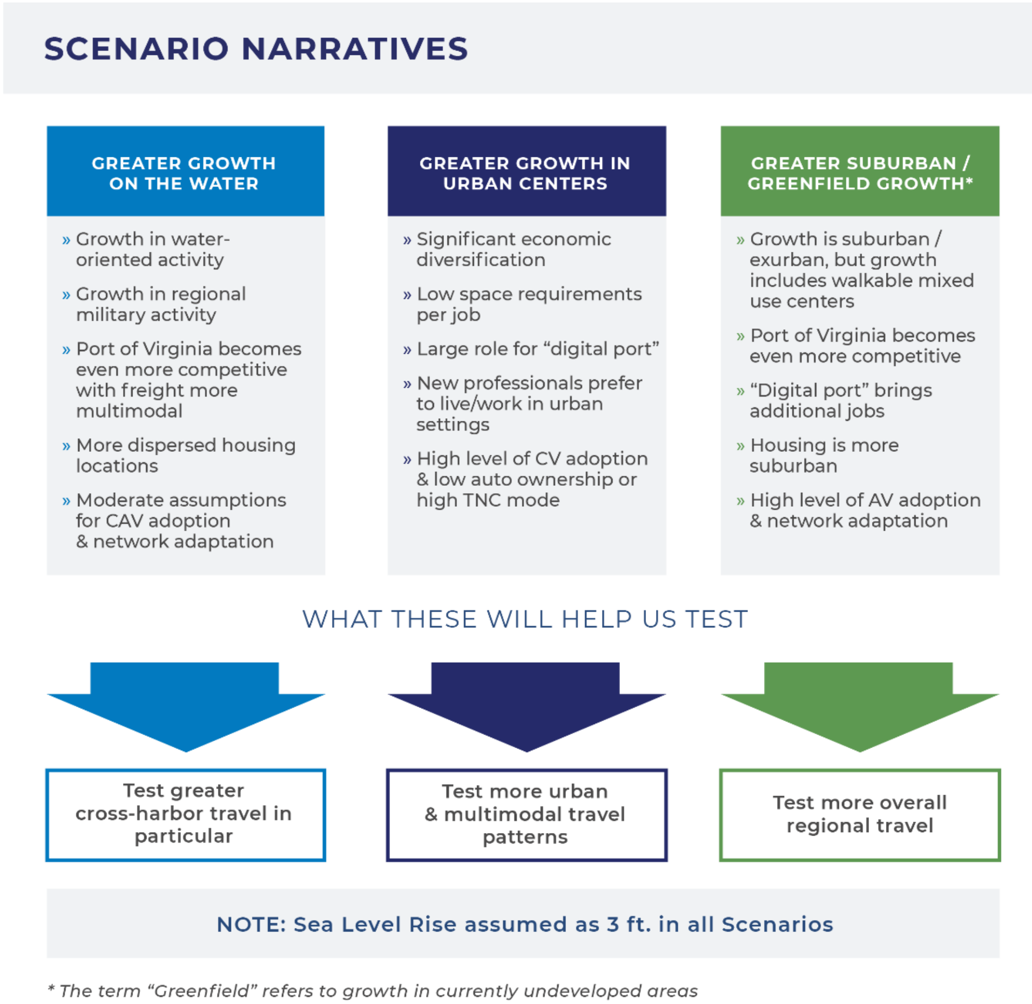


Figure 5. *Greater growth scenario narratives*

Chapter V: Drivers and Suitability Factors

Introduction

The Regional Connectors Study (RCS) scenario planning effort has created three alternative scenarios that explore the implications of plausible additional future growth over the Hampton Roads Transportation Planning Organization's (HRTPO) 2045 growth forecasts. (See the RCS *Scenario Planning White Paper*, November 2019, for additional background information.) The scenarios comprise different trend drivers that represent uncertain aspects of the future including economics, demographics and lifestyle (as related to land use decisions), technology, and the environment. In the RCS scenario planning process, the economic and land use-related drivers affect the spatial distribution of employment and population via the land use allocation model. The technology and port drivers affect the travel parameters specified in the travel demand model. The environmental driver is sea level rise, which is held constant across the three scenarios and reflected in the availability of land in the future, as implemented in the land use model.

Although incremental growth is held constant across the three alternative scenarios, each scenario represents a different vision of the region's economic future. Each scenario frames a different narrative for growth with its own set of drivers from economic, demographic/lifestyle and other perspectives. The drivers specify different types of employment growth sorted into industry clusters, which in turn imply different spatial patterns of employment and population growth. The role of industry clusters and Place Types in the development of spatial Suitability Factors for growth in the three greater growth scenarios is described below.

Drivers Implemented in the Land Use Model

Environmental Driver: Sea Level Rise

As noted above, the primary environmental driver that was modeled for the future was potential sea level rise. Based on Working Group input, the project team used the Medium future scenario identified by the Hampton Roads Planning District Commission (HRPDC) for potential sea level rise based on prior studies done by the HRPDC. For scenario planning purposes, this translated to a 3-foot rise in sea level by 2045. The areas of inundation with three feet of sea level rise are shown in Figure 7. The intent was to include this level of inundation in both the land use and travel demand modeling. As an exogenous factor that would affect all scenarios, the project team held this metric constant across all greater growth scenarios. In other words, since the scenario narratives are about the composition and type of growth in the future, they would not drive different rates of sea level rise in themselves. Instead, sea level rise would potentially affect each scenario in different ways, so the project team held sea level rise constant to study its impacts on different scenario growth assumptions.

However, the 2045 baseline scenario did indeed have growth assumptions in the area potentially inundated in 2045. That is because the TPO's regional land use model and the travel demand models didn't account for sea level rise. They both showed growth – whether as new Place Types in the land use map or as new socioeconomic (SE) data in the traffic analysis zones (TAZs) in the travel demand model (TDM) within the area that could be inundated for the baseline 2045 scenario. Therefore, the growth assumptions in inundated areas that were built into the 2045 baseline scenario were not altered in the land use and travel demand modeling.

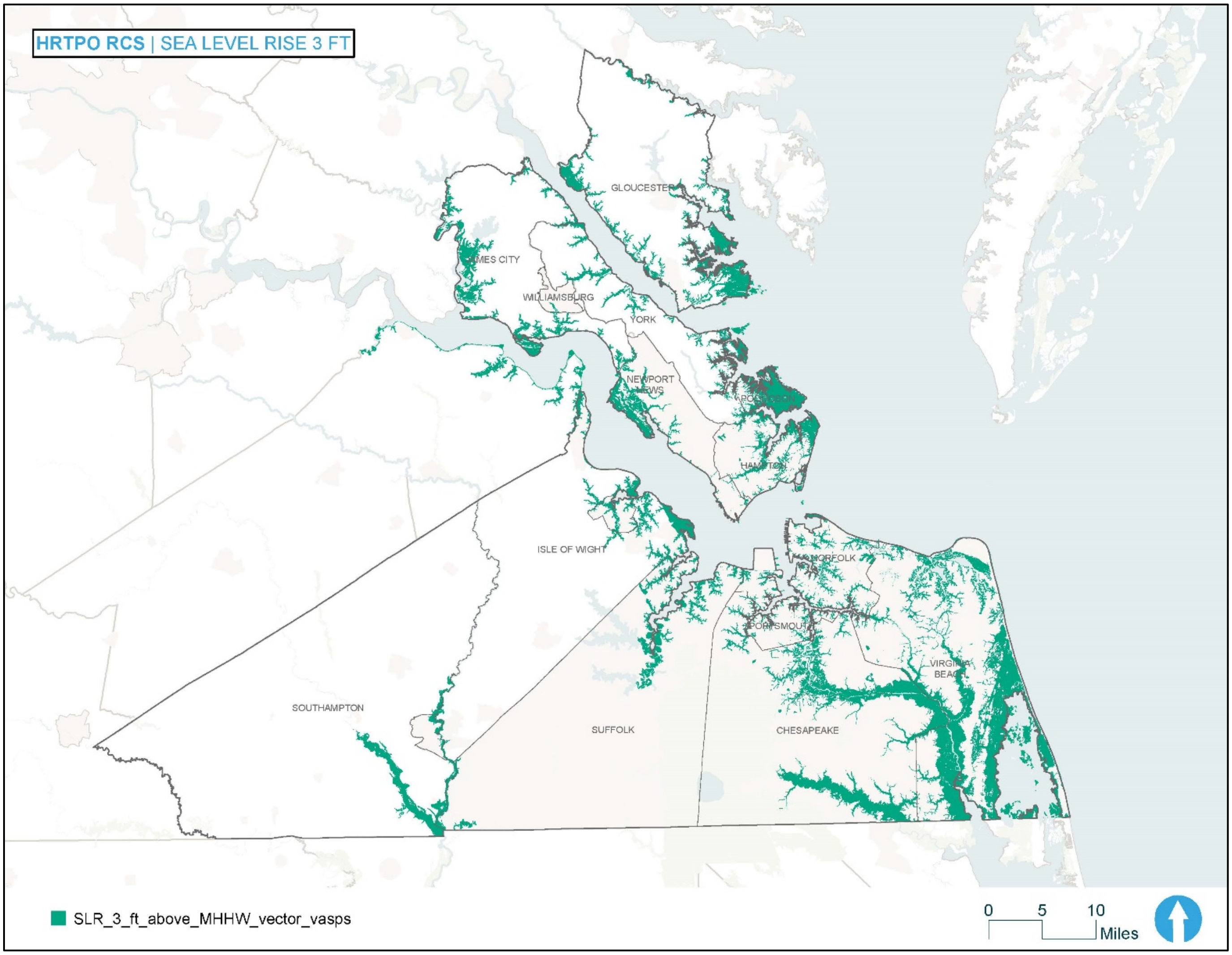


Figure 6. *Sea Level Rise map layer used in the modeling*
Source: Hampton Roads Planning District Commission, see data and methodology.

The land use model included sea level rise as a factor in the capacity allocation only in the greater growth scenarios. Basically, the land use model assigned zero growth capacity to areas assumed to be inundated by sea level rise in 2045 for the greater growth so that the land use allocator wouldn’t allocate any greater growth to these areas. However, the amount of growth already allocated to those areas in the 2045 baseline scenario was not changed. Therefore, the land use modeling took those potentially inundated areas out of play when growth in each of the greater growth scenarios was allocated.

The travel demand model followed the same approach in that it modeled the growth assumed within the inundation areas for the 2045 baseline scenario. For the greater growth scenarios, since the land use model didn’t allocate any additional growth in the inundation areas, the TDM reflected that assumption as well and modeled only the growth from the 2045 baseline that shows up in the inundated areas. In addition, the TDM did not assume changes in the network resulting from Sea Level Rise in any of the scenarios. It is assumed that network adaptation to accommodate rising sea levels will occur gradually over the 25-year period and no substantial portion of the existing network will be removed as a consequence of higher water levels. This latter decision was based on an examination of available data regarding transportation network impacts of sea level rise such as the HRTPO 2016 sea level rise study.[1] There is not one readily-available elevation-based data set of the transportation network to facilitate a simplified analysis of inundation from three feet of sea level rise, and the studies that have been performed in recent years examined different portions of the network and different sea level rise scenarios. A series of Joint Land Use Studies that address sea level rise was underway but not complete at the time of this study. More information on anticipated transportation impacts will be available as the HRPDC's series of Joint Land Use Studies is completed, but one intent of the studies is to identify remediation actions needed with respect to sea level rise, including modifications to existing transportation facilities. Thus, it appears reasonable to assume that major facilities will be adapted by 2045.

Economic Drivers: Assigning Growth Industries to Scenarios

The project team developed three economic scenarios with employment detail on an industry sector basis, anticipating which sectors could be expected to absorb job growth in the future. Considering sources such as HRTPO's 2045 employment forecasts, the Hampton Roads Economic Development Alliance (HREDA) Go-to-Market Strategy, the 2017 Go Virginia Region 5 Growth and Diversification Plan, Bureau of Labor Statistics data on national industry trends, and input from the RCS Working Group and regional stakeholders, the project team created economic profiles of each scenario, as summarized in Figure 8.

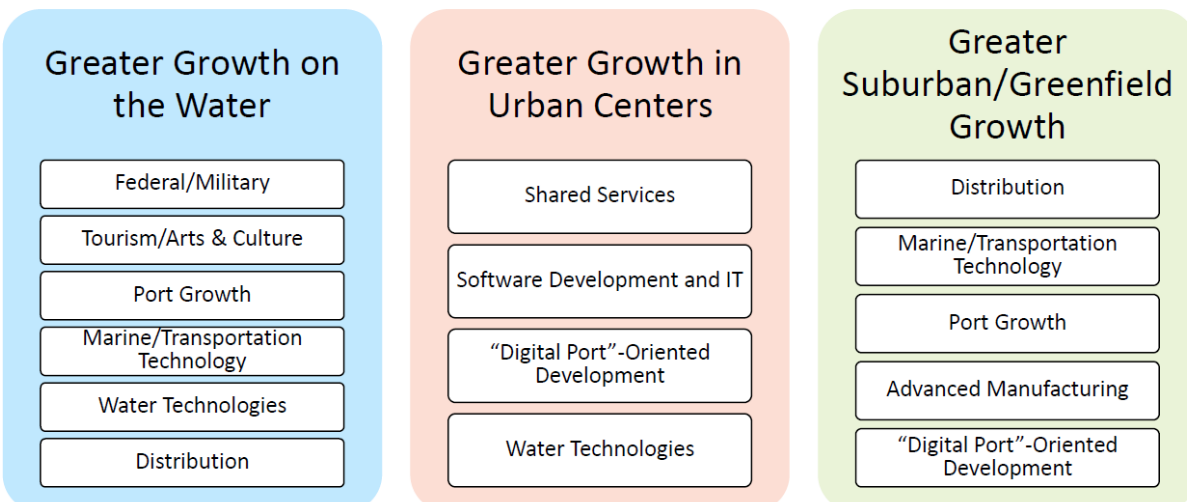


Figure 7. *Sectors and industries assigned to each of the three greater growth scenarios, based on the project team's analysis of economic development strategies and likely direction for regional job growth.*

These economic profiles are composed of the following target industry clusters:

[1] https://www.hrtpo.org/uploads/docs/Sea%20Level%20Rise-Storm%20Surge%20Impacts%20to%20Roadways%20in%20HR%20Final%20Report.pdf; note that this study examined a two-foot sea level rise scenario.

- **Federal/Military:** Armed services installations, civil servants supporting military operations, private defense contractors, and other federal agencies and contractors.
- **Marine/Transportation Technology:** Specialized manufacture, assembly, and repair for maritime equipment, railcars, buses, trucks, sensors, aerospace, etc. Includes ship repair/shipbuilding, advanced materials and components, and unmanned systems/aerospace.
- **Water Technologies:** Architecture, planning, and engineering for coastal areas/climate research. Includes engineering and technical consulting, as well as creative design.
- **Shared Services:** High value internal support functions to corporate operations, including finance and human resources. Includes management and operations services.
- **Software Development and IT:** Development of software applications, support and consulting services for U.S. and international markets. Includes cyber security, data analytics, and modeling and simulation.
- **"Digital Port" -Oriented Development:** Includes data centers and data analytics. Offers a mix of job opportunities includes software engineers and data scientists, but also jobs with lower educational requirement (sales, security, service, etc.).
- **Distribution:** Regional distribution/logistics centers for the eastern U.S. market. Includes port operations, logistics, and warehousing.
- **Port Growth:** Port-oriented employment (in addition to warehousing, distribution, and trucking), such as dockworkers and other terminal employees.
- **Advanced Manufacturing:** Specialized food and beverage manufacturing, medical equipment manufacturing, or other manufacturing from employers with high R&D spending and >20% of jobs requiring a STEM education.
- **Tourism/Arts & Culture:** Includes hospitality, entertainment, culinary businesses, traveler engagement, arts & culture, sporting events, and outdoor recreation.

Connecting Industries to Place Types and Suitability Factors

The employment composition of the three greater growth scenarios is one driver of how the land use model allocates additional growth differently for each scenario. However, the three greater growth scenarios do not specify a precise breakdown of employment growth according to industry in each scenario (with the partial exception of military growth, explained below). Therefore, industry composition of each scenario was indirectly factored into the land use modeling through two types of variables in the land use model, **Suitability Factors** and **Place Types**. These variables are discussed in more detail in Chapter 6 but are described briefly below for their relevance to the overall discussion of drivers.

Place Types are used in the land use model to define capacity and characteristics of potential future growth and ensure that it is in accord with the future growth policies of the region's localities. Industry composition assumptions are built into each Place Type. The Place Types used in this study come from the Hampton Roads Regional Land Use Map, originally compiled by HRTPO staff in 2011 and recently updated and validated by the region's localities. It consists of 21 regional land uses described as Place Types for the purposes of the modeling. The project team did not modify Place Type locations for the greater growth scenarios in order to remain faithful to the future growth policies of the region's localities.[2] Rather, within the capacity provided by the Place Types across the region, the project team differentiated growth allocations using Suitability Factors to guide growth spatially, as described below.[3]

The primary mechanism by which spatial differentiation of growth occurs in the land use model is through Suitability Factors. Suitability Factors act as magnets to growth that tell the allocator in the land use model to pull growth towards different features on the map. Suitability Factors can be in the form of specific spatial features (e.g., port access, access to highway ramps, proximity to institutions of higher education). They can also be in the form of specific Place Types (e.g. using Place Types such as industrial or mixed-use or residential Place Types as attractors or detractors to growth).

The drivers of each scenario influenced the assignment of Place Type preferences and Suitability Factors in each scenario. Given the overall scenario planning goal of stress-testing the transportation system, the project team used the Place Types and Suitability Factors to produce meaningful differences in the scenarios in terms of spatial patterns of growth, travel behavior or trip generation.

Military Growth

The military is a major economic engine for the Hampton Roads regional economy. As noted above, the greater growth scenario narratives give particular attention to the spatial growth of this important sector. The project team implemented military-specific scenario drivers via adjustments to the land use and travel demand model described below.

The Greater Growth on the Water scenario posits growth in regional military activity. This is implemented in the land use model by assigning additional employment and group quarters population to traffic analysis zones (TAZs) designated by HRTPO as containing military activity. In this scenario, military employment is assumed to grow in proportion to the overall greater growth. Between 2015 and 2045, the baseline HRTPO forecast adds approximately 13,000 military jobs, representing 16 percent of the total jobs added in the region between 2015 and 2045. In the Greater Growth on the Water scenario, military employment is similarly assumed to account for 16 percent of the greater growth added above the 2045 baseline. These military jobs are assigned at the TAZ level in proportion to the existing pattern of military employment across TAZs in the 2045 Baseline.

Military employment growth is also linked to growth in on-base group quarters population. To estimate the additional group quarter population added to each military TAZ, the ratio of group quarters population to military employment in the 2045 Baseline was applied to the additional military employment assigned in Greater Growth on the Water, at the zonal level. This resulted in approximately 4% of the greater growth population being assigned to military TAZs in Greater Growth on the Water. With respect to the 2045 Baseline forecast, this formally adopted data set is not subject to change. Any changes to the baseline military employment or population projections would need to go through the formal approval process of the HRTPO.

[2] The project team used Place Type locations from the 2045 Virtual Future, rather than the 2015 Virtual Present as the basis for allocating Greater Growth.

[3] The project team also used modifications in Place Type capacity to guide growth by Place Type (constant across scenarios).

Drivers Implemented in the Travel Demand Model

Economic Driver: Port Growth and Mode Share

In addition to the economic profiles described in the previous sections, each of the greater growth scenarios involve assumptions about containerized volume growth and landside mode share at the Port of Virginia (as discussed in Appendix A: *Economic Trends and Opportunities in the Hampton Roads Region – Technical Memo*). These assumptions are shown in Table 3.

Table 3. *High-level combinations of port scenario drivers for greater growth scenarios*

Port Driver	Greater Growth on the Water	Greater Growth in Urban Centers	Greater Suburban / Greenfield Growth
Containerized volume (TEUs)	↑	–	↑
Rail mode share	↑↑	↑	↓
Barge mode share	↑	–	–
Truck mode share	↓	↓	↑↑

Implementing these assumptions in the scenario analysis requires adjustments to (a) the total units of freight (TEUs) handled at each port terminal, and (b) the mode split across truck, rail, and barge for that cargo.

Both Greater Growth on the Water and Greater Suburban/Greenfield Growth are assumed to achieve Port of Virginia's high-demand growth forecast, shown in Table 3. This amounts to an 11 percent increase in TEUs above the 2045 Baseline levels. Greater Growth in Urban Centers maintains the same level of growth as the 2045 Baseline forecast.

Table 4 breaks down containerized growth forecasts by terminal from the Port of Virginia. It excludes the Newport News Marine Terminal, which is a break-bulk and roll-on/roll-off facility and does not handle shipping containers. The greater growth scenarios focus on containerized freight for two reasons: (a) containerized traffic is core to the Port of Virginia's growth strategy, and (b) the HRTPO travel demand model is calibrated to generate truck traffic as a function of TEU volumes at the selected port terminals (referred to as "special generators").

Table 4. *Port of Virginia baseline and high-demand containerized volume forecasts (TEUs)*
Source: Port of Virginia 2065 Master Plan and TEU data provided by the Port of Virginia

Terminal	2015	2045 Baseline	2045 High-Demand
Norfolk International Terminals (NIT)	1,282,546	2,025,230	2,240,415
Virginia International Gateway (VIG)	1,157,299	2,097,602	2,320,477
Portsmouth Marine Terminal (PMT)	70,255	143,653	158,916
Craney Island Marine Terminal (CIMT)	-	1,073,086	1,187,103
Total	**2,510,099**	**5,339,570**	**5,906,911**

To generate exploratory mode splits at each terminal, the following narrative elements and assumptions were adopted:

Greater Growth on the Water:

- Increased rail capacity allows the Port of Virginia to reach its long-term desired 50% target for rail mode share at NIT, VIG, and CIMT (PMT has 0% rail share in the Port of Virginia's 2045 baseline forecast, which is preserved in all three scenarios)
- Automation of barge service to Richmond reduces costs and increases mode share from 3% in the baseline to 5% at NIT, VIG, and CIMT
- Proportionally less traffic is carried on the road network by trucks than in the Baseline.

Greater Growth in Urban Centers:

- Barge mode share is held constant at 3%
- Urban growth in vicinity of the port increases pressure on the road network serving the port as well as community pressure to manage port growth. In response, increased investment in rail results in increases in rail mode share above the baseline, but less than in Greater Growth on the Water.[4]
- Proportionally less traffic is carried on the road network by trucks than in the Baseline.

Greater Greenfield/Suburban Growth:

- Barge mode share is held constant at 3%
- Automated or semi-automated platooning for trucks increases competition with the railroads, leading to greater truck share.[5]

The resulting mode split assumptions are shown in Table 5. Once joined with the baseline and high growth volume assumptions, the scenarios show varying levels of burden on the road network from port traffic as shown in Figure 9 and Table 6. Greater Growth on the Water illustrates high port growth but with limited burden on road network (21% less than the baseline). Greater Growth in Urban Centers shows the same baseline level of port activity but with some reduction in the burden on the road network (13% less than the baseline). Finally, Greater Greenfield/Suburban Growth explores truck intensive port growth's effects on the road network, with 25% more volume on the road network than the baseline.

[4] This is implemented as rail mode shares midway between the Baseline and Greater Growth on the Water.

[5] This is implemented as a reduction from the Baseline by the same increment between the Baseline and Greater Growth in Urban Centers.

Table 5. *Mode split by terminal under each scenario*
Source: Port of Virginia 2065 Master Plan and TEU data provided by the Port of Virginia.

	2045 Baseline	Greater Growth on the Water	Greater Growth in Urban Centers	Greater Suburban / Greenfield Growth
NIT				
Truck	56.6%	45.0%	51.8%	61.5%
Barge	3.0%	5.0%	3.0%	3.0%
Rail	40.4%	50.0%	45.2%	35.5%
All Modes	100.0%	100.0%	100.0%	100.0%
VIG				
Truck	67.1%	45.0%	57.0%	77.1%
Barge	3.0%	5.0%	3.0%	3.0%
Rail	29.9%	50.0%	40.0%	19.9%
All Modes	100.0%	100.0%	100.0%	100.0%
PMT				
Truck	100.0%	100.0%	100.0%	100.0%
Barge	0.0%	0.0%	0.0%	0.0%
Rail	0.0%	0.0%	0.0%	0.0%
All Modes	100.0%	100.0%	100.0%	100.0%
CIMT				
Truck	72.0%	45.0%	59.5%	84.5%
Barge	3.0%	5.0%	3.0%	3.0%
Rail	25.0%	50.0%	37.5%	12.5%
All Modes	100.0%	100.0%	100.0%	100.0%

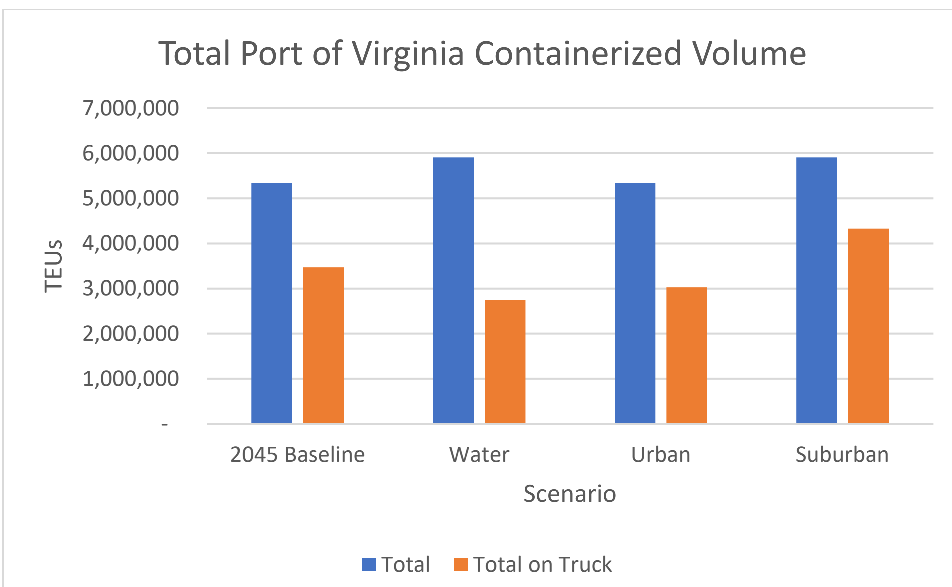


Figure 8. *Port of Virginia containerized volumes – total and by truck, under each scenario*

Table 6. *Containerized volumes by terminal and mode under each scenario*

	2045 Baseline	Greater Growth on the Water	Greater Growth in Urban Centers	Greater Suburban / Greenfield Growth
NIT				
Truck	1,147,205	1,008,187	1,049,532	1,377,150
Barge	60,757	112,021	60,757	67,212
Rail	817,268	1,120,207	914,941	796,053
All Modes	2,025,230	2,240,415	2,025,230	2,240,415
VIG				
Truck	1,407,107	1,044,215	1,196,490	1,789,610
Barge	62,928	116,024	62,928	69,614
Rail	627,567	1,160,238	838,184	461,253
All Modes	2,097,602	2,320,477	2,097,602	2,320,477
PMT				
Truck	143,653	158,916	143,653	158,916
Barge	0	0	0	0
Rail	0	0	0	0
All Modes	143,653	158,916	143,653	158,916
CIMT				
Truck	772,622	534,196	638,486	1,003,102
Barge	32,193	59,355	32,193	35,613
Rail	268,271	593,552	402,407	148,388
All Modes	1,073,086	1,187,103	1,073,086	1,187,103
Total				
All Modes	5,339,570	5,906,911	5,339,570	5,906,911
Truck	3,470,586	2,745,514	3,028,160	4,328,778

Technology Driver – Transportation

The baseline and each of the greater growth scenarios incorporate assumptions regarding the availability and use of mobility as a service (MaaS), smart infrastructure, and connected and autonomous vehicles (CAVs) and their effects on the transportation system. The study faces several challenges in accounting for the effects of technology, including the uncertainty associated with the timeline of adoption and the availability of forecasting tools that are sensitive to the behavioral and operational impacts. The approach used to incorporate the exploratory planning assumptions from the scenario narratives through modeling levers is described in the remainder of this section. The approach relies on a combination of research, which provides the most current thinking about anticipated effects of technology in the future, and the exploratory planning approach of varying assumptions in a logical manner across the three scenarios.

Among the emerging transportation technologies, MaaS is currently prevalent in more urbanized areas; however, the timing, magnitude, type, and location of other technology-driven transportation options is rather uncertain. This study uses a horizon year of 2045, and recent publications indicate that in this timeframe, MaaS usage will increase and CAVs will be present. However, planning analysis will need to consider mixed fleets of CAVs and conventional vehicles.[6] The Baseline scenario incorporates these predictive assumptions regarding the availability and use of technology, while the other three scenarios explore variations of the Baseline in keeping with the exploratory nature of this study, acknowledging the inherent uncertainty associated with technology availability and use. The availability and use of advanced transportation technology will have behavioral and operational impacts on the mobility of the general public and will permeate the 4-step process traditionally used to develop travel demand forecasts for planning purposes: trip generation, trip distribution, mode choice, and trip assignment. Impacts include:

- Increased accessibility for elderly/special needs populations
- Increased travel due to latent demand
- Change in how far people are willing to travel
- Introduction of zero-passenger vehicles (ZPVs)
- Changes in effective roadway capacity
- Reduction in vehicle accidents/improvement in travel time reliability

Chapter 7, below contains a table providing a more detailed accounting of technology impacts as it relates to the 4-step planning process.

A recent update to the HRTPO travel model includes a framework to account for the operational and behavioral impacts of technology considered in this study. Features of the framework include:

- Ability to adjust existing components and the addition of zero passenger vehicle (ZPV) trips
- Incorporation of both privately owned CAVs and shared CAVs
- Ability to specify assumptions about how each behavioral parameter may change for various market segments

This framework will constitute the means to specify magnitude, type, and location of technology to the various scenarios.

Differentiation Between Scenarios

Assumptions about the technology's effect on behavior choices regarding travel translate to "levers" or points of adjustment in the travel demand model. The variation in several parameters associated with these levers allows differentiation of technology assumptions between the scenarios:

- Vehicle Type: Share of household (private) vehicles or trucks that are autonomous. A measure of technology adoption
- Mobility on Demand (MaaS): Share of persons choosing MaaS
- Mobility-On-Demand (AV): Share of person trips choosing MaaS that travel in autonomous vehicles
- Effective Roadway Capacity: Changes in capacity as a result of vehicle spacing due to differing acceleration profiles for autonomous vs. conventional vehicles and the emergence of traffic platooning

[6] NCHRP Research Report 896: Updating Regional Transportation Planning and Modeling Tools to Address Impacts of Connected and Automated Vehicles, December 2018; and Autonomous Vehicle Implementation Prediction – Implications for Transportation Planning, Litman, February 2020.

Figure 10 that follows shows the relative difference between the baseline and greater growth scenarios for these measures in accordance with the scenario narratives. Tables 7 through 9 show the actual values used for the first three measures for each scenario.

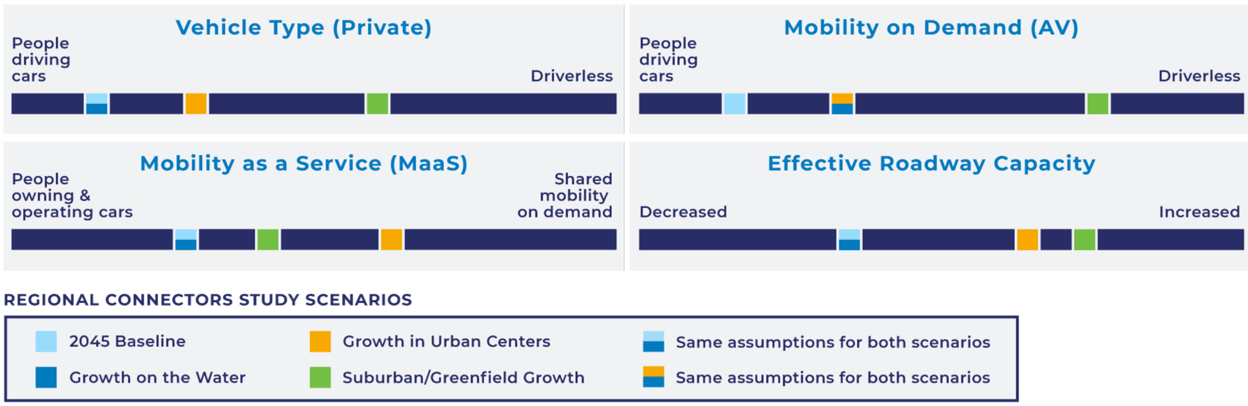


Figure 10. *Technology measures for Baseline and greater growth scenarios*

Table 7. *Autonomous vehicle adoption for Baseline and greater growth scenarios*

	2045 Baseline	Greater Growth on the Water	Greater Growth in Urban Centers	Greater Suburban / Greenfield Growth
Autos				
Internal	30%	30%	40%	75%
Int-Ext	20%	20%	25%	45%
Ext-Ext	25%	25%	30%	60%
Trucks	40%	40%	50%	70%

Table 8. *MaaS shares (all persons) for Baseline and greater growth scenarios*

	2045 Baseline	Greater Growth on the Water	Greater Growth in Urban Centers	Greater Suburban / Greenfield Growth
Peak				
Work	10%	10%	25%	15%
Non-Work	20%	20%	50%	30%
Off-Peak				
Work	10%	10%	15%	10%
Non-Work	30%	30%	60%	45%

Table 9. *Autonomous MaaS shares (MaaS persons) for Baseline and greater growth scenarios*

	2045 Baseline	Greater Growth on the Water	Greater Growth in Urban Centers	Greater Suburban / Greenfield Growth
Peak				
Work	10%	15%	15%	30%
Non-Work	20%	30%	30%	50%
Off-Peak				
Work	10%	10%	10%	20%
Non-Work	30%	45%	45%	75%

Table 7 shows adjustments used to vary effective roadway capacity between the scenarios. Two parameters provide a means to vary capacity in accordance with the scenario narratives that speak to vehicle spacing and behavior as specified in Figure 10.

Roadway Capacity is capacity of roadway to accommodate vehicle demand. Measured in passenger vehicles/lane/hour. Capacity can vary by facility type, area type, and time-of-day**.** *This parameter is used as a proxy to model different vehicle spacing as a consequence of vehicle platooning.* The Growth in Urban Centers scenario features platooning on major roadway facilities because of a high level of CV adoption and use. Table 10 shows the assumption that a 35% increase in capacity on interstates and freeways will result.

Passenger Car Equivalent (PCE) is the amount of roadway capacity a specific type of vehicle uses. PCE for passenger cars equals 1.0. *This parameter is used as a proxy to model different acceleration profiles and spacing for AVs.* A greater PCE value represents greater spacing between vehicles. This value is greater for the Baseline and Growth on the Water scenarios, reducing effective capacity, reflecting AV and conventional vehicle mixed flow. The Suburban/Greenfield scenario assumes a large percentage of roadway traffic will be AVs resulting in a significant increase in capacity.

Table 10. *Effective Roadway Capacity for Baseline and greater growth scenarios*

Adjustment	2045 Baseline	Greater Growth on the Water	Greater Growth in Urban Centers	Greater Suburban / Greenfield Growth
AV PCE	1.20	1.20	1.00	0.50
Roadway Capacity[1]	No Adjustment[2]	No Adjustment[2]	+35%	No Adjustment[2]

1- Interstate/Freeway

2- Default travel model values for conventional vehicles

The variance of changes in effective roadway capacity across the scenarios is representative of prior and recent research as to the potential effects of technology.

Common Parameters

There are several parameters used in the travel demand model to reflect the effect of technology that do not change between the scenarios. Research indicates that one of the more significant impacts of AVs is the introduction of zero-passenger vehicles (ZPVs) on the roadway network. ZPVs can arise as a result of privately-owned AVs or those that are shared through MaaS and operated by transportation network companies. ZPVs from AVs can result from several different kinds of behavior. Behavior types 1 through 4 are associated with private AVs and types 5 through 6 associated with shared AVs. Table 11 describes these behaviors and how they are accounted for in the travel demand model.

Table 11. *Types of zero-passenger vehicle trips*

Behavior/Trip Type	Description
Type 1: Carsharing Among Household Members	• A private CAV drops one household member off at some destination and subsequently travels to some other location to pick up another member of the same household. • Households with at least one CAV but less vehicles than adults. • Only applied to home-based trips.
Type 2: Returning Home to Avoid Paid Parking	• Private CAVs. • Only applied to home-based trips.
Type 3: Travel to Non-Home Locations to Avoid Paid Parking	• Private CAVs. • New trips generated between locations with paid parking and nearby locations. with free parking.
Type 4: Circulating in Lieu of Parking or to Avoid Paid Parking	• Private CAVs. • Applied to trips with short activity duration (home based non-work).
Type 5: Travel to Pick-up Passengers	• MaaS or Shared CAVs.
Type 6: Travel to/from Centralized Depots	• MaaS or Shared CAVs. • Return to centralized depots intermittently, either to re-charge or when demand is low. • Asserting that some locations contain depots with set capacities.

Table 12 shows the level of ZPV trip generation for privately-owned AVs by the fraction of households engaging in a certain behavior type, by trip purpose, by time-of-day, and by area type of origin. These assumptions are the same for all scenarios. Except for trips originating from suburban areas, the parameter values are the default values for the travel demand model[7]. The suburban area values reflect this study's assumption that ZPV trip generation will be greater for this area type than others. Depot locations for shared AVs are in four locations in downtown Norfolk.[8]

[7] Based on "reasonable assumptions" by the developer of the HRTPO Travel Demand Model.

[8] Traffic analysis zones 1, 2, 3, 8, and 15.

Table 12. *Fraction of households generating zero-occupant vehicle trips*

Behavior/ Trip Type	Central Business District	Urban	Dense Suburban	Suburban	Rural
Type 1 – Carsharing Among Household Members					
HBW_PK	0.10	0.10	0.10	0.15	0.10
HBO_PK	0.20	0.20	0.20	0.30	0.25
HBW_OPK	0.10	0.10	0.10	0.15	0.10
HBO_OPK	0.15	0.15	0.15	0.25	0.20
Type 2 – Returning Home to Avoid Paid Parking					
HBW_PK	0.10	0.10	0.10	0.20	0.15
HBO_PK	0.20	0.20	0.20	0.25	0.20
HBW_OPK	0.10	0.10	0.10	0.20	0.15
HBO_OPK	0.15	0.15	0.15	0.20	0.15
Type 3 – Travel to Non-Home Locations to Avoid Paid Parking					
HBW_PK	0.10	0.10	0.10	0.20	0.15
HBO_PK	0.20	0.20	0.20	0.30	0.20
NHB_PK	0.30	0.30	0.30	0.40	0.30
HBW_OPK	0.10	0.10	0.10	0.20	0.15
HBO_OPK	0.15	0.15	0.15	0.20	0.15
NHB_OPK	0.25	0.25	0.25	0.35	0.25
Type 4 - Circulating					
HBO_PK	0.20	0.20	0.20	0.30	0.25
HBO_OPK	0.15	0.15	0.15	0.25	0.20

HBW: home-based work; HBO: home-based other; NHB: non home-based; PK: peak period; OPK: off-peak period

Table 13 lists values for various other parameters covering a range of travel behaviors thought to be affected by the introduction of transportation technologies that are the subject of this study.

Table 13. *Other behavioral parameters*

Parameter		Value	Travel Behavior
Induced Demand			Trips by seniors, children (non-work).
Autos	Home-Base Other	+20%	Passengers sleep during long distance trips.
	Home-Based Shopping	+30%	Latent demand for freight movement.
	External-External	+25%	
	Internal-External	+50%	
Trucks	Internal, External	+50%	
Value-of-Time			Account for added productivity for
	Home-Based Work	-20%	autonomous vehicle travel.
	Home-Based Other	Unchanged	
Truck AV Diurnal Distribution			Shift in truck trips to overnight to avoid
	Peak	25%	daytime congestion.
	Off-Peak	75%	

Table 14 lists some typical technology impacts in the conventional Four Step travel demand modeling process.

Table 14. *Technology impacts in the four-step planning process*

Step	Impact/Adjustment	Issues/Effects
Trip Generation (Step 1)	Auto Ownership - Overall ownership level. - CAV vs. Conventional. Induced Trips - Trips by seniors, children (non-work trips).	- Level of CAV adoption. - Private vs. shared vehicles. - Account for latent travel demand.
External/Truck Trip Generation (Step 1)	Induced Trips - Factor trip rates. Time-of-Day - Adjust diurnal distributions.	- Passengers sleep during long distance trips. - Latent demand for freight. - Shift in truck trips to overnight to avoid daytime congestion.
Trip Distribution (Step 2)	- Adjust trip lengths for home-base work travel.	- Longer commutes. - Added productivity.
Mode Choice (Step 3)	- Add MaaS modes. - Add CAV & conventional submodes.	- Ride hailing. - Micro transit. - First/last mile -public transport.
ZPV Trip Generation (New Step)	- Add vehicle trips to account for new trip legs with no passengers .	- Private CAV to family, home, free parking, circulate. - Shared CAV to next pickup, depot.
Trip Assignment (Step 4)	- Adjust to reflect mixture of CAVs and conventional vehicles. - Designate CAV only lanes/facilities.	- Tech lanes. - Changes in speeds and capacities.

Chapter VI: Land Use Modeling Methodology

Base Geography

The modeling of potential future growth in the Land Use Model is conducted using the CommunityViz Scenario 360 software. CommunityViz is a GIS software developed by City Explained, Inc. that provides a range of quantitative analysis and visualization tools that facilitate geo-design and scenario planning. CommunityViz has been used to model growth in numerous regional transportation planning efforts across the country.

A regional base map created in GIS serves as a starting point for scenario analysis. The base map for the scenario analysis was based on the HRTPO Regional Land Use Map. First developed in 2011 and updated since then, the map synthesizes the existing and future land use maps from the comprehensive plans of the region's sixteen jurisdictions into a single set of land use categories that was agreed to and adopted by the HRTPO Board. This unified existing and future land use map provides a common language for analyzing, planning and envisioning land use patterns and growth across the region. The land use categories from the regional land use map were adopted as the Place Types for the computer modeling in the scenario planning process.

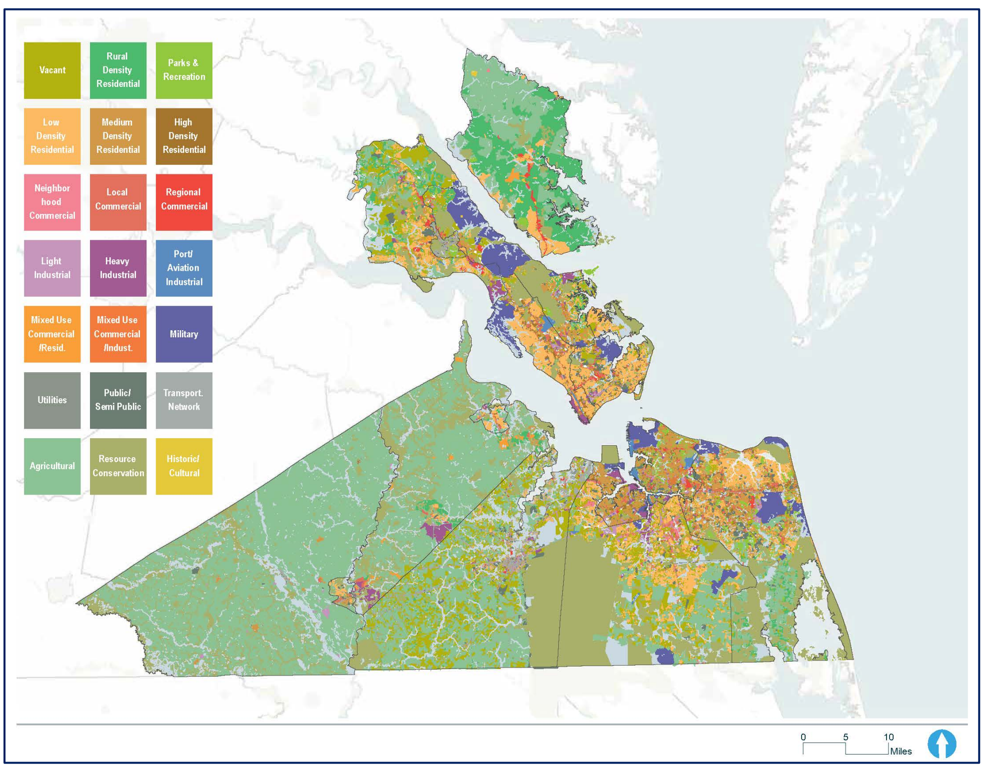


Figure 11. *The Regional land use map with the 2015 (existing) Place Type geography*

Simplifying the Parcel Based Land Use Map

Given that the Regional Land Use Map was developed at the parcel level, it consists of several hundred thousand polygons. This number of polygons is too many to allow the Land Use Allocation computer model in CommunityViz to function, so the parcel geography was simplified.

A translational layer with a smaller number of polygons was created and combined with the regional land use map to provide a simpler geography, but still with an accurate reflection of the 2015 and 2045 regional land uses. A grid comprised of 80-acre cells was intersected with the parcel-based map to reduce the total number of features in the base map to around fifty thousand features which allows computer modeling of the scenarios.

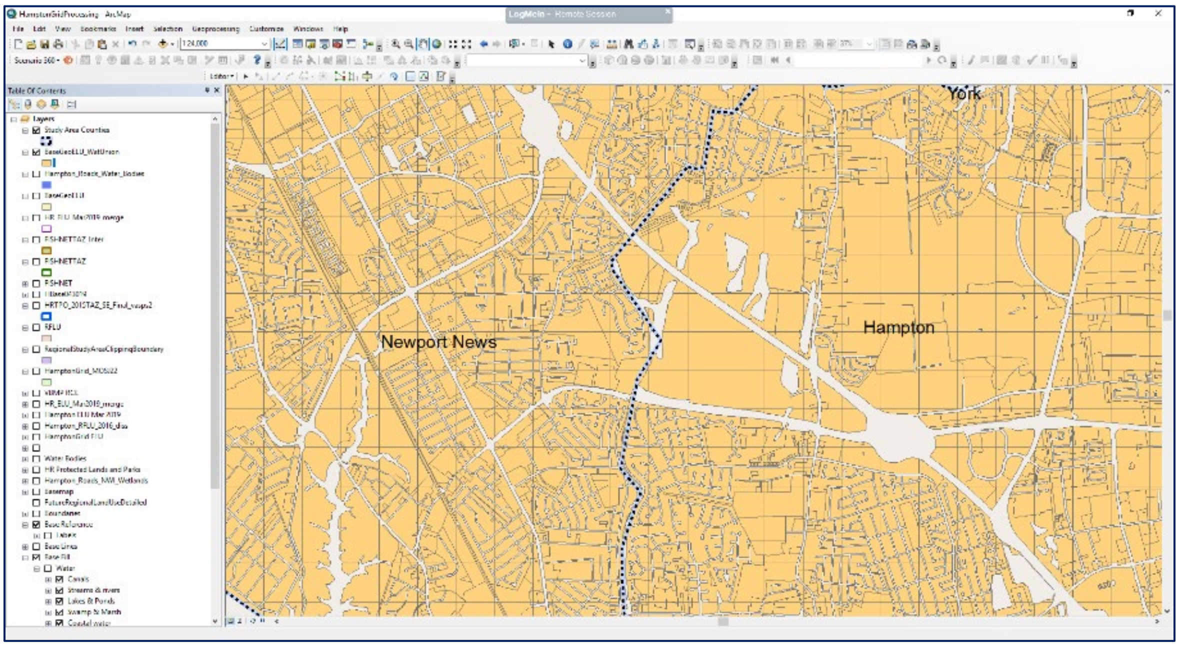


Figure 12. *Example of simplifying the parcel geography with an overlaid grid*

Developing the No Build Layer

After the base geography was simplified, any areas of nondevelopable land were identified to create a “no build’ layer that was removed from the base map. The nondevelopable land or No Build layer is made up of the following data features derived from available HRTPO datasets:

- Water
- Wetlands
- Parks
- Other Protected Areas, e.g., wildlife refuges and management areas
- Roadways
- Chesapeake Bay Resource Protection Areas

In addition, potential sea level rise was accommodated in the scenario planning process through incorporating a data layer for l three-foot sea level rise, as described above in Chapter 5 and assigning it to have no capacity for any allocation of population or employment in the greater growth scenarios. This refined base map, minus the no build areas became the base for allocating population and growth in the scenario planning process.

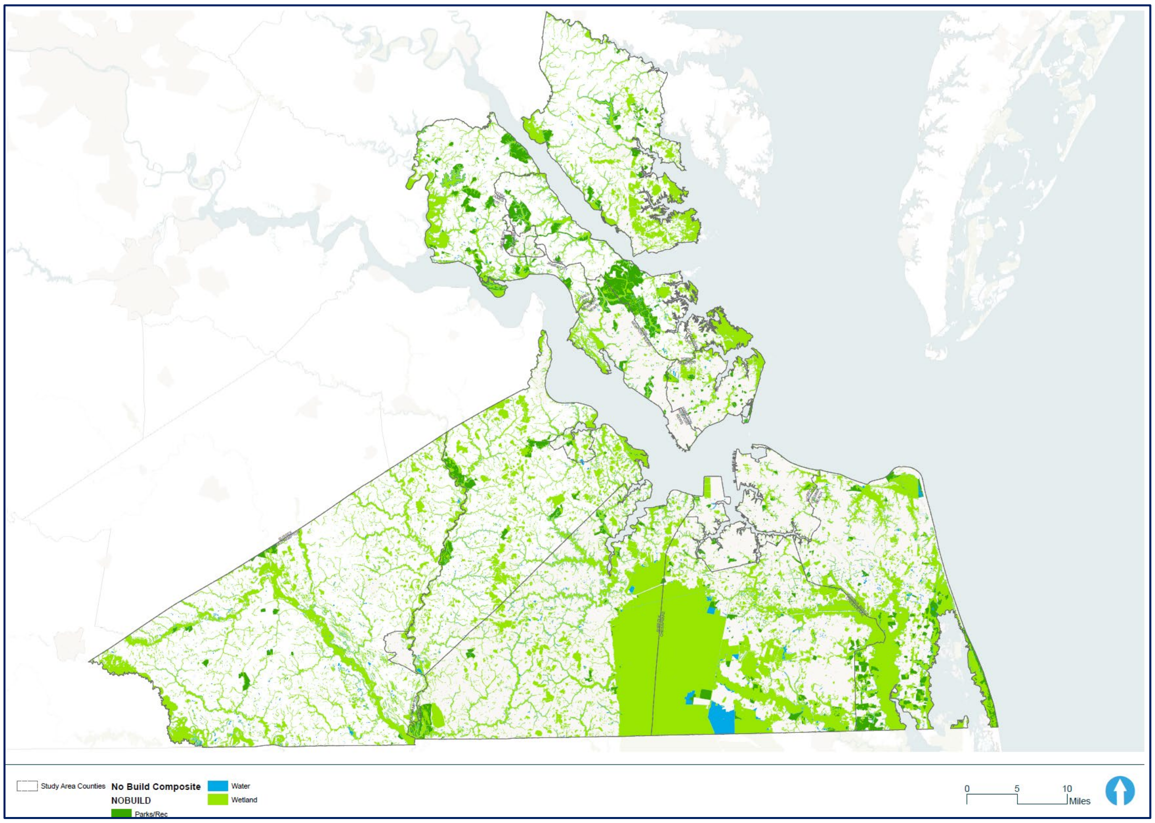


Figure 13. *Sample No Build mapping for the region*

Place Types

The land use allocation aspect of the scenario planning process is conducted through a "Place Type" approach. This involved converting the existing and future land use data categories from the region into a series of typical community or "place" types, with names such as Residential Suburban Community, Agricultural Community, or High-Density Mixed-Use Community. These Place Types are used both to profile the existing land use pattern in the region and to construct each of the future land use scenarios. Available HRTPO datasets of existing and future land uses served as the basis for the Place Types.

Maintaining Local Land Use Policies for Growth

For the purposes of scenario planning, the base maps containing the 2015 and 2045 Place Types are called the "Virtual Present" and "Virtual Future" maps. As described above, these Virtual Present and Virtual Future maps are derived directly from the existing and future land use mapping of each locality that was done for the development of HRPDC's Regional Land Use Map. One of the key principles in this scenario planning process agreed upon by the Working Group is to maintain the future land use plans and policies of each jurisdiction, rather than to try and change them. This meant preserving the basic geography and locations of future land uses that each jurisdiction has adopted, as affirmed in the Regional Land Use Map and the 2045 regional TDM.

Therefore, the greater growth scenarios all use the same distribution of land uses in each jurisdiction as the 2045 Regional Land Use Map and the TDM, which translated each jurisdiction's comprehensive plans into a series of unified Place Types (see Figure 14). The spatial variations of growth in each scenario were accomplished by allocating more or less growth to various Place Types throughout the region rather than changing the locations of regional Place Types. In other words, the scenarios vary by how much growth is allocated to each Place Type cell, rather than by rearranging the Place Type cells on the map.

Figure 14. *The 21 basic Place Types used in the Regional Land Use Map*

Assigning Capacity to Place Types

Since the capacity of each Place Type to accommodate additional growth is central to the scenario planning process, the Place Types must be assigned both an existing level of growth and a capacity for future growth. The Regional Land Use Map only assigned different land uses to parcels; it did not have data about the density or intensity of those land uses. Therefore, each Place Type had to be populated with a certain amount of population and employment and a capacity for future growth.

The first step in quantifying growth in the Place Types entailed profiling the existing and future land use types in the region to determine the existing employment and population characteristics. Based on sampling of existing densities and intensities of Place Types across the region (through available census data), quantitative summaries of each Place Type were developed that summarized land uses and socioeconomic data for each Place Type. Additionally, 3-D visualizations of each Place Type were developed in order to explain their characteristics to stakeholders and the public.

The result of the sampling was a standardized maximum capacity of population and employment density for each Place Type. The Place Type density data were used to generate the quantitative summaries of the Place Types, which include a description of the land use along with the ranges of dwelling units per acre, floor-to-area ration (FAR), people per acre, and jobs per acre for each Place Type . The Land Use Allocation Model uses this Place Type capacity data to determine how much additional growth can be placed in each Place Type polygon when it runs the allocations. The amount of growth that each Place Type polygon can accommodate is the difference between its capacity (how much growth it can accommodate) and how much growth it already has (its existing density). An example of growth capacity mapping is shown in Figure 15.

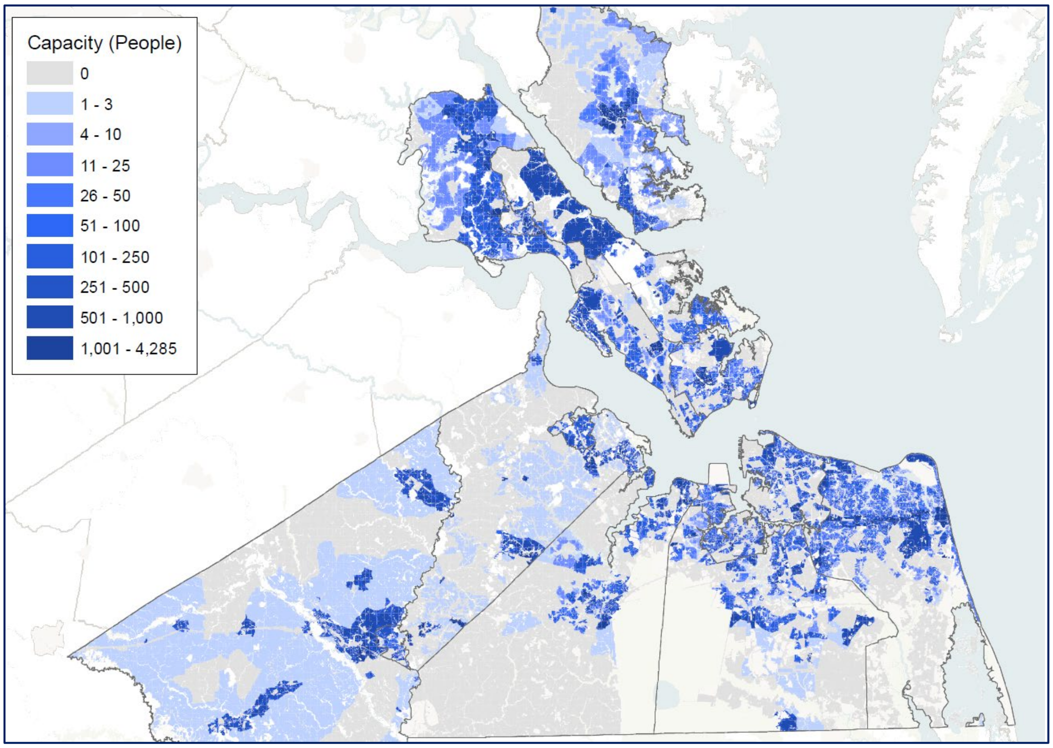


Figure 15. *Sample mapping of capacities across the region*

Associating the Place Types to TAZs

This simplified base map was then associated with the Transportation Analysis Zone (TAZ) geography from the regional TDM, which links the land use mapping to the TDM. Since the grid cells in the translational layer are smaller than the TAZs, the Place Type data was aggregated up to the grid cells, and then associated to each of the larger TAZs. This exercise results in a unified base map where the socioeconomic data in each Place Type is exactly correlated with the socioeconomic data in each TAZ. This allows the Place Type base map to be used in scenario planning with the confidence that its data "matches" the data in the travel demand model.

Calibrating the Place Type Data to TAZ Control Totals

The Virtual Present map represents a picture of where development is currently located in the region. Building the Virtual Present map of the region started with allocating the typical densities associated with each Place Type (from the prior sampling exercise) into all of the Place Type polygons. However, since these densities were based on a regional sampling exercise, the totals for people and jobs did not necessarily match the respective population and employment numbers for the Transportation Analysis

Zones (TAZs) from the Travel Demand Model (TDM) in any given location. Therefore, a second step in the process was to adjust the jobs and population totals in each Place Type polygon so that they matched the control totals in their respective TAZs. Since the scenario analysis outputs were to be used in conjunction with the TDM, the population and job totals in the Virtual Present map needed to exactly match the control totals for the distribution of jobs and people throughout the region in the TAZs from the TDM.

In order to correlate the land use data in the Place Types to the socioeconomic data in the TAZs, a ratio was developed and applied to the Place Type allocations in order to relate them with the TAZ control totals. The ratio, called the Development Factor, was applied to the polygons in the Virtual Present map to remedy the disparity between the TAZ numbers and the Place Type allocation numbers. The Development Factor for each polygon was derived by dividing the TAZ control total numbers by the Place Type allocation numbers for jobs and for people. The Development Factor was then applied to the Place Type allocation numbers to correlate them to the TAZ control numbers. This basic process of reconciling the Place Type densities and intensities with the TAZ numbers through the use of Development Factors represents the process of calibrating the Land Use Model to the Regional Travel Demand Model.

Figure 16 illustrates this process of applying development factors. The same process used to create the Virtual Present map was also used to create the Virtual Future map, with the 2045 control totals from the TDM applied to the parcels in each TAZ using the Development Factor methodology.

The output of this calibration process was GIS mapping of the Virtual Present and Virtual Future for the region that shows the existing and future Place Types. Importantly, this mapping correlated each locality's existing and future land use maps to the socioeconomic data in the regional TDM.

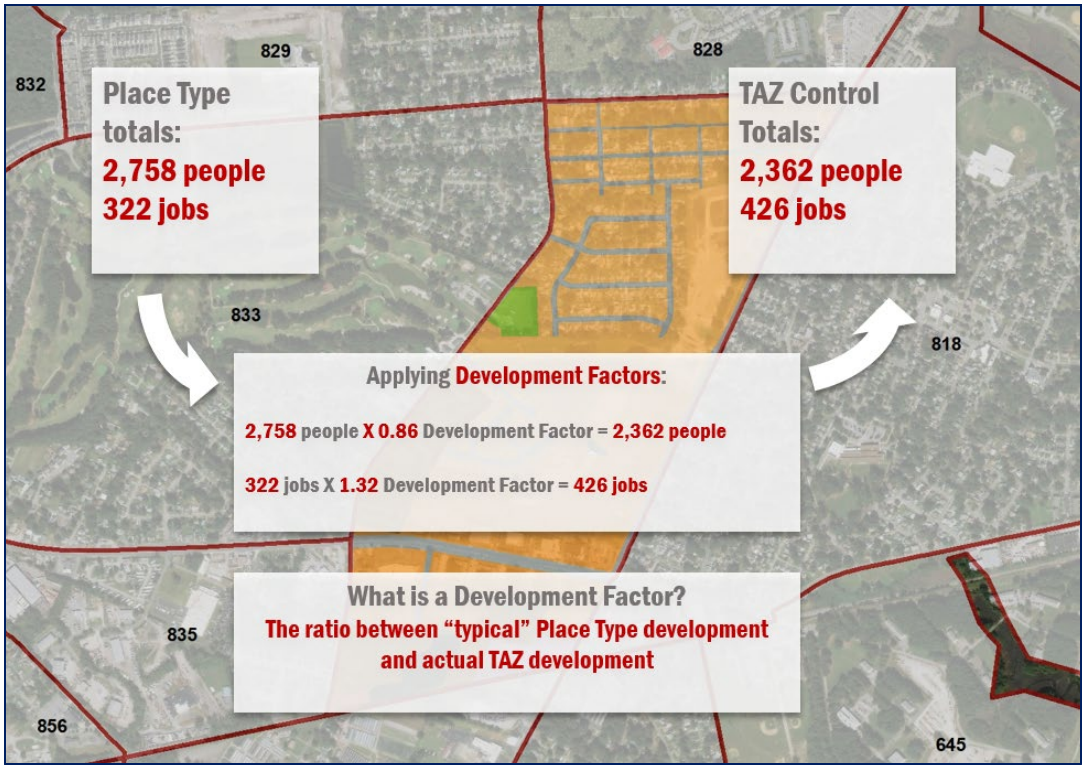


Figure 16. *Slide from a presentation explaining the use of development factors in calibrating Place Type totals to TAZ totals*

Suitability and Land Use Allocations

CommunityViz uses two basic frameworks to model future growth in scenarios; suitability and capacity. In the simplest terms, suitability controls where growth will be allocated first (i.e., where growth is most desirable), while capacity controls how much growth can be allocated in a given location. However, the allocation process can consider both factors together as explained below. Detailed modeling results can be found in this document in Part II. Documenting Modeling Data and Assumptions.

Suitability is a way of characterizing site desirability for growth across the region. The suitability feature of CommunityViz allows users to specify the factors that should be considered for attracting or repelling growth, such as proximity to roads or overlap with floodplains. The program uses these factors to determine where growth should be allocated. These factors can be extensively customized using data provided by the user, with factors such as "waterfront proximity" based on a user-defined GIS data layer. Once the suitability factors for a given scenario have been determined, the program allows users to change the weighting of each factor to better match the characteristics of a particular scenario.

The Allocator Tool

The Allocator 4 tool available in CommunityViz was used to model the distribution of growth in the three alternative greater growth scenarios. The allocator requires three inputs: the forecasted growth amount (or growth control total), a capacity map and a suitability map. The capacity map (see Figure 15) represents the capacity for development and the suitability represents the desirability for development. The allocator tool then uses these to allocate growth to each Place Type polygon based on its capacity for employment and its capacity for population, along with its associated set of suitability scores.

The allocator assigns the forecasted growth amount among the polygons in the base map in order of higher suitability to lower suitability according to the polygons' suitability scores. In essence, the allocator distributes growth to the polygons with the highest suitability scores until their capacity is used up and then moves on to the next highest sets of polygons, with some additional adjustment through a randomization feature included in CommunityViz. The randomization feature is designed to avoid an oversimplified allocation based rigidly on the suitability scores. The randomization feature allows the allocation to deviate from the suitability as determined by the suitability analysis and incorporates a level of uncertainty into the allocation process, mirroring the real world, where market and other forces may steer development away from occurring only in the most suitable locations. A basic randomization feature available in the allocator tool is used in all the scenario allocations in this project.

Suitability Mapping

Suitability mapping for each scenario was prepared to geographically represent the suitability factors that guide the Allocator. The suitability analysis assigned a specific suitability score to each polygon that measures its desirability for development given its spatial relationship to the set of suitability factors. For each greater growth scenario, a set of suitability factors was developed to match the basic narrative description of each scenario. For example, for the Greater Growth on the Water scenario, suitability factors such as proximity to ports and shipbuilding were used. Similarly, for the Greater Growth in Urban Centers scenario, suitability factors such as proximity to transit stops or to city centers were used. The suitability factors for each scenario represent the spatial aspects of drivers that inform the varying growth patterns in each scenario. Collectively, the suitability factors were combined and a suitability score was assigned to each Place Type polygon. Figure 17 provides an illustration of what suitability mapping could look like for a given suitability factor.

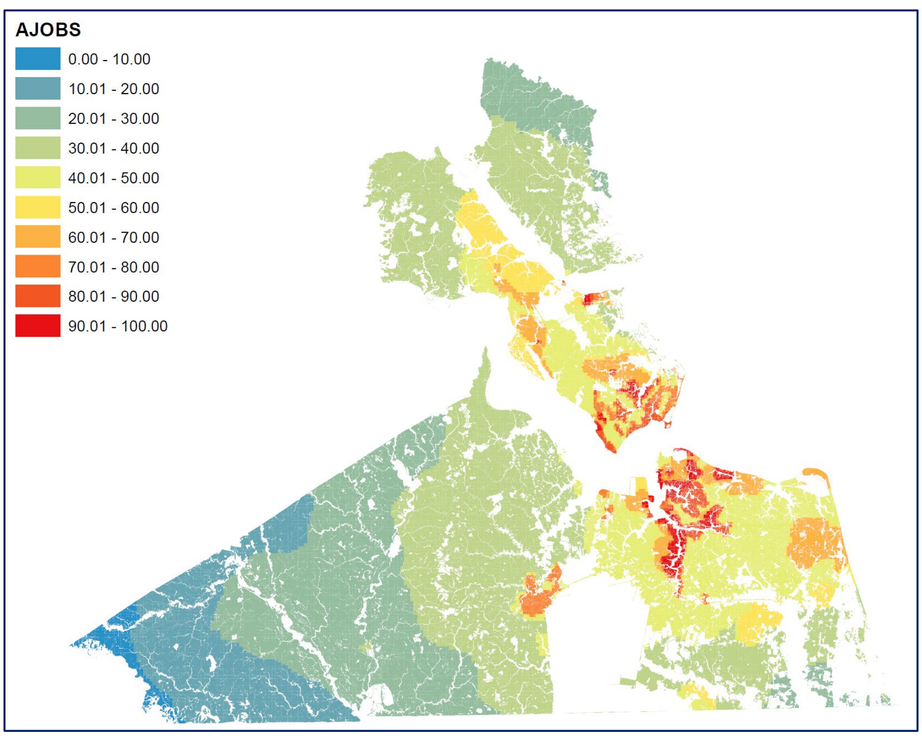


Figure 17. *Sample mapping of suitability for employment across the region*

To identify relevant suitability factors for each scenario, two types of suitability factors were used: Place Type suitability factors and spatial attractor suitability factors. Place type factors consist of Place Types on the base map that are considered as growth attractors for a given scenario. For example, the High Density Residential Place Type was used as a suitability factor selected to attract population growth in the Greater Growth in Urban Centers scenario.

By contrast, the spatial attractors are specific places, objects, boundaries or systems that attract growth toward them or repel growth away from them. For example, the locations of large undeveloped parcels were used as a factor that increases the suitability for employment growth in the Greater Growth in Suburban Centers scenario, while close proximity to major transportation corridors was used as a "detractor" of population growth in the same scenario. Separate maps were created for each scenario for employment and for population suitability, so that there were six suitability maps in total.

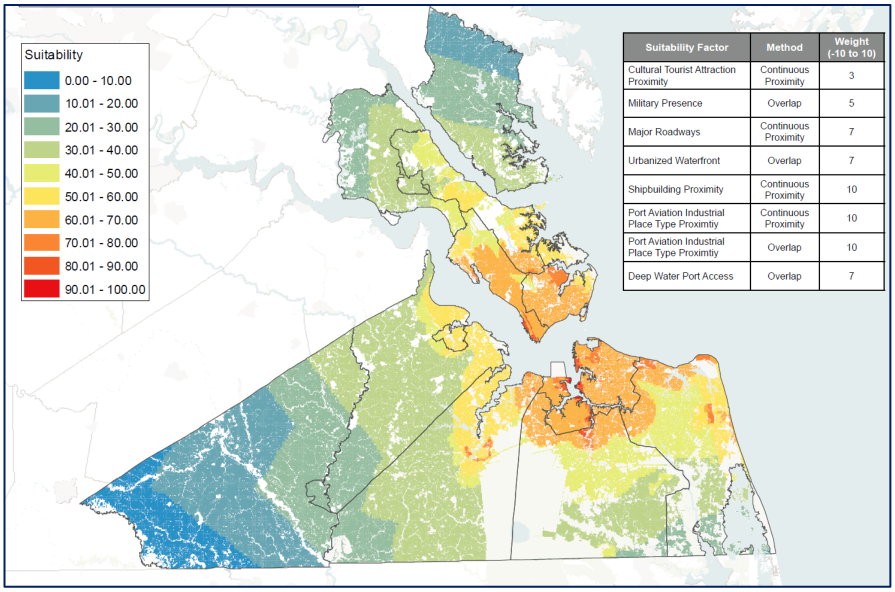
Setting Suitability Weights

The Suitability Wizard tool in CommunityViz also allows the specific weighting of each suitability factor to be varied by the user. The suitability factors each received a relative weight that is set by the user to amplify or mitigate their spatial effect. The weights range from negative ten (for detractors) to positive ten (for attractors.)

In each scenario, the methods and weights of relevant suitability factors were determined based on their role in influencing the scenario drivers. In other words, the suitability weights were calibrated to match each scenario narrative as closely as possible, based in part on iterative reviews of allocation results. For example, while two scenarios may have the same suitability factor, such as proximity to water and sewer service areas, the weights of that factor could be set differently according to the scenario factors (e.g. high weighting for the "Urban" scenario and relatively low weighting for the "Suburban" scenario). As another example, the industry clusters emphasized in the Greater Suburban/Greenfield Growth scenario (e.g., distribution, manufacturing) tend to require larger building footprints and thus need large sites for development. As a result, proximity to large developable sites is a heavily weighted Suitability Factor for this scenario only.

Some spatial features used for suitability were shared across two or more scenarios (such as recreational trails or ports/shipbuilding features). In these cases, the project team used suitability weighting factors to increase or decrease the relative importance of different Suitability Factors to best fit each scenario narrative. The sum of suitability factors for each polygon were further normalized onto a 1-100 scale wherein each polygon had a relative score of 0 to 100, where 100 was the highest suitability score.

The output of the suitability analysis consists of six maps – one for each scenario for both population and employment. Figure 18 provides an illustration of what a suitability mapping output looks like.



Suitability Factor	Method	Weight (-10 to 10)
Cultural Tourist Attraction Proximity	Continuous Proximity	3
Military Presence	Overlap	5
Major Roadways	Continuous Proximity	7
Urbanized Waterfront	Overlap	7
Shipbuilding Proximity	Continuous Proximity	10
Port Aviation Industrial Place Type Proximtiy	Continuous Proximity	10
Port Aviation Industrial Place Type Proximtiy	Overlap	10
Deep Water Port Access	Overlap	7

Figure 18. *Sample suitability mapping with associated weighting of suitability factors*

Many of the Suitability Factors were revised in response to the characteristics of available datasets and to the results of the project team's analysis of that data. For example, the project team originally intended to apply an "Active Transportation" Suitability Factor to the Urban scenario to draw greater growth to urban areas where walking or bicycling commuting are more viable. However, through analysis, the project team learned that the available datasets on active transportation facilities focused more on rural/outlying areas, so this Suitability Factor was reweighted to emphasize the Greater Growth on the Water and Greater Suburban/Greenfield Growth scenarios and was relabeled as "Recreational Trails and Bikeways." In some cases, the project team also sought alternative data sets to more closely align Suitability Factors with scenario narratives. For instance, at the suggestion of the project Working Group, the transit station proximity factor was revised to incorporate additional information on future transit demand from the travel demand model as a proxy for locations with higher proportions of transit service.

For each Suitability Factor and Place Type considered, Table 15 presents its connection to future industry clusters and its weighting for the three greater growth scenarios. This weighting factor represents its relevance to employment and population growth. Table 15 essentially translates the proposed scenario narratives to specific Suitability Factors that are used to define and model the difference between future scenarios.

Table 15. Connections between suitability factors (including Place Type suitability factors), industry clusters, and greater growth scenarios

Suitability Factor	Dataset Used (Existing = 2015 or closest similar year; Future = 2045)	Relevance to Industry Cluster and/or Significance to Scenario	Scenario Relevance (High, Medium, N/A, Negative)		
			Water	Urban	Suburban/ Greenfield
City Center Proximity	**Existing**	**Urban.** Industries with urban location preferences (shared services; software development and IT); population and employment attracted to city centers. **Greenfield.** Industries seek spacious non-urban locations (distribution, advanced manufacturing); employment repelled by city centers.	N/A	`H	Negative
Regional Commercial Place Type Proximity	**Future**	**Greenfield.** Following suburban patterns of distribution/logistics activity and population, retail and other commercial activity are less likely to occur in urban core and more likely drawn to larger footprint regional commercial Place Type .	N/A	N/A	M
Major Employment Area Accessibility	**Future**	**Urban.** Growth in sectors that benefit from spatial clustering and high levels of access to talent (shared services; software development and IT); Greater Suburban/Greenfield Growth and Greater Growth on the Water scenarios purposely not weighted towards job centers to show greater differences between them and the Greater Growth in Urban Centers scenario.	N/A	H	N/A
Heavy Industrial Place Type Proximity	**Existing**	**Greenfield.** Industrial employment (advanced manufacturing; distribution) attracted to existing industrial areas.	N/A	N/A	H
Higher Education Facilities Proximity	**Existing**	**Urban.** Shared services; software development and IT; digital port-oriented development; employment in urban scenarios requires a more highly educated workforce.	N/A	H	N/A
Large Developable Sites Proximity	**Existing**	**Greenfield.** Large-footprint industries tend to seek large sites ripe for development (distribution; advanced manufacturing).	N/A	N/A	H
Low-Density Residential Place Type Proximity	**Future**	**Urban.** Strong preference of population not to live in low-density residential Place Types.	N/A	Negative	N/A
Major Roadways Proximity	**Existing**	**Water and Greenfield.** Attractor for jobs in the Greater Growth on the Water scenario to support port-oriented growth.	M (jobs)	N/A	Negative (pop)

Suitability Factor	Dataset Used (Existing = 2015 or closest similar year; Future = 2045)	Relevance to Industry Cluster and/or Significance to Scenario	Scenario Relevance (High, Medium, N/A, Negative)		
			Water	Urban	Suburban/ Greenfield
		Detractor for population in Greater Growth on the Water and Greater Suburban/Greenfield Growth scenarios because traditional dispersed residential development prefers locating away from major roadways. In the Greater Growth in Urban Centers scenario, major roadways are not a detractor as they provide concentrated urban access.	Negative (pop)		
Medium- and High-Density Residential Place Types Proximity	**Future**	**Urban.** Population attracted to medium- and high-density residential Place Types, reflecting urban lifestyle preferences.	N/A	H	N/A
Military Place Type Proximity	**Future**	**Water.** Scenario calls for specific "spot allocations" of military employment growth on military bases. Military Place Type is also a Suitability Factor, reflecting greater growth in employment and population growth attracted to zones with military presence.	M	N/A	N/A
Mixed Use Commercial / Industrial Place Type Proximity	**Future**	**Urban and Greenfield.** Both scenarios call for mixed use employment growth.	N/A	H	H
Mixed Use Commercial / Residential Place Type Proximity	**Future**	**Urban and Greenfield.** Mixed use commercial employment and residential growth is greatest in the core in the Greater Growth in Urban Centers scenario, but still a factor driving growth in suburban centers.	N/A	H	M
Port/Aviation Industrial Place Type Proximity	**Future**	**Water.** Port-oriented employment growth (port growth; marine/transportation technology).	H	N/A	N/A
Public/Semi-Public Place Type Proximity	**Future**	**Greenfield.** Employment growth drawn to public/semi-public Place Types, which represent low-density, high-capacity parcels suitable for dispersed growth; employment growth occurs in campus-style public employment centers.	N/A	N/A	M
Recreational Trails and Bikeways Proximity	**Future**	**Water and Greenfield.** Recreational trails data served as a dispersion factor for growth as trails are concentrated in suburban/greenfield areas. In the Greater Growth on the Water scenario, this factor is only applied to population, to	H	L	H

Suitability Factor	Dataset Used (Existing = 2015 or closest similar year; Future = 2045)	Relevance to Industry Cluster and/or Significance to Scenario	Scenario Relevance (High, Medium, N/A, Negative)		
			Water	Urban	Suburban/ Greenfield
		support the scenario narrative of more dispersed population than employment.			
Redevelopment Potential	**Existing**	**Urban.** High-tech employment growth (Shared services; software development and IT) drawn to high-value underutilized parcels in the core in the Greater Growth in Urban Centers scenario.	N/A	M	N/A
Shipbuilding/Ports Proximity	**Existing**	**Water and Urban.** Both scenarios include industries that build on the region's existing shipbuilding strength (marine/transportation technology; water technologies); influence is stronger for the Greater Growth on the Water scenario.	H	M	N/A
Shoreline Proximity	**Existing**	**Water.** Population drawn to coastal amenities in the Greater Growth on the Water scenario.	H	N/A	N/A
Tourism Proximity	**Existing**	**Water.** Growth in Tourism/Arts & Culture (especially coastal tourism); also an amenity attracting population growth.	H	N/A	N/A
Transit Proximity	**Future**	**Urban.** Workforce and to some degree employment (shared services; software development and IT) drawn to urban amenities like transit.	N/A	H	N/A
Urbanized Waterfront Proximity	**Existing**	**Water and Urban.** Employment growth strongly attracted by urbanized coastal areas in the Greater Growth on the Water scenario; Some employment attraction to urbanized waterfront in Greater Growth in Urban Centers scenario.	H	M	N/A
Utility Service Areas Proximity	**Existing**	**All scenarios.** Utility service area influences development across all scenarios; influence the strongest for the Greater Growth in Urban Centers scenario (to encourage urban redevelopment).	M	H	M
Vacant Land	**Existing**	**Greenfield.** Land intensive new development (advanced manufacturing, distribution).	N/A	N/A	M
High Density Employment and Population Area Proximity	**Future**	**Urban.** Lower square feet requirements per worker in Greater Growth in Urban Centers scenario; existing density attracts future greater growth density.	N/A	H	N/A

Suitability Factor	Dataset Used (Existing = 2015 or closest similar year; Future = 2045)	Relevance to Industry Cluster and/or Significance to Scenario	Scenario Relevance (High, Medium, N/A, Negative)		
			Water	Urban	Suburban/ Greenfield
Warehouse Facilities Proximity	**Existing**	**Greenfield.** Growth in distribution and advanced manufacturing; tendency to follow spatial pattern of existing warehouse facilities.	N/A	N/A	M

Running Allocations and Outputs to Other Models

Running the Allocations

Once the capacity and suitability maps were developed, the Allocator function in CommunityViz was used for each scenario to create a pattern of future growth to match each scenario narrative. An important feature of this process was to conduct a series of iterative allocation runs of each scenario while slightly adjusting the suitability factor weighting for each scenario so that the pattern of growth more closely matched the intended narrative of each scenario. In some cases, this included identifying additional suitability factors to differentiate the scenario based on geographic features, such as existing urban density. The goal of this process was to produce three distinctively different land use patterns of growth, each keyed to a respective set of drivers described in the scenario narratives.

Upon completion of this task, the scenario results were outputted into the types of socioeconomic data needed to run the TDM for each scenario.

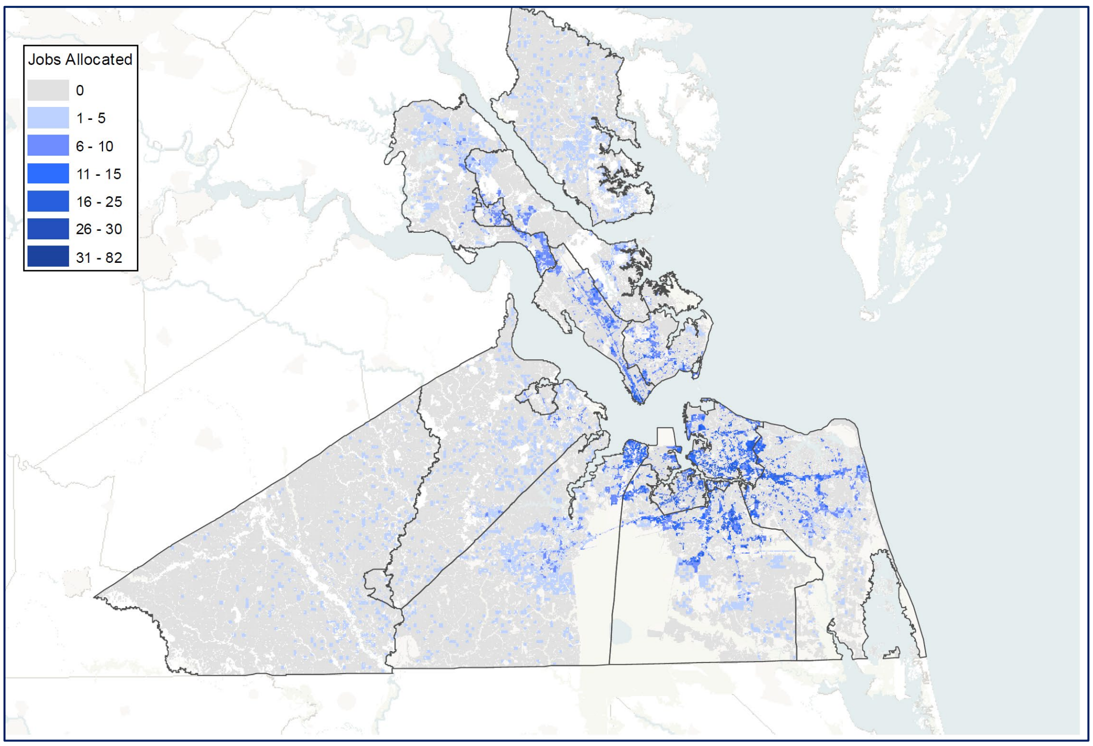


Figure 19. *Sample final employment allocation across the region*

Completing the Greater Growth Scenario Planning

After completion of the land use allocation for each Greater Growth scenario, the scenario planning process moved on to the TDM. The socioeconomic data generated by the land use model was translated into inputs that could be used by the TDM to model future potential travel patterns under each scenario.

In addition to applying a unique set of socioeconomic data by TAZ from the land use model, the TDM was also used to apply the technology drivers of each scenario. The TDM was developed with some levers incorporated to allow assumptions relating to technology, such as the growth of transportation demand in response to people having the ability to operate autonomous cars without a driver's license (i.e., youth, elderly, blind, etc.). These levers were then adjusted for each scenario to reflect the technology driver assumptions. In addition to the technology levers, the TDM was adjusted to reflect alternative performance assumptions in the transportation network, such as dedicated lanes for connected vehicles in platoons.

The full set of TDM adjustments and assumptions, along with the detailed spatial assumptions for the three greater growth scenarios, are provided in this document in Chapter V: Drivers and Suitability Factors.

Once the TDM analysis of travel patterns under each scenario was complete, the TDM outputs were provided to the economic model (TREDIS), where economically-based performance measures were calculated. The performance measure outputs of all three models were provided in a dashboard that summarized the performance measures for each scenario, as illustrated in Figure 20. The HRTPO staff also ran the TDM results through the HRTPO regional prioritization tool to determine the projects that score best across all future scenarios. These results informed selection and prioritization of RCS alternatives to move forward into project development.

The details of the performance measures approved by the RCS Working Group and Steering Committee are provided in this document in Chapter III: Goals, Objectives & Performance Measures.

Figure 20. *Illustration of the three scenario models and performance dashboard*

Chapter VII: Travel Modeling Methodology

This chapter summarizes the travel modeling methodology and results, including the connection between the land use model and the travel model and the general structure of the travel model. The travel model uses information from the land use model to interpret how the greater growth scenarios affect how many trips are generated, their destinations, preferred travel mode, and travel routes selected in the region and, in turn, how this affects travel demand, accessibility, and congestion.

Overview of Travel Modeling Approach

The travel model uses information from the land use model to interpret how the greater growth scenarios affect how well the E+C[9] transportation network accommodates travel demand relative to the 2045 Baseline. This comparative approach differs from that which will be used in the evaluation of individual regional connector projects. During project evaluation, forecasts from the travel model will allow the evaluation of performance of the transportation network with the proposed RCS project compared to performance without the project, under each of the four scenarios. The purpose of these initial travel forecasts and network performance evaluation of the greater growth scenarios is to confirm that there is differentiation in outcomes due to changes in land use and will therefore serve as a meaningful set of scenarios against which to test the regional connector projects, establishing their resilience across multiple futures.

RCS Travel Demand Model

One of the centerpieces of the Regional Connectors Study (RCS) is the measurement of transportation benefits associated with the inclusion of several major roadway segments not included in the HRCS SEIS Preferred Alternative. The travel model used in this study will need to display a sensitivity to congestion, travel time reliability, and accessibility in the context of scenario planning, focusing on accuracy for cross-Harbor travel. The model will also need to assess the reaction of travelers of different income levels to specific scenarios, enabling the evaluation of social and economic justice, and in-part economic impacts. Considering these needs, a review of national best practices, model enhancements in other regions; in the latter part of 2018, the study team developed a list of potential enhancements to the HRTPO regional travel model that address the needs of this study, as well as broaden the model's analysis capabilities. Priority recommendations included:

- Evaluate travel patterns associated with major facilities, harbor crossings, and external travel with information from GPS and mobile device origin-destination data[10].
- Include a sensitivity to trip purpose and income when determining traveler behavior; accounting for different values-of-time.
- Enhance capabilities of the travel model to discern who is willing to use tolled facilities.

Some of these recommendations overlapped with the regional travel model update undertaken by the Virginia Department of Transportation (VDOT) and its consultants that was completed in Spring 2020. As a result of reviewing the regional model update and its associated performance, the study team implemented additional enhancements to create a "project-focused" model for use in this study: the RCS Travel Model. This section describes the general structure and features of the VDOT-updated HRTPO regional travel model as well as the added enhancements associated with the RCS Travel Model.

[9] Existing infrastructure plus committed, or fully funded projects.

[10] Data sources Streetlight and AirSage.

The updated model builds on the previous version of the HRTPO regional travel demand model. Documentation on the updated model was obtained from VDOT and includes the following:

- Hampton Roads Transportation Planning Organization*, Regional Travel Demand Model Technical Documentation (Ver. 2.0),* January 2020.
- Hampton Roads Transportation Planning Organization, *Regional Travel Demand Model User Guide (Ver. 2.0),* January 2020.

As part of the update, the model was re-estimated and calibrated based on 2015 observed data, 2009 National Household Travel Survey (NHTS) data for Virginia, and GPS/mobile device origin-destination data from Streetlight. The final validation was based on 2017 observed average weekday daily traffic counts provided by VDOT.

The discussion below summarizes the model structure, modeling procedures, software, and data flows associated with the model. The updated HRTPO regional travel model estimates automobile (single-occupant, carpool) and heavy truck trips on the highway network and bus, light rail, and fringe parking trips on the transit network producing time-of-day estimates of average weekday travel in the Hampton Roads region. Travel estimation for the fifteen-jurisdiction HRTPO region is based on a "four-step", trip-based, model formulation developed by using CUBE/Voyager software as the development platform. The four steps include trip generation, trip distribution, mode choice, and trip assignment. Time-of-day estimation in the travel model manifests itself through two (2) separate components for passenger vehicles and light trucks: one for "peak" and one for "off-peak" travel – determining trip distribution and mode choice. Roadway trip assignment is further divided into two (2) periods for the peak component, 6-9AM and 3-6PM; and two (2) periods for the off-peak component, 9AM-3PM and 6PM-6AM. A separate four-step model estimates heavy trucks using the same time-of-day partitioning as the previously described passenger vehicle and light truck model. Figure 21 illustrates the relationship between these steps and the associated data flows. The model can run in a "standard" mode or with a "technology template" that allows testing the effect of connected and autonomous vehicles (CAV). The model also accommodates a mobility-as-a-service (MaaS) or ride hailing mode.

The travel model provides estimates for 2017 and 2045 based on 2015 household and employment data and 2045 land use forecasts provided by HRTPO. The model was validated to 2017 observed traffic volumes. A brief overview of the modeling process follows. Reference documentation cited above provide a more in-depth discussion.

Trip Generation

Trip generation estimates person trips for four (4) travel purposes: home-based work, home-based shopping, home-based social/recreation, and home-based other. The number of person trips is based on applying household trip rates to the number of households at various locations in the region. Heavy truck trip estimates are based on employment (industrial, retail, office) and number of households, as well as development density. Resulting trips for persons and trucks are then separated into "peak" and "off-peak" time periods for input into the two-separate time-of-day components of the model. The trip generation can also account for induced demand in passenger vehicles and trucks due to the presence of CAV technology. The regional modeling process beginning with trip generation is shown in Figure 21.

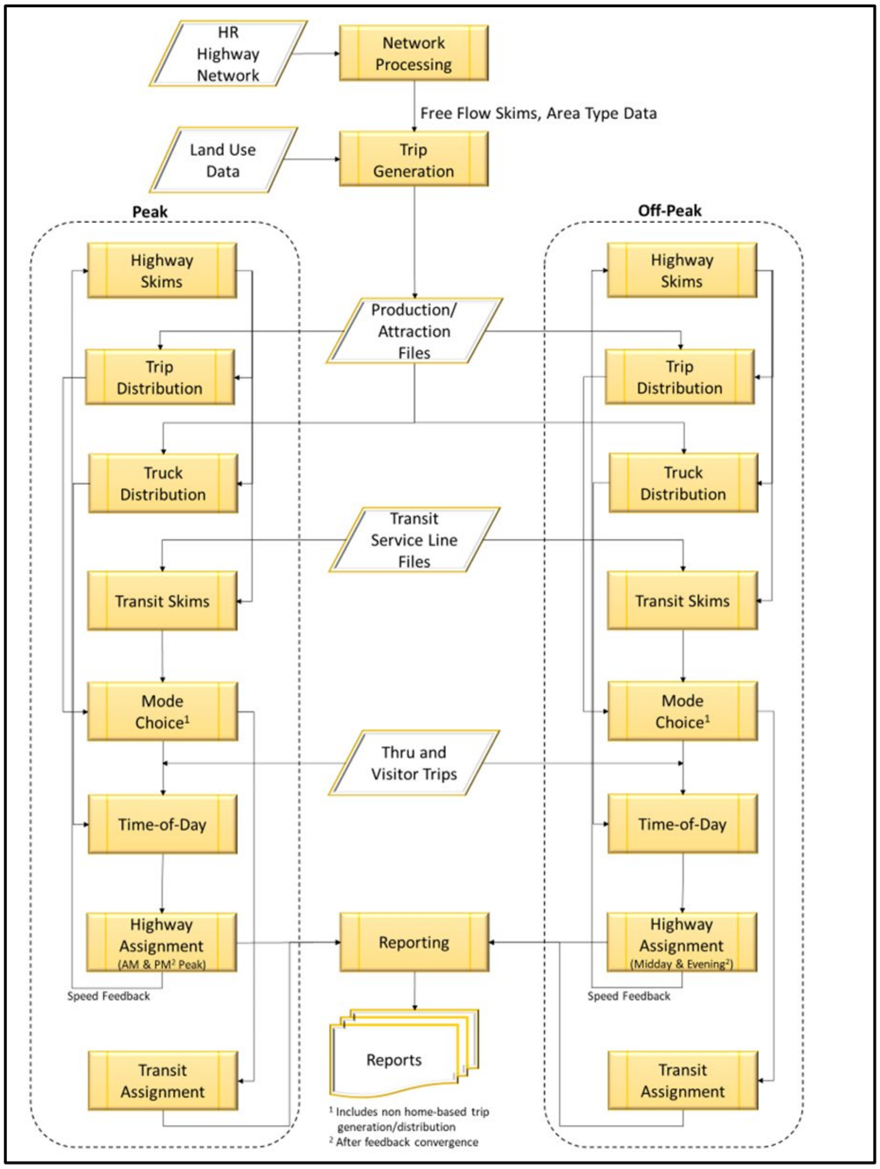


Figure 21. *Regional modeling process*

Trip Distribution

Trip distribution estimates the location of destinations for person trips and heavy truck trips by time-of-day yielding travel patterns for trip traveling within the region. Highway travel costs (time and tolls), as well as how trip generation is concentrated throughout the region, are factors that determine the distribution of trips. The trip distribution process estimates separately each person trip purpose and heavy trucks. When run with the technology template, this process can account for changes in distribution due to changes in travelers' value-of-time in response to the presence of CAV technology. For trips traveling outside the HRTPO region Streetlight origin-destination data determines the trip patterns.

Mode Choice

The mode choice process divides home-based work, home-based shopping, and home-based other person trips into each of the three (3) principal modes: auto, transit, and MaaS. In addition to these main modes, the choice model estimates three levels of auto occupancy (drive alone, two-person carpools, three plus-person carpools), two types of transit access (walk and drive), and two types of MaaS (1 passenger and 2+ passenger). The costs (travel time, tolls, fares) of competing highway and transit services and household automobile ownership determine the mode shares for any given time-of-day and trip purpose. The exception is the MaaS mode. No observed ride hailing data was used in the development of the mode choice process, therefore at this time the MaaS mode share has to be asserted. Note, when run with the technology template, the mode choice model will differentiate CAVs from conventional vehicles in accordance with asserted mode shares.

Trip Assignment

The trip assignment process assigns vehicle trips to roadways and persons that use transit specific routes or lines. The highway assignment procedure is income and trip purpose-based and is sensitive to the presence of high-occupancy vehicle (HOV) facilities in the highway network and permits only HOV trips to use HOV facilities. The highway assignment process generally tries to minimize travel costs (time and tolls) over the entire roadway network and is sensitive to congestion due to limited roadway capacity. Trucks and passenger vehicles are assigned to the roadway network together since they both compete for the same roadway capacity. Trip assignment can also account for the effects of CAV technology on effective roadway capacity. Transit assignment uses output from the mode choice process to assign trips to peak and off-peak periods. Within each period there are separate assignments for each transit access mode (walk and drive). Similar to the highway assignment procedure, transit assignment tries to minimize travel cost (time and fare) relative to available service.

Review of the Hampton Roads modeling process revealed a need to make enhancements to improve the forecasting capabilities of the model for use in the RCS. Enhancements include a sensitivity to travel time reliability, and improvements to truck trip generation associated with the ports and conventional vehicle MaaS trips. Part II of this document discusses these enhancements in more detail.

Transportation Performance Measures in the RCS

The RCS Travel Model translates land use data and a description of the transportation infrastructure into information describing the location and magnitude of travel demand and congestion; providing a means to quantify the performance measures listed below. Several terms used in the performance measures reflect important transportation and regional planning concepts. Performance measures include:

- Accessibility: The collective ability of travelers to access specified types of destinations (such as jobs) within a reasonable travel time by the specified mode of travel (automobile, transit, etc.) on the transportation network.
- Reliability: The predictability of travel times; for example, the amount of extra time that must be allowed for a certain trip to accommodate the worst level of recurring congestion.
- Mode Share Index: The profile of the share of travel for each mode (automobile, transit, bike, etc.) for a particular area such as a traffic analysis zone.
- Delay: The difference between congested and uncongested travel times.

- Circuity: The difference between the distance of a route traveled on the network and the straight-line distance between the origin and destination.
- Average trip length: The average distance or time travel going from origin to destination for all trips or a subset.
- Bottlenecks: Congestion hot-spots that create upstream congestion, such as lane reductions or busy interchange weaving areas.

Measures can also reflect change of the greater growth scenario relative to the 2045 Baseline– this indicates that the baseline metric will be reported for the 2045 Baseline scenario, and the performance will be reported as the change in that metric relative to the 2045 Baseline.

Inputs from the Land Use Model

The travel model uses land use model outputs, *only reflecting the greater growth portion*, for each scenario as inputs, that when combined with data describing land use in the 2045 Baseline; generate the transportation performance measures for the various scenarios. Model outputs from the land use model include a series of measures reflecting socio-economic activity, provided by traffic analysis zone for the entire region. These measures include:

- Population
- Group Quarters Population
- Number of Households (by occupancy and vehicle ownership)
- Total Employment
- Retail Employment
- Non-Retail Employment
- Office Employment
- Industrial Employment

Additional Travel Model Inputs (Not from Land Use Model)

The travel model also uses a description of the transportation infrastructure available to the traveling public. In addition, the travel model contains numerous parameters that describe observed traveler behavior that have been documented[11].

[11] Hampton Roads Transportation Planning Organization, Regional Travel Demand Model Technical Documentation (Ver. 2.0), January 2020.

Roadway System	Transit Service
• Observed Traffic Volumes • Roadway Segment Distance • Number of Directional Through Lanes • Functional Classification • Posted Speed Limit (mph) • Capacity (vehicles per lane, per hour) • Toll Amount • Truck Prohibitions • HOV Restrictions	• Observed Ridership • Type of Service (Bus, Rail) • Frequency of Service (minutes) • In-Vehicle Travel Time (minutes) • Stop Locations • Available Transfer Connections

Figure 22: *Transportation infrastructure description*

There are also parameters that dictate the port growth and mode share, as well as the penetration and effect of technology for the Baseline and greater growth scenarios in this document in Chapter V: Drivers and Suitability Factors.

Port Growth and Mode Share

Each of the greater growth scenarios involve assumptions about containerized volume growth and landside mode share at the Port of Virginia. These assumptions are shown in Table 16.

Table 16: *Transportation infrastructure description*

Port Driver	Greater Growth on the Water	Greater Growth in Urban Centers	Greater Suburban / Greenfield Growth
Containerized volume (TEUs)	↑	–	↑
Rail mode share	↑↑	↑	↓
Barge mode share	↑	–	–
Truck mode share	↓	↓	↑↑

* comparative to the 2045 Baseline

Transportation Technology

The baseline and each of the greater growth scenarios incorporate assumptions regarding the availability and use of MaaS, smart infrastructure, and CAVs; and their effects on the transportation system. The Baseline scenario incorporates these predictive assumptions regarding the availability and use of technology, while the other three scenarios explore variations of the Baseline in keeping with the exploratory nature of this study, acknowledging the inherent uncertainty associated with technology availability and use. Figure 23 provides a brief technology-oriented narrative for the scenarios.

2045 Baseline	• Moderate assumptions for autonomous vehicle (AV) adoption and network adaptation. • AV acceleration profiles moderated compared with conventional vehicles, resulting in greater spacing between AVs and AV-Conventional. • Results in reduced effective capacity for mixed-vehicle flow.
Growth on the Water	• Moderate assumptions for AV adoption and network adaptation. • AV acceleration profiles moderated compared with conventional vehicles, resulting in greater spacing between AVs and AV-Conventional. • Results in reduced effective capacity for mixed-vehicle flow.
Growth in Urban Centers	• High level of connected vehicle (CV) adoption and network adaptation with low auto ownership. • Relatively high mode share for mobility on demand (MaaS). • Emergence of CV traffic platooning and generally closer spacing of vehicles (primarily on major roadway facilities). • Results in enhanced effective capacity for some roadways.
Suburban/ Greenfield Growth	• High level of AV adoption and network adaptation. • Traffic flow primary consists of AVs allowing optimal harmonization of demand and supply (on most roadway facilities). • Results in significantly higher effective capacity.

Figure 23: *Transportation technology narratives*

Travel Demand Estimates

Data from the land use model and other information described above was entered into the travel model to create demand estimates to support a series of scenario analyses. Output data from each scenario forecast were used to develop the performance measures. The scenario forecasts included:

- Greater Growth on The Water: Testing greater cross-harbor travel
- Greater Growth in Urban Centers: Testing more urban and multimodal travel patterns
- Greater Suburban/Greenfield Growth: Testing more overall regional travel

Transportation Modeling Results and Interpretation

Discussion below highlights some general observations regarding the effects of the greater growth scenarios in the context of the scenario narratives. Chapter VIII: Economic Modeling Methodology presents additional aspects of transportation modeling results that affect the economic analysis. Tables 17 and 18 depict regional results of the baseline and scenario estimates through regional roadway network performance in terms of vehicle-miles traveled (VMT), vehicle-hours traveled (VHT), delay, and average free-flow and congested roadway speeds.

Table 17 compares these measures between the 2045 Baseline and 2017 base year. Moving into the future from the base year, VHT increases by 31%. However, the amount of VHT due to congestion, or delay, increases at more than twice that rate (65%) – indicating that the effects of congestion are more significant in the future. This can be seen examining the average daily congested travel speed on the regional roadway network in Table 18; it drops from 36 mph in 2017 to 34 mph in 2045.

***Table 17**: Average daily regional transportation system performance*

Description	2017 Base Year	2045 Baseline w/Tech*	Change**
Vehicle-Miles Traveled	42,225,948	52,106,565	+23.4%
Vehicle-Hours Traveled	1,173,533	1,538,821	+31.1%
Delay (Hours)	221,122	365,076	+65.1%
Average Free-flow Speed (mph)	44.3	44.4	+0.2%
Average Congested Speed (mph)	36.0	33.9	-5.8%

* includes MaaS
**compared with 2017 Base Year

Table 18 provides a comparison of the greater growth scenarios with the 2045 Baseline, principally indicating the effect of adding a particular scenario's greater growth land use and technology assumptions. Figures 24, 25, and 26 provide an illustration of the location of changes in delay on the regional roadway network for the three scenarios. The "warmer" colors represent delay increases and the "cooler" colors show decreases in delay compared with the 2045 Baseline.

Table 18: *Average daily regional transportation system performance*

Description	2045 Water	Change*	2045 Urban	Change*	2045 Suburban	Change*
Vehicle-Miles Traveled	55,576,661	+6.6%	56,351,507	+8.2%	61,889,830	+18.8%
Vehicle-Hours Traveled	1,708,757	+11.0%	1,569,875	+2.0%	1,922,009	+25.0%
Delay (Hours)	450,519	+23.4%	291,644	-20.1%	496,414	+36.0%
Average Free-flow Speed (mph)	44.2	-0.4%	44.1	-0.7%	43.4	-2.3%
Average Congested Speed (mph)	32.5	-4.1%	35.9	+5.9%	32.2	-5.0%

*compared with 2045 Baseline w/ Tech

The Greater Growth on the Water scenario shows a moderate increase in VMT (6.6%) and VHT (11%) over the Baseline. Since technology assumptions between this scenario and the Baseline are the same, these increases can be attributed to the addition of the greater growth portion of population and employment to the regional totals present in the Baseline, as well as the land use allocation assumptions of the Greater Growth on the Water scenario with more centrally concentrated job growth in the region but dispersed population growth. Notice that the increase in delay (23.4%) is more pronounced than the increases in VMT and VHT. The comparison of the 2017 base year and 2045 Baseline in Table 17 also revealed a pronounced increase in delay compared with VMT and VHT. This is because delay accumulates more quickly and does not increase in a linear fashion with VHT. The increase in delay of the Greater Growth on the Water scenario as compared with the Baseline is also evident in the regional roadway average speed, which decreases from about 34 mph in the Baseline to 32.5 mph.

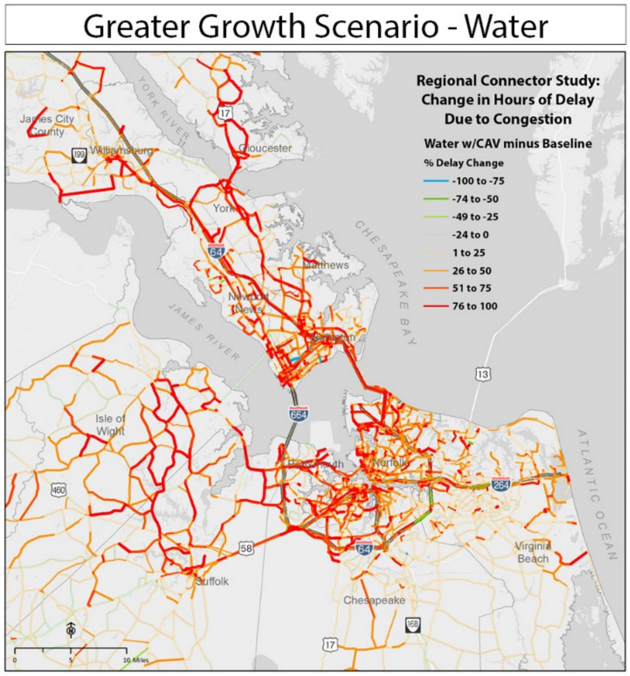


Figure 24: *Delay changes (Greater Growth on the Water)*

The Greater Growth in Urban Centers scenario shows a similar increase in VMT over Baseline as the Water scenario. Note however a much smaller increase in VHT (2%) and an actual decrease (-20%) in delay compared with the Baseline. These changes reflect the more balanced job and population allocation of the incremental greater growth in urban areas. However, they are a primarily influenced by the technology assumptions associated with the Greater Growth in Urban Centers scenario, which apply to all of the future transportation users and system. Note that a feature of the Greater Growth in Urban Centers scenario is a high level of connected vehicle adoption and implementation of smart infrastructure. These features result in the emergence of traffic platooning and a generally closer spacing of vehicles, primarily on major roadway facilities. The net result is an increase in effective roadway capacity. The reduction in delay results in a nearly 6% increase of average regional roadway speeds.

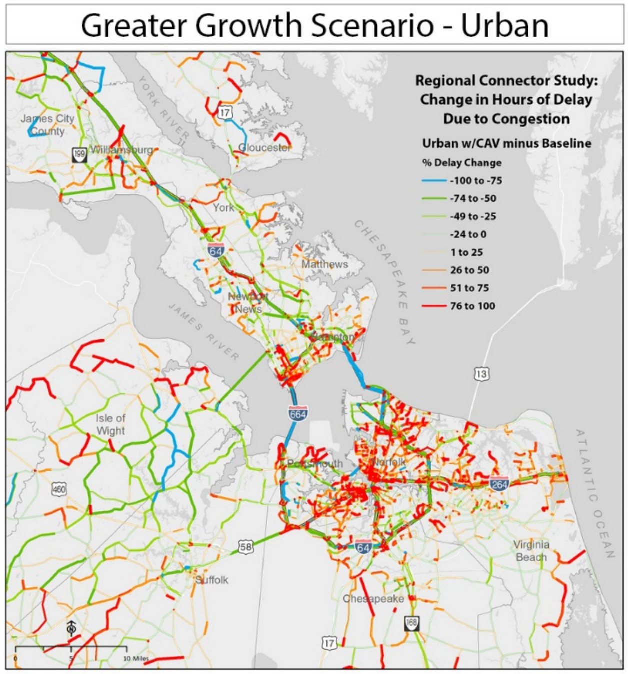


Figure 25: *Delay changes (Greater Growth in Urban Centers scenario)*

The Greater Suburban/Greenfield Growth scenario results in the greatest increases in VMT, VHT, and delay over the Baseline compared with the other scenarios and represents the sum of several different effects. There is a high level of CAV adoption in this scenario, allowing for more closely spaced vehicles that increase effective roadway capacity, even more ubiquitous than in the Greater Growth in Urban Centers scenario. However, another consequence to high CAV adoption is a significant increase in vehicles on the roadway network due to the generation of zero-occupant vehicles. Additionally, the distribution of greater growth in population and employment for the Greater Suburban/Greenfield Growth scenario favors an increase in VMT and VHT. The latter effects of land use and autonomous vehicle usage in this scenario eclipse any roadway capacity benefits as a result of technology resulting in increases in VMT over Baseline that are 2-3 times greater than the other scenarios. This VMT increase leads to increases in VHT and delay.

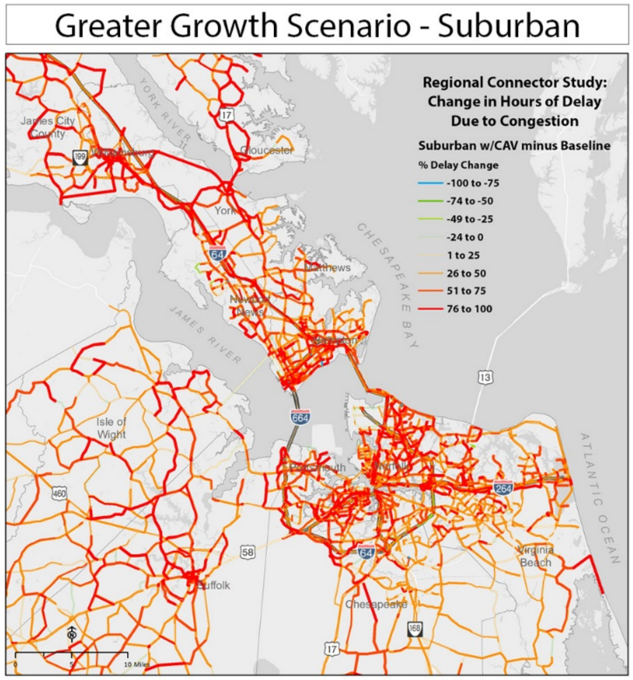


Figure 26: *Delay changes (Greater Suburban/Greenfield Growth)*

Figures 27 and 28 below show how Harbor crossings perform in the different scenarios. Figure 27 shows an increase in average daily vehicle crossings over the 2045 baseline for each of the scenarios. The increases are in part due to the added population and employment inherent in the greater growth scenarios as well as the distribution of that growth. Note in the Greater Suburban/Greenfield Growth scenario that the Harbor crossings increase is at least twice that of the other scenarios.

Figure 28 shows that delay increases over the 2045 Baseline for the Harbor crossings in the Greater Growth on the Water scenario (22%) is about the same as the average regional rate of increase (23-24%), while the rate of increase for the Greater Suburban/Greenfield Growth scenario (29%) is less than the regional rate (36%). Most notably the decrease in delay for the crossings in the Greater Growth in Urban Centers scenario (-55%) is more than twice as great as the regional average (-20%). The changes in delay for the Harbor Crossings introduced by the scenarios as compared with the regional averages in the Greater Growth in Urban Centers and Greater Suburban/Greenfield Growth scenarios is likely due to the effective capacity increases provided by technology. Since the Monitor Merrimac Memorial Bridge-Tunnel and the Hampton Roads Bridge-Tunnel are major roadway facilities, it follows that these facilities will be a focal point for capacity enhancements due to technology.

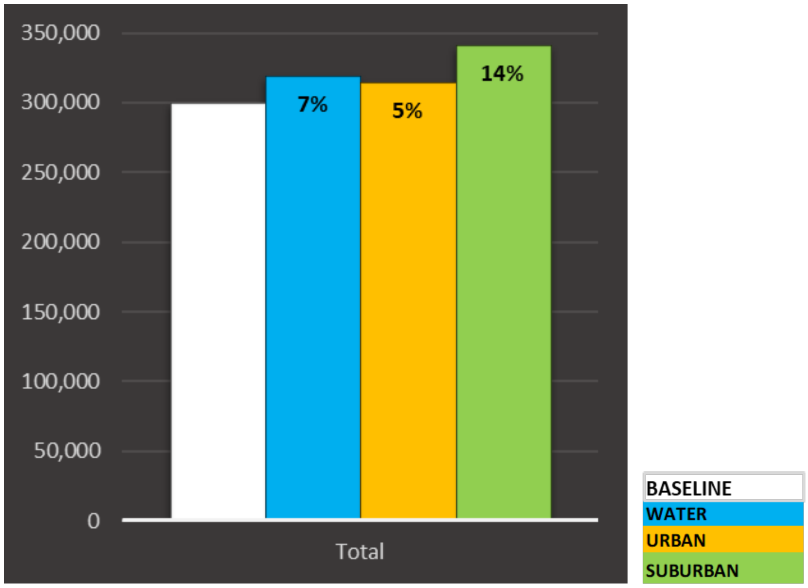


Figure 27: *Harbor crossings (average daily volume). XX% represents percent change compared to the 2045 Baseline w/ Tech.*

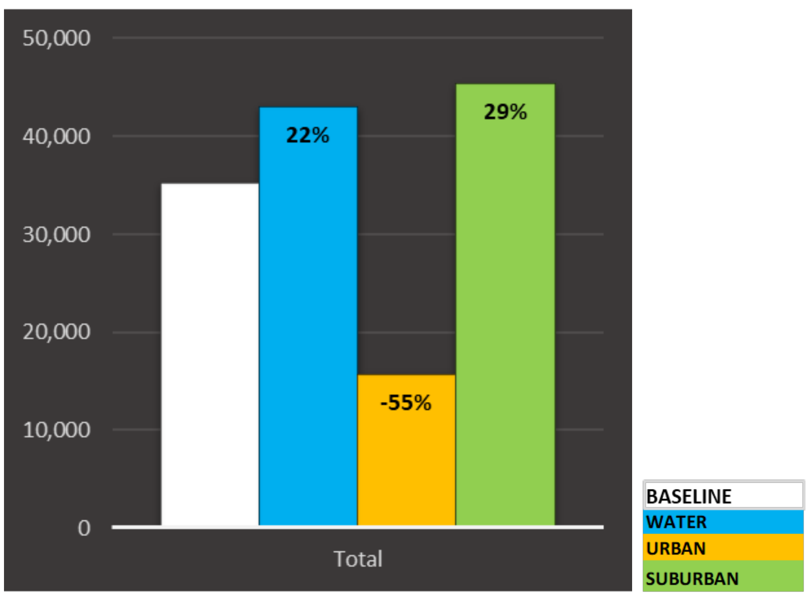


Figure 28: *Harbor crossings (average daily delay in hours). XX% represents percent change compared to the 2045 Baseline w/ Tech.*

Chapter VIII: Economic Modeling Methodology

Just as the land use model interfaced with the region's TDM to allow modeling of the transportation impacts of land use scenarios, the economic analysis model (TREDIS) used the TDM results to generate economic performance measures. This chapter summarizes the economic modeling methodology and results, including the connection of the TDM and TREDIS and the analytical functions performed within TREDIS. The economic model uses information from the TDM to interpret how the greater growth scenarios change the relative efficiency of trips in the region and, in turn, what this improvement or decline in efficiency means in terms of societal cost and regional economic impacts.

Overview of Economic Modeling Approach

The economic model uses information from the travel model to interpret how the greater growth scenarios change the relative efficiency of trips in the region and, in turn, what this improvement or decline in efficiency means in terms of societal cost and regional economic impacts. The economic modeling compares each of the three greater growth scenarios to the 2045 Baseline. This comparative approach differs from that which will be used in the economic evaluation of individual regional connector projects. When projects are evaluated, economic analysis will evaluate the performance of the transportation network with the proposed RCS project compared to performance without the project, under each of the four scenarios. The purpose of this initial economic evaluation of the greater growth scenarios is to confirm that the scenarios are different from one another and will therefore serve as a meaningful set of scenarios against which to test the regional connector projects, establishing their resilience across multiple futures.

Figure 29 illustrates how the economic analysis is driven by facets of the scenarios and resulting performance on the transportation system. Each scenario has growth, technology, and land use assumptions. These result in changes in transportation performance, as measured by changes in trips by mode, travel distance and time, congestion, and crash rates (reflecting different levels of CAV adoption).

Transportation outcomes then serve as inputs into two types of economic analysis:

- Societal Cost of Travel: The first type of economic analysis quantifies the societal costs of travel in the region in monetary (dollar value) terms. This valuation reflects both market costs of travel (for example, the costs of operating a vehicle or paying a truck driver) and societal evaluation of other factors such as travel time, emissions, or crashes that are important but do not directly translate into monetary flows in the economy.
- Impacts on the Economy: The second analysis assesses how businesses in the region will respond to changes in travel costs, as expressed in either growth or contraction of the economy.

These are separate ways of evaluating the economic performance of the scenarios, but they are linked in the same economic model runs and are based on the same measures of transportation performance.

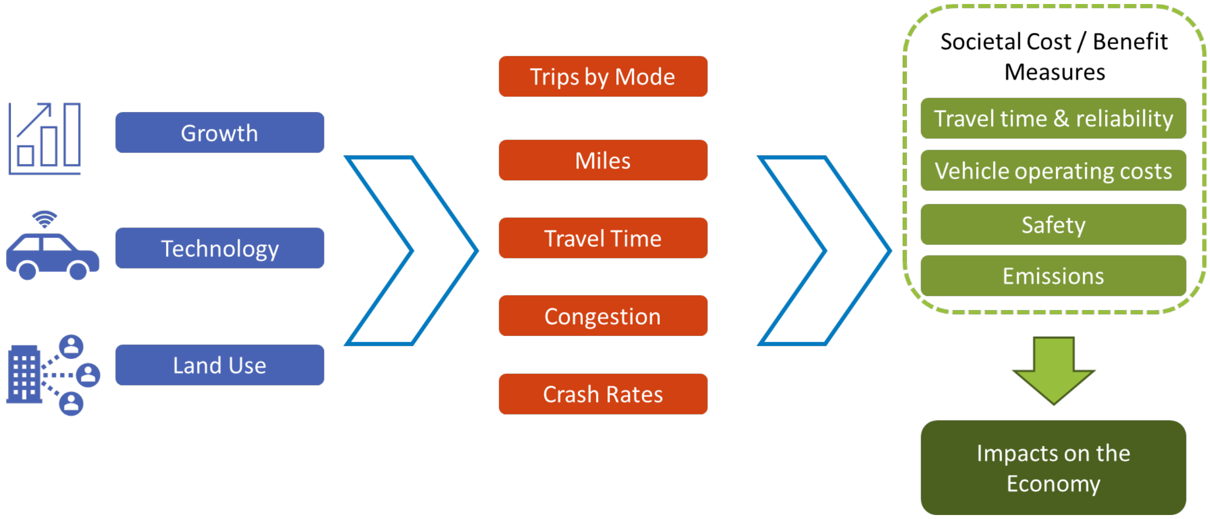


Figure 29. *Economic modeling approach*

The economic evaluation of scenarios is focused on understanding the relative efficiency of the greater growth scenarios, compared to the 2045 Baseline. To do that, the economic analysis applies only to trips that would be made in both the 2045 Baseline scenario and in the greater growth scenarios. Each greater growth scenario also introduces new trips due to increased regional population and employment as well as the ways that vehicle automation can allow trips that wouldn't have been possible otherwise. These additional trips represent benefits to the region and also carry with them additional costs. However, because there is no data to describe the 2045 Baseline conditions of these trips, we do not include them in the economic analysis.

Introduction to TREDIS

The economic modeling in the RCS is conducted using TREDIS.[12] TREDIS is a decision support system for transportation planners that spans benefit-costs analysis, economic impact analysis, and freight and trade impact analysis. TREDIS is multimodal and each TREDIS license is calibrated to a specific local, regional, or state economy – in this case the economy of the Hampton Roads region.

TREDIS consists of several model elements including:

- A *travel cost module* that translates changes in traffic volumes, vehicle occupancy, speed, distance, reliability, and safety into travel efficiency changes and direct cost savings for household and business travel.
- A *benefit-cost module* that calculates benefits and costs over time. Valuation follows international best practice, including the benefit-cost guidance of USDOT modal agencies. This module can be used to conduct full benefit-cost analysis in which net benefits and costs are compared to assess the efficiency of a project or program. It can also be used, as in this project, to quantify and report the societal costs associated with different transportation performance characteristics.

[12] TREDIS has been used in 43 US states and Canadian provinces. Subscribers include a wide set of state DOTs and MPOs, as well as local transportation agencies, universities and leading consulting firms. For more information: https://tredis.com/products/product-overview/inside-tredis

- An *economic adjustment module* that incorporates a dynamic, multi-regional economic-demographic model to estimate economic impacts over time from changes in transportation system performance. The model accounts for changes in productivity, capital investment, labor supply and demand, employment and wage shifts, and population migration. Changes in supply, demand, and prices redirect spending patterns to different industries and affect their relative profitability and competitiveness. In this way various transportation changes can affect the magnitude of economic growth.

TREDIS is a decision-support tool typically used by planners to evaluate economic outcomes of proposed projects, programs and policies. TREDIS will be applied in this manner in a subsequent phase of this project to evaluate individual RCS projects. Application of TREDIS to different greater growth scenarios, while holding the transportation network constant, is a less standard, but nevertheless informative, use of TREDIS to demonstrate how different visions of the future in the Hampton Roads relate to overall travel efficiency and resulting societal costs and impacts for businesses.

Running the TREDIS Model

Economic Performance Measures in the RCS

The RCS uses TREDIS to translate travel data from the TDM into the performance measures listed below.

The first set of performance measures include Total Societal Costs of Travel and its subcomponents:

- **Environmental Costs of Emissions***:* This category is based on the change in emissions and reflect the value for each type of pollutant which includes Carbon Dioxide ($C0_2$), Nitrogen Oxide (NOx), Sulfur Dioxide (SOx), Volatile Organize Compounds (VOC), and Particulate Matter (PM). Changes in emissions are driven by changes in vehicle miles traveled (VMT) by mode, vehicle fuel efficiency (including the introduction of electric autonomous vehicles), and changes in the proportion of vehicular travel occurring in congested conditions.
- **Safety Costs***:* Crashes result in fatalities, personal injuries, and property damage, with each type of crash having an associated value. The number of crashes in each scenario reflect overall travel exposure (as measured by VMT), mode share (because some modes like public transportation are safer on a per mile basis compared to passenger car travel), and degree of CAV adoption (with increased adoption reducing overall crash rates).
- **Vehicle Operating Costs:** These include costs associated with tires, maintenance, depreciation, and fuel and are estimated on a per mile basis (reflecting changes in VMT). For mileage driven in congestion, additional fuel consumption costs reflect stop-and-go conditions. Electric autonomous vehicles incur lower per mile operating costs than conventional passenger vehicles.
- **Person-Based Travel Time and Reliability:** Travel time costs include the value of time for drivers, passengers, and crew. Reliability costs capture additional time costs associated with the "buffer time" that travelers add on top of average travel time to ensure an on-time arrival 95% of the time.
- **Freight Time Costs:** As with passengers and crew, freight travel time has an opportunity cost, which is related to handling or storage costs, lost sales or late delivery penalties, and production costs associated with holding extra inventory or raw materials. These costs accrue to shippers and receivers of freight.

These performance measures are reported both at a regional level and for the subset of cross-harbor travel.

In addition, **impacts on the economy** of each greater growth scenario relative to the 2045 Baseline are evaluated and expressed in terms of **value added**. Also known as Gross Regional Product (GRP), value added represents the total value of production minus the cost of intermediate goods and services. Value added is used to measure the scale of the economic response of regional businesses to changes in transportation system performance.

Economic Analysis Inputs from the TDM

The economic analysis uses TDM outputs for each scenario as inputs to generate the economic performance measures. Model outputs from the TDM include a series of aggregate vehicle-based measures, provided either for the entire region, or specifically for cross-harbor trips. The three key measures are:

- Vehicle trips
- Vehicle miles traveled (VMT)
- Vehicle hours of travel (VHT)

For transit modes (i.e., bus and light rail), TDM outputs also include passenger trips and passenger miles. For all other modes, the TDM outputs include vehicle occupancy, which is used to translate vehicle trip data to passenger trip data. For non-transit modes, the TDM output contains the fraction of VMT under congested conditions (V/C>0.9). Finally, the TDM outputs include various measures of tolls or fares charged. Together these measures enable the calculation of costs incurred during travel.

All the outputs described above were provided from the TDM by mode, time period, and trip purpose. The modes considered in this analysis include:

- Passenger car
- Low-income passenger car
- Private connected and autonomous vehicles (CAVs)
- Private autonomous zero-passenger vehicles (ZPVs)
- Conventional ridehailing/transportation network company (TNC)
- Autonomous TNC
- Zero-passenger conventional TNC
- Zero-passenger autonomous TNC
- Passenger bus
- Light rail
- Tractor trailer truck

TREDIS includes mode specific parameters to account for factors such as vehicle operating costs and crash rates that vary by mode. TDM outputs are organized into two time periods: the morning/afternoon peak and the off-peak. This allows TREDIS to appropriately account for the effects of congestion.

Finally, TDM outputs were organized into four trip purposes: business, personal, commute, and freight. Trip purposes vary in their effects on regional economic activity. “On-the-clock” business and freight trips directly affect costs incurred by businesses, whereas personal trips are societally beneficial but do not directly affect the economy. Commute trips have some effect on businesses in that improvements for commuters can translate into reductions in the wage premiums that employers have to pay their workers to overcome overly long or burdensome commutes.

Data Validation

To confirm the reasonableness and consistency of the TDM outputs with the scenario narratives, the economic team performed a series of validation checks before proceeding with the economic analysis. For each scenario, the team calculated average trip distance (i.e., total vehicle miles divided by total vehicle trips), average trip speed (i.e., total trip vehicle miles by total travel time), percent congested VMT, and average vehicle occupancy. Additional details on changes in these and other key drivers of economic results are described below in the section “Drivers of Economic Results.”

Data Transformations to Match TREDIS Format

The data required several transformations in order to match the input format needed to complete TREDIS analysis. First, the TDM outputs were presented as a daily measure of weekday vehicle travel. Because TREDIS analyzes annual travel data, these daily measures were annualized by multiplying all trip measures by a factor of 330. This factor assumes 260 weekdays and 105 weekend days per year, with weekend vehicle travel at 2/3 the level of weekday travel.

Second, the economics team subtracted low-income passenger car trips from all passenger car trips to calculate non-low-income passenger car trips. This was necessary because the passenger car trip measures in the TDM outputs include travelers at all income levels and TREDIS requires that no mode-purpose combination be overlapping with another.

Third, ZPV trips were reallocated to their associated mode and vehicle occupancy was recalculated to account for “deadhead” vehicle miles without any passengers present. This was necessary because while the TDM tracks ZPV trips separately, TREDIS models them along with the occupied CAV or TNC trips that they support. To achieve this, the economic team proportionally reallocated by period and mode: private ZPV trips to private CAV trips, conventional ZPV TNC trips to conventional TNC trips, and CAV ZPV TNC trips to CAV TNC trips.

Additional TREDIS Inputs (Not from TDM)

Next, the transformed TDM outputs were paired with additional analytical inputs that TREDIS needs to calculate economic impacts and user benefits.

While TREDIS provides default crash rates by mode and crash severity, these crash rates needed to be adjusted to account for the influence of CAV penetration on safety outcomes in each scenario. Table 19 presents these adjusted crash rates and the Part II documentation provides greater detail on the development of these rates. Note that crash rates are the same in the Baseline and Greater Growth on the Water scenarios as these have the same assumptions regarding CAV adoption. The Greater Growth in Urban Centers scenario shows some improvements in safety and the Greater Suburban/Greenfield Growth scenario shows the greatest reductions in crash rates stemming from higher levels of CAV use.

***Table 39.** Adjusted crash rates by scenario, mode, and severity (crash rates are per 100 million VMT)*

Mode	Severity	Baseline	Water	Urban	Suburban
Passenger Vehicle	Fatal	0.66	0.66	0.61	0.39
	Injury	79.51	79.51	72.17	43.71
	Overall	129.79	129.79	116.48	68.21
Passenger Bus	Fatal	0.36	0.36	0.34	0.27
	Injury	38.50	38.50	36.50	28.51
	Overall	56.25	56.25	53.03	40.17
Tractor Trailer Truck	Fatal	0.67	0.67	0.59	0.41
	Injury	12.24	12.24	10.64	6.89
	Overall	20.36	20.36	17.34	11.14

Next, TREDIS requires a per-vehicle mile fare estimate for TNC rides. While other fares and tolls are reported directly from the TDM, this fare is not. Based on an analysis of current Virginia rate structure from Lyft and Uber and individual ride cost estimates in Norfolk and Virginia Beach, the economic analysis assumed an average fare of $1 per vehicle mile. This estimate incorporates the initial cost and service fee of TNC rides, the price per mile, and the price per minute, as well as average travel time and trip length estimates for taxi/TNC trips in the 2017 National Household Travel Survey. Significant uncertainty exists regarding the future structure of the TNC industry in 2045. Nevertheless, this cost assumption is necessary to drive the response of the local transportation industry in the TREDIS model.

Finally, the economic team assigned a default TREDIS value for freight tons per tractor trailer truck (17.5 tons), as well as default fuel efficiencies and fuel cost by mode. All CAVs were assumed to be electric vehicles, while all trucks were assumed to be diesel powered, and all conventional passenger cars gasoline. Passenger car gasoline use per mile was assumed to be 0.04 (i.e., 22.5 miles per gallon), while truck diesel use per mile was assumed to be 0.16 (i.e., 6.1 miles per gallon). Electricity costs were set to 0.09 cents per mile. Additional detail on default fixed factors is available in TREDIS software user documentation.

Adjusting Data to Focus on Efficiency of Trips Already Existing in the Baseline

The final step before executing TREDIS analysis runs was to adjust the TDM outputs to focus on the efficiency of existing baseline trips only. This was necessary because the three alternative scenarios all resulted in increases to overall vehicle travel associated with the greater growth in population and employment. For that reason, any analysis comparing unadjusted vehicle trip characteristics in an alternative scenario to the baseline would be dominated by the increased costs of moving more people and more goods through the transportation system, instead of focusing on the changes in travel efficiency of trips.

To address this problem, the economic team held baseline passenger and truck trips constant across the alternative scenarios and scaled down vehicle trip characteristics in the alternative scenarios accordingly. This required calculating the ratio of passenger trips in each alternative scenario to passenger trips in the baseline: 1.05 for the Greater Growth on the Water scenario, 1.14 for the Greater Growth in Urban Centers scenario, and 1.11 for the Greater Greenfield/Suburban Growth scenario. (These ratios included TNC drivers as passengers, as the TDM drew TNC drivers from other pre-existing trips.) Similarly, the team calculated the ratio of truck trips in each alternative scenario to truck trips in the baseline: 1.05 for the water scenario, 1.13 for the urban scenario, and 1.28 for the suburban scenario. Passenger and truck vehicle trips, VMT, and VHT were then scaled down by these ratios for each combination of mode, period, and trip purpose.

The team replicated this same procedure for the subset of cross-harbor travel. In this case, the ratios described above were recalculated for only this subset of trips. Specifically, the ratio of passenger trips in each alternative scenario to passenger trips in the baseline were 1.04 for the Greater Growth on the Water scenario, 1.07 for the Greater Growth in Urban Centers scenario, and 1.05 for the Greater Greenfield/Suburban Growth scenario. Again, the team calculated the ratio of truck trips in each alternative scenario to truck trips in the baseline: 0.99 for the water scenario, 1.18 for the urban scenario, and 1.25 for the suburban scenario. In the case of cross-harbor truck trips in the water scenario, truck trip characteristics were scaled up slightly to account for the minor loss of truck trips relative to the baseline.

Table 20 presents a summary of regional trip characteristics (including both passengers and freight) by scenario both before and after this scaling adjustment. Table 21 presents the same information for cross-harbor trips only. Both tables also present average systemwide trip length, speed, and occupancy. Because vehicle trip characteristics were scaled uniformly, this transformation had no effect on average trip length, speed, and occupancy. These characteristics are indicators of the changes the relative efficiency of travel across scenarios.

Part II of this document provides greater detail on the adjustment of truck trips according to the process described above.

Table 40. *Summary of regional vehicle and passenger trip characteristics before and after scaling person trips in the alternative scenarios to match person trips in the baseline*

	Scenario	Person Trips	Vehicle Trips	VMT	VHT	Length (mi)	Speed (mph)	Occupancy*
Unadjusted Trip Characteristics	Baseline	9,338,783	6,995,995	52,156,358	1,546,366	7.46	33.73	1.33
	Water	9,756,686	7,574,132	55,627,648	1,716,751	7.34	32.40	1.29
	Urban	10,674,677	8,354,013	56,389,464	1,575,825	6.75	35.78	1.28
	Suburban	10,386,978	9,295,466	61,940,257	1,929,997	6.66	32.09	1.12
Adjusted Trip Characteristics	Baseline	9,338,783	6,995,995	52,156,358	1,546,366	7.46	33.73	1.33
	Water	9,338,783	7,249,662	53,243,523	1,643,182	7.34	32.40	1.29
	Urban	9,338,783	7,309,309	49,355,264	1,379,110	6.75	35.79	1.28
	Suburban	9,338,783	8,340,925	55,220,941	1,722,777	6.62	32.05	1.12

* Average occupancy includes the influence of zero-passenger vehicles.

Table 21. *Summary of cross-harbor vehicle and passenger trip characteristics before and after scaling person trips in the alternative scenarios to match person trips in the baseline*

	Scenario	Person Trips	Vehicle Trips	VMT	VHT	Length (mi)	Speed (mph)	Occupancy*
Unadjusted Trip Characteristics	Baseline	403,274	290,063	7,923,820	228,098	27.3	34.74	1.39
	Water	418,960	306,068	8,402,110	254,289	27.5	33.04	1.37
	Urban	432,110	294,527	7,963,531	213,307	27.0	37.33	1.47
	Suburban	423,976	320,170	8,264,802	244,107	25.8	33.86	1.32
Adjusted Trip Characteristics	Baseline	403,274	290,063	7,923,820	228,098	27.3	34.74	1.39
	Water	403,274	295,589	8,137,310	246,224	27.5	33.05	1.36
	Urban	403,274	272,647	7,320,789	195,929	26.9	37.36	1.48
	Suburban	403,274	300,516	7,670,236	226,923	25.5	33.80	1.34

* Average occupancy includes the influence of zero-passenger vehicles.

Economic Model Runs

After the completion of all the adjustments to the TDM outputs described above, the travel data was ready to be entered into TREDIS to support a series of TREDIS economic modeling runs. After each run, results from TREDIS' economic impact and benefit-cost modules were exported for inclusion as performance measures. The scenario analysis required eight TREDIS runs:

- Regional baseline analysis (i.e., calculation of user costs in the baseline)
- Regional comparison, baseline vs. water scenario (i.e., changes in costs from the baseline to the alternative scenario)
- Regional comparison, baseline vs. suburban scenario
- Regional comparison, baseline vs. urban scenario
- Cross-harbor baseline analysis
- Cross-harbor comparison, baseline vs. water scenario
- Cross-harbor comparison, baseline vs. suburban scenario
- Cross-harbor comparison, baseline vs. urban scenario

Drivers of Economic Results

Table 22 summarizes directional changes in regional performance metrics that drive the economic analysis results for all trips in the region. Table 23 presents the same information for cross-harbor trips only. In both tables, green cells indicate positive change (i.e., faster trips, leading to greater efficiency), while red cells indicate negative change (i.e., lower vehicle occupancy, leading to less efficiency). The first four indicators derive directly from TDM results, while crash rates and fuel consumption and emissions are also a function of CAV adoption rates.

Part II of this document provides additional detail on changes in truck performance metrics that drive the economic analysis results.

***Table 22**. Trends in regional TDM performance by scenario (all regional trips)*

Performance (Average Regional)	Greater Growth on the Water	Greater Growth in Urban Centers	Greater Suburban/ Greenfield Growth
Trip Length	↓	↓	↓
Speed	↓	↑	↓
Congestion	↑	↓	↑
Vehicle Occupancy (including ZOVs)	↓	↓	↓↓
Crash Rates (from CAV adoption)	--	↓	↓↓
Fuel Consumption and Emissions (from electric CAV adoption)	(↓)	↓	↓↓

***Table 23**. Trends in cross-harbor TDM performance by scenario (cross-harbor trips only)*

Performance (Average Regional)	Greater Growth on the Water	Greater Growth in Urban Centers	Greater Suburban/ Greenfield Growth
Trip Length	↑	↓	↓
Speed	↓	↑	↓
Congestion	↑	↓	↑
Vehicle Occupancy (including ZOVs)	↓	↑	↓
Crash Rates (from CAV adoption)	--	↓	↓↓
Fuel Consumption and Emissions (from electric CAV adoption)	(↓)	↓	↓↓

Overall, the trends in regional performance are consistent with the intended scenario narrative and demonstrate differentiation across scenarios.

In the Greater Growth on the Water scenario, slower speeds, more congestion, and lower vehicle occupancy makes for less efficient regional travel. While trip lengths go down slightly on average, this is counteracted by lower vehicle occupancy, meaning that regional VMT increases. CAV adoption levels are the same as in the baseline and are therefore not a major driver of safety or fuel efficiency benefits. However, there is a net increase in VMT on autonomous modes, most of them TNCs, and this, combined with a VMT decrease for trucks, results in modest emissions reductions.

The Greater Growth in Urban Centers scenario demonstrates overall gains in travel efficiency through not only shorter trips, but also faster trips and less congestion. Despite these gains, the urban scenario does also result in lower vehicle occupancy due to a mix of competing factors; while the scenario leads to more carpooling, the technology penetration also results in greater ZOV travel. This scenario sees mild safety improvements from automation and fuel efficiency improvements from electrification of the autonomous vehicle fleet.

Finally, the Greater Suburban/Greenfield Growth scenario is characterized by slower and more congested travel. Trips are shorter on average in this scenario, reflecting land use changes. The scenario also results in significantly reduced vehicle occupancy due to the higher penetration of CAVs and resulting ZOV travel, which drives an increase in VMT despite decreases in average trip lengths. On the other hand, this is the scenario with the greatest automation and vehicle electrification, thereby generating significant crash and emissions reductions.

Performance for cross-harbor trips is generally consistent with regional differences across the scenarios, with a few points of divergence. Average trip length for trips crossing the harbor increases in the Greater Growth on the Water scenario, whereas regional trips in general in that scenario were shorter relative to the Baseline. Similarly, the Greater Growth in Urban Centers scenario shows an increase in vehicle occupancy for cross harbor trips relative to the Baseline, which diverges from the decrease in vehicle occupancy seen in that scenario regionwide.

Economic Modeling Results and Interpretation (TREDIS Output)

Regional Economic Modeling Results

Table 24 presents the first set of regional economic modeling results, the societal costs of travel in 2045, expressed in annual millions of dollars. The first row of results represents the societal costs associated with travel in the Baseline. These costs then change due to changing transportation conditions across each of the greater growth scenarios.

The results indicate that, compared to the 2045 baseline societal costs, the Greater Growth on the Water scenario raises costs related to crashes and congestion for passenger travel and the Greater Suburban Growth scenario raises congestion-related costs for both passengers and freight. In total, however, only Greater Growth on the Water yields a net increase in societal costs. Both Greater Urban Growth and Greater Suburban Growth reduce societal costs compared to the baseline. The summary shows meaningful differences between the scenarios, and the reasons behind the differences align with the scenario narratives. Additional details for each scenario are provided below.

Table 24. *Regional economic results; societal costs of travel in 2045 (annual, $ in millions)*

	Societal Costs of Travel (Components and Total)						Change in Cost from 2045 Baseline
Scenario	Environmental Costs of Emissions	Safety Costs	Vehicle Operating Cost	Person-Based Travel Time & Reliability	Freight Time Costs	TOTAL COST	
Baseline	$3,335	$3,481	$7,570	$14,227	$1,747	**$30,360**	--
Water	$3,267	$3,564	$7,570	$15,180	$1,713	**$31,294**	**$934**
Urban	$2,585	$2,998	$6,722	$11,898	$1,550	**$25,753**	**-$4,608**
Suburban	$1,773	$2,075	$6,230	$14,757	$1,823	**$26,658**	**-$3,702**

The Greater Growth on the Water scenario is overall less efficient at handling regional travel. The dominant effect is an increase in person-based travel time and reliability costs above the Baseline, as speed and congestion get worse. Other changes are more subtle. The societal costs of crashes increase in this scenario. While average trip length goes down, because vehicle occupancy also goes down in this scenario, there is still a net increase in VMT. This means more exposure to crashes that can cause property damage, injury, or loss of life. VMT increases on autonomous modes, which yields some limited emissions benefits, as these vehicles are also assumed to be electric. Vehicle operating costs remain constant due to two counteracting effects in the scenario. The increase in mode share of electric CAVs yields a savings in fuel costs. However, other mileage-based vehicle operating costs increase commensurate with the increase in VMT. Finally, shippers and receivers of freight save on freight time costs. While trucks are traveling at slower speeds in this scenario, they are also shorter on average, meaning there are overall time savings and goods spend less time tied up in transit. The components of societal costs add up to yield a net increase in the cost of travel in the Greater Growth on the Water scenario, relative to the Baseline. This represents a disbenefit to the region.

The Greater Growth in Urban Centers scenario is the most efficient, with societal costs savings across all categories. The regional transportation system performs better in terms of congestion, such that travel time and reliability costs decrease, as do freight time costs. Increased usage of electric CAVS impart emissions and safety benefits. Vehicle trips are shorter. This, combined with fuel savings from electrification, yields vehicle operating costs savings.

Finally, the Greater Suburban/Greenfield Growth scenario presents a mixed picture. Travel time and reliability costs again increase based on worsening congestion. However, there are emissions, safety, and vehicle operating costs savings from a significant shift toward electric CAVs. On net, travel costs decrease, but not as much in the Urban scenario.

Table 25 presents the second set of regional economic modeling results, the impacts on the economy in 2045 of travel efficiency changes in each of the scenarios, relative to the 2045 baseline. Results are reported in millions of dollars of value added, also referred to as Gross Regional Product (GRP). Note that the economic impacts include only the impact of trips that would be made in both the Baseline and in the scenarios.

Table 25. *Regional economic results – impacts on the economy in 2045, relative to the 2045 Baseline (annual, $ in millions)*

Scenario	Value Added (GRP) in $M
Greater Growth on the Water	$30
Greater Growth in Urban Centers	$1,851
Greater Suburban/Greenfield Growth	$1,341

Some of the changes in travel costs shown in Table 24—those related to business activity or to actual monetary spending on travel—also cause changes in the regional economy. For example, when freight, business travelers, and commuters spend less time in traffic, this helps businesses become more productive and grow. Additionally, when people change the way they spend on travel (by spending less on gas or more on mobility as a service), this changes regional business activity. On the other hand, some of the societal costs of travel analyzed above (safety, emissions, travel time savings for personal travel) are important but do not affect economic growth.

Table 25 shows how overall economic impacts to the region vary by scenario. Because of savings for business-related travel and new spending on mobility as a service, the greater growth scenarios all have a net positive impact on the regional economy. The Greater Growth on the Water scenario has the smallest net positive economic impact. Most passenger travel is more costly in that scenario, resulting in a drag on the economy. However, freight time savings do result in industry growth. The Greater Urban Growth scenario has the greatest economic impact, corresponding to its greatest savings in travel costs overall. Greater Suburban Growth also sees positive economic impacts, which are a result of growth in the regional mobility as a service industry in that scenario.

Cross-Harbor Economic Modeling Results

Table 26 presents the economic modeling results specifically for cross-harbor trips. As before, the societal costs of travel in 2045 are expressed in annual millions of dollars. The first row of results represents the societal costs associated with cross-harbor travel in the Baseline. These costs then change due to changing transportation conditions for those crossing the harbor in each of the greater growth scenarios.

As was the case for region results, the cross-harbor results show that, compared to the 2045 baseline societal costs, the Greater Growth on the Water scenario raises costs related to crashes and congestion for passenger travel, resulting in a net increase in societal costs. Both Greater Urban Growth and Greater Suburban Growth reduce societal costs compared to the baseline. Unlike the regional results, the cross-harbor results actually show the greatest reductions in societal costs of cross-harbor travel in the Greater Suburban Growth scenario. The cross-harbor results reinforce that there are meaningful differences between the scenarios. Additional details for each scenario are provided below.

Table 26. Cross-harbor economic results – societal costs of travel in 2045 (annual, $ in millions)

Scenario	Societal Costs of Travel (Components and Total)						Change in Cost from 2045 Baseline
	Environmental Costs of Emissions	Safety Costs	Vehicle Operating Cost	Person-Based Travel Time & Reliability	Freight Time Costs	TOTAL COST	
Baseline	$636	$503	$1,425	$2,140	$769	**$5,472**	--
Water	$619	$520	$1,419	$2,276	$715	**$5,550**	**$78**
Urban	$511	$423	$1,259	$1,811	$680	**$4,683**	**-$789**
Suburban	$380	$276	$1,143	$2,094	$630	**$4,524**	**-$947**

As with the regional results, cross-harbor trips are the least efficient in the Greater Growth on the Water scenario. Again, the dominant effect is an increase in person-based travel time and reliability costs above the Baseline, as speed and congestion across the harbor get worse. Freight time costs savings for goods moving across the harbor are more pronounced in this scenario than at the regional level, reflecting both more direct and slightly faster truck trips across the harbor in this scenario.

Also consistent with the regional results, cross-harbor trips are the most efficient in the Greater Growth in Urban Centers scenario, with the biggest savings in person-based travel time and reliability.

Results for cross-harbor trips in the Greater Suburban growth scenario diverge somewhat from regional results. Notably, there are societal cost savings across all categories. While average speeds across the harbor in this scenario are slightly lower than in the baseline, average trip length for cross-harbor trips also goes down, resulting in a slight net savings in travel time costs. The cross-harbor commuter market also sees time savings in this scenario. Also, unlike the regional picture, cross-harbor truck trips are faster in the Greater Suburban/Greenfield Growth scenario than in the baseline. This leads to significant savings in freight time costs, as well as some crew costs savings that are reported under person-based travel time and reliability costs. As in the regional results, the Greater Suburban growth scenario has the largest cross-harbor trip savings in safety, emissions, and vehicle operating costs as a result of being the scenario with the greatest use of electric CAVs.

Because impacts on the economy are best considered at a regional level, the cross-harbor economic analysis only focused on the societal costs of travel.

Chapter IX: Scenario Differentiation

Using the Scenario Results as a Resilience Test

As described in the above chapters, the scenario planning process was in the Regional Connectors Study as a basis for analyzing potential future transportation alternatives for the region. This scenario planning process differs from normal transportation alternative testing where a single future land use scenario is used and built into the regional TDM.

The purpose of this more robust approach is to give a more sophisticated “resilience test” of each of the transportation alternatives. The exploration of different land use growth patterns allows deeper analysis of the resilience of future transportation investments in the face of uncertainty and can help reveal how beneficial and robust potential transportation investments will likely be.

A key principle in this type of resilience testing is that there must be sufficient differentiation between each of the scenarios to provide a robust platform for testing the resilience of investments. In other words, each “future” must be different from the others so that we can test how transportation investments perform under different futures.

As shown by the results from the land use, travel demand and economic modeling described in the above chapters, there is significant differentiation between each of the greater growth scenarios that will provide a good basis for the resilience testing of potential transportation alternatives. Across a wide variety of outputs and performance measures, there is good differentiation between the scenarios, for example in differences in growth near key destinations (land use model), differences in free flow speed and vehicle miles traveled (travel demand model) and differences in societal costs of travel (economic model). Each of the scenarios yielded model results that were intuitively consistent with the scenario narratives and drivers that made up each scenario.

The overall goal of the RCS project is to make the wisest possible transportation investments, ones that will stand up optimally in light of several potential growth futures and will be most resilient to change and uncertainty. The effective differentiation between the scenarios as shown in the model results provides a highly effective platform against which to test this resilience when the transportation alternatives are modeled under each scenario in the next phase of the process.

Part II. Documenting Modeling Data and Assumptions

Part II of the Technical Guide consists of a detailed documentation of the data used in the land use modeling process. These pages include content from technical memos on Phase II, as well as other documentation. While Part I will help the reader understand the land use model, assumptions and process, Part II is the technical documentation of that data, along with the inner workings of the model.

Part II includes documentation on the following tasks:

A. Documentation of Land Use Model Elements
    1. Documentation of GIS Datasets
    2. Documentation of Place Types
    3. Documentation of Suitability, Capacity and Land Use Allocations
    4. Documentation of Land Use Model Performance Measures
    5. Documentation of Land Use Inputs for the Travel Demand Model
B. Documentation of Transportation Model Elements
    1. Travel Time Reliability
    2. Port Trip Generation
    3. Zero-Passenger Vehicle Trip Generation
C. Documentation of Economic Model Elements
    1. Truck Trip Data Adjustments
    2. Drivers of Economic Results: Truck Trips
    3. Adjusting Crash Rates to Account for Technology Adoption

A. Documentation of Land Use Model Elements

Documentation of GIS Datasets

This section documents the two base geography shapefiles for 2015 (Virtual Present) and 2045 (Virtual Future) as part of the HRTPO Regional Connector Study Scenario Planning effort. The GIS files and related tables are labeled Base15.shp (Virtual Present, year 2015) and the Base45.shp (Virtual Future, year 2045).

The files were created in an ArcGIS environment using Community Viz software. These files are datasets exported from that model. These files constitute the virtual present and virtual future datasets, which were the baseline on top of which the three greater growth population and employment scenarios were built. These datasets contain the Place Types, existing development quantities, as well as development capacities, for each Place Type polygon in the region. Each element in the dataset (shapefile or dbf table) is summarized below along with descriptions of relevant attribute metadata, and Community Viz formulas.

Base15.shp

Description: This is the 2015 "Virtual Present" dataset. It is the product of intersecting TAZ, HRTPO 2015 Regional Land Use and the 80 Acre "fishnet" polygon grid to produce a base 2015 geography shapefile to associate jobs and employment to sub-TAZ level polygons.

- BOEMP15 - Build out for employment, Round ([Attribute:Base15:ACRE_EPR] * Get ([Attribute:PT_LOOKUP_RCS3:EMP_AC15], Where ([Attribute:PT_LOOKUP_RCS3:LU_CAT] = [Attribute:Base15:MinorLU])), 0)
- BOPOP15 - Build out for population, Round ([Attribute:Base15:ACRE_EPR] * Get ([Attribute:PT_LOOKUP_RCS3:POP_AC15], Where ([Attribute:PT_LOOKUP_RCS3:LU_CAT] = [Attribute:Base15:MinorLU])), 0)
- EPRACRESUM -- Produces the sum of EPR Acres for each TAZ. Is a lookup function to SumEPRAcreTAZ15
- CAPEMP – Calculated remaining capacity for employment. Round (If ([Attribute:BOEMP15] - [Attribute:VPEMP15] <= 0, Then (0), Else ([Attribute:BOEMP15] - [Attribute:VPEMP15])), 0)
- CAPPOP - Capacity calculation for population, Round (If ([Attribute:BOPOP15] - [Attribute:VPPOP15] <= 0, Then (0), Else ([Attribute:BOPOP15] - [Attribute:VPPOP15])), 0)
- CAPEMP2 - Capacity employment reduced by SLR coverage percent, If ([Attribute:CAPEMP] > 0 And [Attribute:PCTSLR3FT] > 0, Then ([Attribute:CAPEMP] * (1 - [Attribute:PCTSLR3FT])), Else ([Attribute:CAPEMP]))
- CAPPOP2 - Reduces capacity of pop by pct SLR, If ([Attribute:CAPPOP] > 0 And [Attribute:PCTSLR3FT] > 0, Then ([Attribute:CAPPOP] * (1 - [Attribute:PCTSLR3FT])), Else ([Attribute:CAPPOP]))
- DVEMP15 - Looks up DV from DEVFACT, Get ([Attribute:DEVTFACT15:DVF_EMP15], Where ([Attribute:DEVTFACT15:TAZ15Int] = [Attribute:TAZ15Int]))
- DVPOP15 - Looks up the Devt factor for pop from DEVFACT, Get ([Attribute:DEVTFACT15:DVF_POP15], Where ([Attribute:DEVTFACT15:TAZ15Int] = [Attribute:TAZ15Int]))
- PCTSLF3FT - Percent of polygon acres under 3 feet of Sea Level Rise
- ACRESLR3ft - IfError ([Attribute:SLR3ft_Acr] / [Attribute:ACRE_EPR], 0)

- EPRACRESUM - Produces the sum of EPR Acres for each TAZ. Is a lookup function to SumEPRAcreTAZ15, Get ([Attribute:SumEPRAcreTAZ15:Sum_ACRE_EPR], Where ([Attribute:SumEPRAcreTAZ15:TAZ15Int] = [Attribute:TAZ15Int]))
- PCTSLR3FT - Percent of polygon acres under 3 feet of Sea Level Rise, IfError ([Attribute:SLR3ft_Acr] / [Attribute:ACRE_EPR], 0) PercentTAZ, [Attribute:ACRE_EPR] / [Attribute:EPRACRESUM]
- ACRE – Original TAZ land area. This is only for reference as the acreage of each polygon was recalculated out after the merging process of combing a 80 acre fishnet, plus TAZ, plus Regional Land Use (2015)
- ACRE_EPR – Recalculated acres, actual area of each polygon.
- POP2015 – TAZ control total for 2015 pop
- TEMP2015 – TAZ control total for 2015 emp
- RCSID – Unique Id for each Base15 polygon
- SLR3ft_Acr – Acres of 3ft Sea Level Rise for each polygon
- TAZ15 – TAZ unique identifier, String
- TAZ15Int – TAZ unique identifier integer
- VirPresMil15 – Military contributing Employment per poygon, 2015
- VPEmp15Manual – Interim field for calculating Military employment. This was the formula sued. used to be this Get ([Attribute:HR_MIL_TAZ_EMP:EMP15MIL], Where ([Attribute:HR_MIL_TAZ_EMP:TAZ15Int2] = [Attribute:TAZ15Int]))
- VP15Final - Adds VPEMP15 with VirPresMil15 to get the final employment for each polygon
- MinorLU – 2015 HRTPO Regional Land Use, Minor Category
- PctDev – Percent of polygon developed, covered by USGS NLCD 22-24 developed area classifications.
- LOCALITY_1 – HRTPO locality
- SCENARIO – Field inserted by Community Viz. Did not use in process or to differentiate greater growth scenario. Ignore.

DEVTFACT15.dbf

Description: This DBF generates the development factors for each TAZ for 2015. The development factor is calculated as the TAZ Buildout divided by the TAZ control total.

- BuildoutEmp15 - Calculates sum of build out by TAZ and inserts that value into DevtFactor, Sum ([Attribute:Base15:BOEMP15], Where ([Attribute:Base15:TAZ15Int] = [Attribute:TAZ15Int]))
- BuildOutPop15 - Calculates sum of build out by TAZ and inserts that value into DevtFactor, Sum ([Attribute:Base15:BOPOP15], Where ([Attribute:Base15:TAZ15Int] = [Attribute:TAZ15Int]))
- DVF_EMP15 – Calculates the Development factor IfError ([Attribute:BuildOutEmp15] / [Attribute:TEMP15NoMil], 0). Note, devt factor is calculated with the employment-less-military emp.
- DVF_POP15 - IfError ([Attribute:BuildOutPop15] / [Attribute:Minimum_POP2015], 0)
- Mil15 – Military contributing emp in 2015 by TAZ
- Minimum_POP2015 – Population control total from TAZ15
- Minimum_TEMP2015 – Employment control totals from TAZ15. Note does not have Military contributing employment separated out for purposes of handling the two step process for
- TAZ15Int – TAZ Unique ID, Integer

DEVTFACT.dbf

Description: This DBF generates the development factors for each TAZ for 2045. The development factor is calculated as the TAZ Buildout divided by the TAZ control total.

- BuildoutEmp - Calculates sum of build out by TAZ and inserts that value into DevtFactor, Sum ([Attribute:Base45:BOEMP], Where ([Attribute:Base45:TAZ15Int] = [Attribute:TAZ15Int]))
- BuildOutPop - Calculates sum of build out by TAZ and inserts that value into DevtFactor, Sum ([Attribute:Base45:BOPOP], Where ([Attribute:Base45:TAZ15Int] = [Attribute:TAZ15Int]))
- DVF_EMP - Development factor for EMP, IfError ([Attribute:BuildOutEmp] / [Attribute:Minimum_EMP45], 0)
- Minimum_EMP45 – TAZ control total for employment 2045
- Minimum_POP45 – TAZ control total for population 2045
- TAZ15Int – TAZ ID, integer

Military Taz.dbf

- DBF of military contributing jobs per TAZ for 2015 and 2045
- EMP45 – Total employment 2045 per TAZ
- Emp45Mil – Military contributing jobs 2045 per TAZ
- EMP15 – Total employment 2045 per TAZ
- Emp15Mil – Military contributing jobs 2045 per TAZ
- DIFF45 – Total emp less military contributing jobs, 2045
- DIFF15 – Total emp less military contributing jobs, 2015
- Locality – Locality
- Facility – Military facilities in TAZ
- TAZ – TAZ ID
- TAZ15Int – TAZ ID, integer
- TAZIdTake2 – duplicate TAZ Id, ignore this. Was created to troubleshoot some geodatabase indexing issues.
- SCENARIO – Field inserted by Community Viz application. Not used. Everything is set up in "Base Scenario" just ignore.

BASE45.shp

Description: Product of intersecting TAZ, HRTPO 2015 Regional Land Use, and the 80 Acre "fishnet" polygon grid to produce a base 2055 geography shapefile to associate jobs and employment to sub-TAZ level polygons.

- BOEMP - Build out employment, Round ([Attribute:Base45:ACRE_EPR] * Get ([Attribute:PT_LOOKUP_RCS3:EMP_AC45], Where ([Attribute:PT_LOOKUP_RCS3:LU_CAT] = [Attribute:Base45:MinorLU])), 0)
- BOPOP – Build out population, Round ([Attribute:Base45:ACRE_EPR] * Get ([Attribute:PT_LOOKUP_RCS3:POP_AC45], Where ([Attribute:PT_LOOKUP_RCS3:LU_CAT] = [Attribute:Base45:MinorLU])), 0)
- CAPEMP - Calculated remaining capacity for Employment, Round (If ([Attribute:BOEMP] - [Attribute:VFEMP] <= 0, Then (0), Else ([Attribute:BOEMP] - [Attribute:VFEMP])), 0)-

- CAPEMP2- Capacityy employment reduced by SLR percent, If ([Attribute:CAPEMP] > 0 And [Attribute:PCTSLR3FT] > 0, Then ([Attribute:CAPEMP] * (1 - [Attribute:PCTSLR3FT])), Else ([Attribute:CAPEMP]))
- CAPPOP - Capacity calculation for population, Round (If ([Attribute:BOPOP] - [Attribute:VFPOP] <= 0,
- Then (0), Else ([Attribute:BOPOP] - [Attribute:VFPOP])), 0)
- CAPPOP2 - Reduces capacity of pop by pct SLR, If ([Attribute:CAPPOP] > 0 And [Attribute:PCTSLR3FT] > 0, Then ([Attribute:CAPPOP] * (1 - [Attribute:PCTSLR3FT])), Else ([Attribute:CAPPOP]))
- DVEMP - Looks up DV from DEVTFACT, Get ([Attribute:DEVTFACT:DVF_EMP], Where ([Attribute:DEVTFACT:TAZ15Int] = [Attribute:TAZ15Int]))
- DVPOP - Looksup the Devt factor for pop from DEVTFACT, Get ([Attribute:DEVTFACT:DVF_POP], Where ([Attribute:DEVTFACT:TAZ15Int] = [Attribute:TAZ15Int]))
- EPRACRESUM – Looks up and inserts TAZ level net acres, Get ([Attribute:SumEPRAcreTAZ:Sum_ACRE_EPR], Where ([Attribute:SumEPRAcreTAZ:TAZ15Int] = [Attribute:TAZ15Int]))
- PCTACTTAZ2 - Percent of a polygons share of a TAZ's acreage (sum of EPR acres, not the original TAZ acres as that does not account for takeaways like water etc), IfError ([Attribute:ACRE_EPR] / [Attribute:EPRACRESUM], 0)
- PCTSLF3FT - Percent of polygon acres under 3 feet of sea level rise, IfError ([Attribute:AcrSLR3ft] / [Attribute:ACRE_EPR], 0)
- AcrSLR3ft – Acres of a polygon that are under 3 feet of sea level rise.
- VFEMP - Calculates virtual future (2045) for employment by applying devt factor to build out potential, If ([Attribute:DVEMP] > 0,Then ([Attribute:BOEMP] / [Attribute:DVEMP]), Else ([Attribute:EMP45] * [Attribute:PCTACTAZ2])) + [Attribute:VFEMPMil]
- EMP45 – TAZ control total for employment, less military contributing employment (subtracted in separate manual process)
- VFPOP - Calculates virtual future (2045) for pop by applying devt factor to build out potential, If ([Attribute:DVPOP] > 0, Then ([Attribute:BOPOP] / [Attribute:DVPOP]), Else ([Attribute:POP45] * [Attribute:PCTACTAZ2]))
- POP45 – TAZ control total for population
- Military – Where =1, the TAZ as defined in a spreadsheet of military TAZ by TPO. Note, the TAZ may include some non military placetypes but for the most part the TAZs listed here are predominately military.
- MinorLU – HRTPO Regional Land Use 2045, Minor Category (Place Types)
- VEMPMil - Applies military emp to military polygons. This was part automatic and part manual, to fix rounding errors. First this equation was used in the formula [Round (If ([Attribute:Military] = 1,Then (Get ([Attribute:HR_MIL_TAZ_EMP:EMP45MIL], Where ([Attribute:HR_MIL_TAZ_EMP:TAZ] = [Attribute:TAZ15Int])) * [Attribute:PCTACTAZ2]), Else (0)), 2)] Then the differences of 416 was manually applied to MM 31 MM polygons that were less than -400 difference.

PT_LOOKUP_RCS3.dbf

Description: Community Viz table that is linked to the excel sheets used for detailing Place Types. See excel tables PT_LOOKUP_15.xlsx and PT_LOOKUP_45.xlsx for source values and formulas.

PT_LOOKUP_15.xlsx

Description: Place type densities, intensities and composition used in creating the 2015 virtual present.

PT_LOOKUP_45.xlsx

Description: Place type densities, intensities and composition used in creating the 2045 virtual future.

SLR_3_ft_above_MHHW_vector.shp

Description: 3ft Seal Level Rise layer, source HRTPO Geo site.

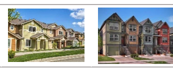
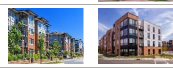
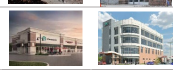
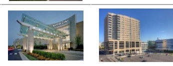
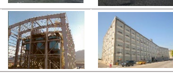
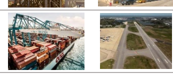
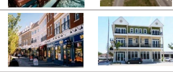
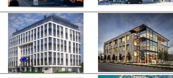
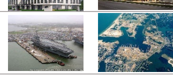
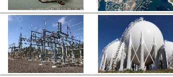
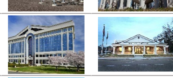
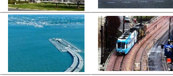
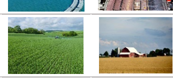
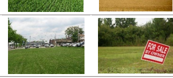
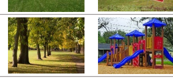
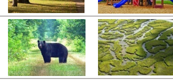
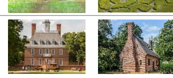
NoBuild_WatWetPark_2045_Dissolve.shp

Description: Merged and dissolved layer of no build features including water bodies, wetland and parks. Source files are all HRTPO Geo site.

Documentation of Place Types

Place Type Development Process

As discussed above in chapter 6, regional land uses were used as the Place Types for the land use modeling for both the Baseline and greater growth scenarios in the Regional Connectors Study. For each of the 21 Place Types in the dataset, map sampling and calculations were done in several locations in the region to determine the land use characteristics and typical densities of each Place Type. This allowed a table to be built of the features and characteristics of each Place Type, as shown below.

Code	Name[1]	Examples	DU/Acre Range	FAR Range	People / Acre[2]	Jobs / Acre	Description
RR	Rural Residential		0.1-.9	-	0.4-3	0	Very large lot single family homes in a rural context interspersed with some agricultural uses
RLD	Low Density Residential		1-3	-	4-10	0	Large lot single family homes in a low-density suburban context
RMD	Medium Density Residential		4-12	-	10-36	0	Attached homes and small lot single family homes in a moderate density suburban or urban context
RHD	High Density Residential		13+	-	37+	0	Multifamily apartments and condominiums in a high density urban or suburban context
CN	Neighborhood Commercial		-	.1-.3	-	5-10	Limited scale shopping, business, or trade activity
CL	Local Commercial		-	.1-.3	-	11-20	Inter-neighborhood shopping, business, or trade activity
CR	Regional Commercial		-	.4+	-	21+	Regional shopping, business, or trade activity
IL	Light Industrial		-	.05-.3	-	7-15	Light industrial uses (Research & Development, warehousing, service, etc.)
IH	Heavy Industrial		-	.05-.8	-	15+	Heavy industrial uses with possible adverse environmental impacts (manufacturing, etc.)
IPA	Port/Aviation Industrial		N/A	N/A	N/A	N/A	Port, General and Commercial Aviation related industrial operations
MCR	Mixed Use Comm/Res		4+	0.6+	10+	20+	Commercial/ residential mixed use activity
MCI	Mixed Use Comm/Ind		5+	0.6+	12+	30+	Commercial/ industrial mixed use activity
MM	Military		N/A	N/A	N/A	N/A	Military related facilities
IU	Utilities		-	-	-	1-3	Utility facilities
IP	Public/Semi-Public		-	-	5-10	30-60	Government/Educational/Religious/Social or healthcare facilities
IT	Transportation Network		-	-	-	-	Transportation facilities
AA	Agriculture		.01-.1	-	.03-.3	.03-.3	Agricultural operations
V	Vacant		-	-	-	-	Vacant developable lands
NP	Parks and Recreation		-	-	-	-	Open space and recreational uses
NC	Resource Conservation		-	-	-	-	Conservation lands
NH	Historic/ Cultural		-	0.1+	3-5	6-12	Historic Preservation / Cultural uses

[1] Note that all Place Types are assumed to be single land uses except for the Mixed-Use ones
[2] Population and employment density/intensities were developed by sampling place types in localities throughout the region and averaging the results but are expressed in a range of densities and intensities.

Figure 30. *The Place Type Matrix showing general descriptions of the Place Types*

Place Type Lookup Tables

The Place Types above were translated into detailed Place Type Lookup Tables for the land use scenario planning process. The Place Type Lookup Tables are used by CommunityViz software to define the characteristics of growth by Place Type and characterize it by density, employment types, occupancy and a variety of other parameters used by the TDM.

This section describes the Place Type Lookup Tables and their characteristics.

LU_CAT	LU_NM	FAR	DENSITY	TOTPCT	PCT_RES
RR	Rural Residential	0.05	0.25	1.00	70%
RLD	Low Density Residential	0.00	3.00	1.00	100%
RMD	Medium Density Residential	0.00	8.00	1.00	100%
RHD	High Density Residential	0.00	20.00	1.00	100%
CN	Neighborhood Commercial	0.20	0.00	1.00	0%
CL	Local Commercial	0.35	0.00	1.00	0%
CR	Regional Commercial	1.00	0.00	1.00	0%
IL	Light Industrial	0.25	0.00	1.00	0%
IH	Heavy Industrial	0.40	0.00	1.00	0%
IPA	Port or Aviation Industrial	0.50	0.00	1.00	0%
MCR	Mixed Use Comm-Res	1.25	40.00	1.00	60%
MCI	Mixed Use Comm-Ind	1.50	20.00	1.00	40%
MM	Military	0.00	4.00	1.00	100%
IU	Utilities	0.00	0.00	1.00	0%
IP	Public or Semi-Public	0.40	3.00	1.00	0%
IT	Transportation Network	0.00	0.00	1.00	0%
AA	Agriculture	0.00	0.01	1.00	80%
V	Vacant	0.00	0.00	100%	0%
NP	Parks and Recreation	0.00	0.00	100%	0%
NC	Resource Conservation	0.00	0.00	100%	0%
NH	Historic, Cultural	0.30	12.00	1.00	50%

Figure 31. *A portion of the Place Type Lookup Table showing the first few data columns for each Place Type*

The Place Type Lookup Tables have a series of data columns that profile each Place Type. Below is a list of the data column with a brief explanation of each column.

- FAR – Floor Area Ratio
- DENSITY – residential density in dwelling units per acre
- TOTPCT – cross checking cell to ensure totals add up to 100%
- PCT_RES – percent of residential land use
- CheckSum - cross checking cell to ensure totals add up to 100%
- 1PPHH, 2PPHH, 3PPHH, etc. – percent of 1,2,3, etc. person households
- H1V0, H1V1, H1V2, etc. – percent of 1,2,3 etc. person households by 1,2,3, etc. vehicles per household
- PCT_NONRES
- CheckSUMORIO - cross checking cell for the ORIO (Office, Retail, Industrial, Other) percentages
- PCT_IND – Percent of Industrial employment
- PCT_RET - Percent of Retail employment

- PCT_OFF - Percent of Office employment
- PCT_OTH - Percent of Other employment
- BOP_STAT_1PH, BOP_STAT_2PH, BOP_STAT_3PH, etc. – The buildout potential (capacity) for 1,2,3, etc. person households
- BOP_STAT_IND, BOP_STAT_RET, etc. - The buildout potential (capacity) for office, retail, etc. employment
- EMP_AC45 – The employees per acre for the virtual future (2045)
- DU_AC45 – The dwelling units per acre for the virtual future (2045)
- POP_AC45 – The population per acre for the virtual future (2045)
- AVGPP_HH – The average household size for the virtual future (2045)

Household Size / Vehicle Composition in Place Types

As part of the data needed for the TDM, each Place Type was classified into occupancy and vehicle ownership profiles. This was done through the use of US Census PUMS data on household occupancy and vehicle ownership.

First, census block groups in the region were isolated that had a predominance of one single Place Type. Then, the PUMS data was used to find the household occupancy mix and vehicle ownership for each census block group that had that Place Type as the dominant land use. These were then averaged to come up with a typical profile of occupancy and vehicle ownership for each Place Type.

These profiles were then built into the lookup tables for each Place Type. The resultant matrix is shown below and this data was translated into the master Place Type Lookup Table as discussed above.

	H1V0	H1V1	H1V2	H1V3	H2V0	H2V1	H2H2	H2V3	H3V0	H3V1	H3V2	H3V3	H4V0	H4V1	H4V2	H4V3
Regional Avg	3.90%	18.00%	4.10%	1.00%	1.50%	7.80%	18.20%	6.90%	0.70%	3.50%	6.80%	6.20%	0.80%	3.30%	9.40%	8.00%
Rural Residential	1.25%	6.25%	7.50%	10.00%	2.00%	10.00%	12.00%	16.00%	0.75%	3.75%	4.50%	6.00%	1.00%	5.00%	6.00%	8.00%
Low Density Residential	1.25%	6.25%	10.00%	7.50%	1.50%	7.50%	12.00%	9.00%	1.00%	5.00%	8.00%	6.00%	1.25%	6.25%	10.00%	7.50%
Medium Density Residenti	3.00%	10.50%	12.00%	4.50%	3.00%	10.50%	12.00%	4.50%	2.00%	7.00%	8.00%	3.00%	2.00%	7.00%	8.00%	3.00%
High Density Residential	2.00%	6.00%	8.00%	4.00%	3.00%	9.00%	12.00%	6.00%	2.00%	6.00%	8.00%	4.00%	3.00%	9.00%	12.00%	6.00%
Mixed Use Comm-Res	2.50%	8.75%	8.75%	5.00%	3.00%	10.50%	10.50%	6.00%	2.00%	7.00%	7.00%	4.00%	2.50%	8.75%	8.75%	5.00%
Mixed Use Comm-Ind	7.00%	14.00%	10.50%	3.50%	6.00%	12.00%	9.00%	3.00%	5.00%	10.00%	7.50%	2.50%	2.00%	4.00%	3.00%	1.00%
Military	0.75%	4.50%	7.50%	2.25%	1.50%	9.00%	15.00%	4.50%	1.25%	7.50%	12.50%	3.75%	1.50%	9.00%	15.00%	4.50%
Agriculture	0.00%	4.00%	8.00%	8.00%	0.00%	8.00%	16.00%	16.00%	0.00%	4.00%	8.00%	8.00%	0.00%	4.00%	8.00%	8.00%
Historic and Cultural	1.25%	13.75%	7.50%	2.50%	1.50%	16.50%	9.00%	3.00%	1.00%	11.00%	6.00%	2.00%	1.25%	13.75%	7.50%	2.50%

Figure 32. *Household occupancy and vehicle ownership distributions for each Place Type*

Documentation of Suitability and Land Use Allocations

Suitability Factors and Weighting

The Suitability Factors, as described above, are used by CommunityViz software to guide the growth allocations. Figures 33 through 35 below show the final suitability factors and weights that were used for the land use allocations.

A. Water Scenario					
Jobs			Population		
Sutability Factor	Method	Weight	Sutability Factor	Method	Weight
Deep Water Port Access	Overlap		Active Transportation Infrastructure	Distance	
Future Port or Aviation Industrial Place Type	Overlap		Major Roadways	Distance	
Future Port or Aviation Industrial Place Type	Distance		Military Presence	Distance	
Major Roadways	Distance		Shoreline	Distance	
Military Presence	Overlap		Tourism	Distance	
Shipbuilding Businesses & Ports	Distance		Utilities Service Area	Overlap	
Tourism	Distance				
Urbanized Waterfront	Overlap				

Figure 33. *Suitability factors and weighting for the Greater Growth on the Water scenario*

B. Urban Scenario					
Jobs			Population		
Sutability Factor	Method	Weight	Sutability Factor	Method	Weight
Active Transportation Infrastructure	Distance		2045 Employment Density	Distance	
Proximity to Dense City Centers	Distance		2045 Population Density	Distance	
Employment Accessibility	Distance		Active Transportation Infrastructure	Distance	
Higher Education Facilities	Distance		Proximity to Dense City Centers	Distance	
Future Mixed Use Comm/Ind Place Type	Distance		Employment Accessibility	Distance	
Future Mixed Use Comm/Res Place Type	Distance		Higher Education Facilities	Distance	
Redevelopment Potential	Distance		Future Mixed Use Comm/Res Place Type	Distance	
Shipbuilding Businesses & Ports	Distance		Redevelopment Potential	Distance	
Transit Proximity	Distance		Future High Density Residential Place Type	Distance	
Urbanized Waterfront	Distance		Future Low Density Residential Place Type	Distance	
Utilities Service Area	Overlap		Future Medium Density Residential Place Type	Distance	
2045 Employment Density	Distance		Transit Proximity	Distance	
			Utilities Service Area	Overlap	

Figure 34. *Suitability factors and weighting for the Greater Growth in Urban Centers scenario*

C. Suburban Scenario					
Jobs			Population		
Sutability Factor	Method	Weight	Sutability Factor	Method	Weight
Active Transportation Infrastructure	Overlap		Active Transportation Infrastructure	Distance	
Proximity to City Centers	Distance		Major Roadways	Distance	
Future Regional Commercial Place Type	Distance		Future Mixed Use Comm/Res Place Type	Distance	
Existing Heavy Industrial Place type	Distance		Undeveloped Land Availability	Distance	
Existing Warehouse Facilities	Distance		Utilities Service Area	Overlap	
Future Public/Semi-Public Place Type	Distance				
Large Developable Sites	Distance				
Future Mixed Use Comm/Ind Place Type	Distance				
Future Mixed Use Comm/Res Place Type	Distance				
Undeveloped Land Availability	Distance				
Utilities Service Area	Overlap				

***Figure 35**. Suitability factors and weighting for the Greater Suburban/Greenfield Growth scenario*

Suitability Mapping

The CommunityViz software allowed a visualization of the suitability factors through a combined "heat map" for the region that showed the relative attractiveness of each portion of the region for a particular combination of suitability factors and weights. Shown below are the maps for each scenario for both population and employment suitability.

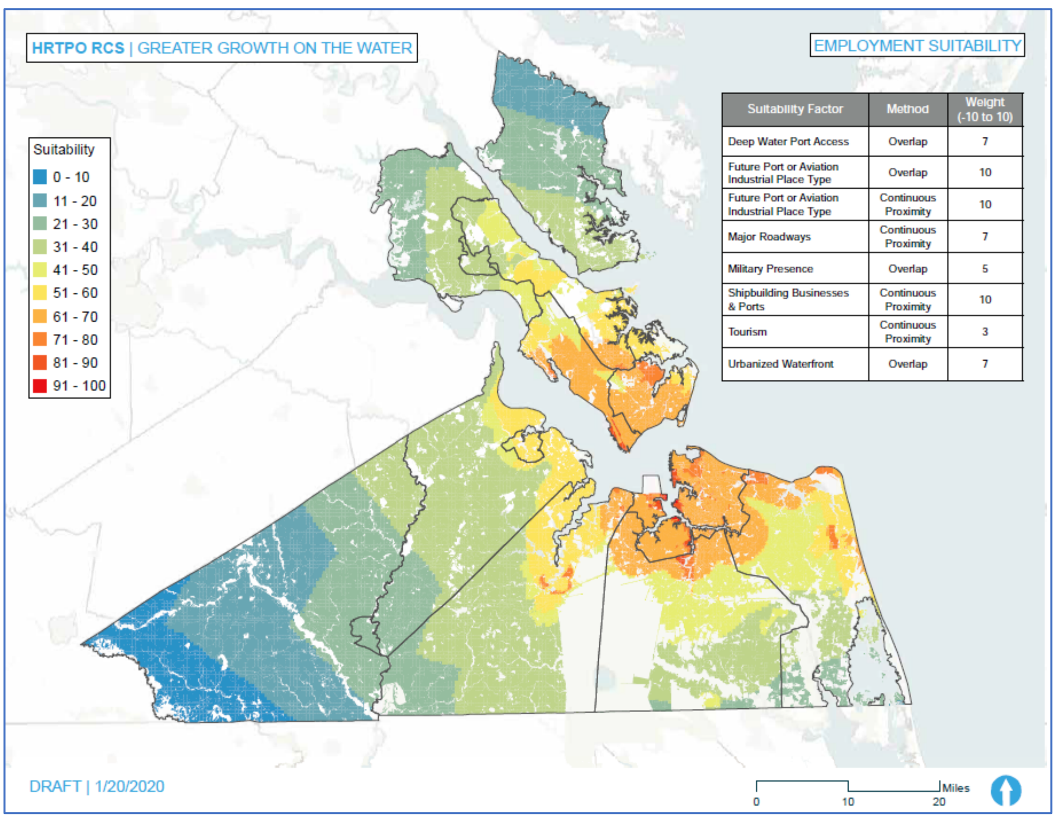


***Figure 36.** Final Suitability Factor mapping for employment suitability for the Greater Growth on the Water scenario*

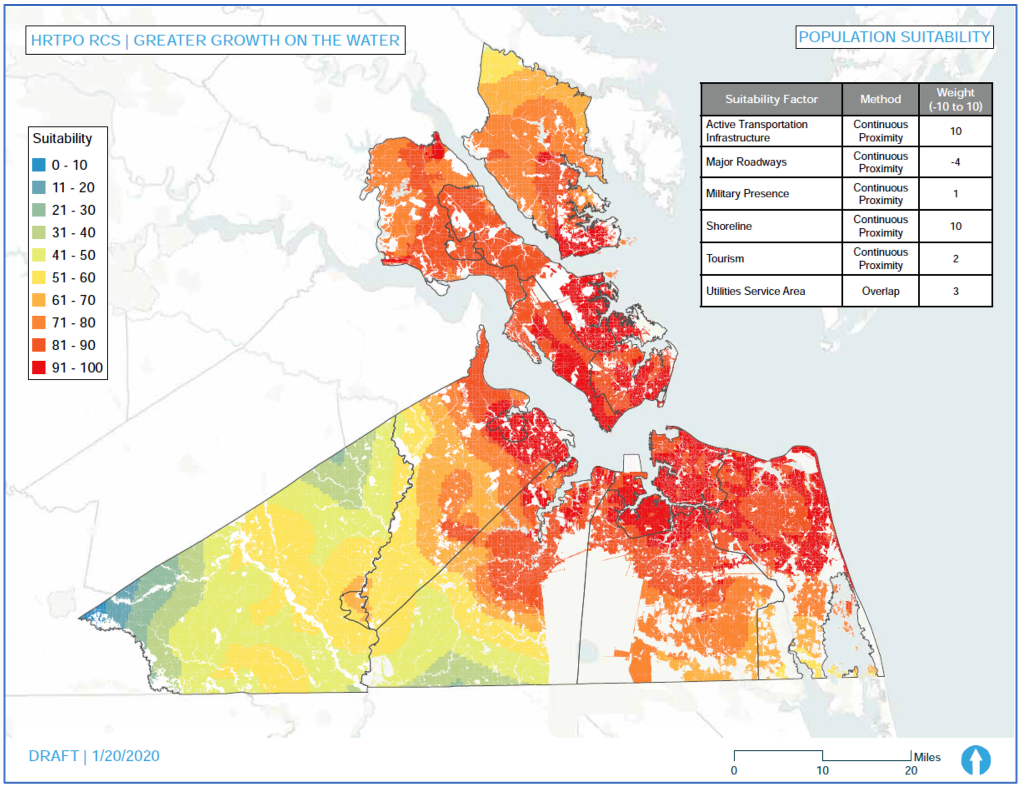


Figure 37. *Final Suitability Factor mapping for population suitability for the Greater Growth on the Water scenario*

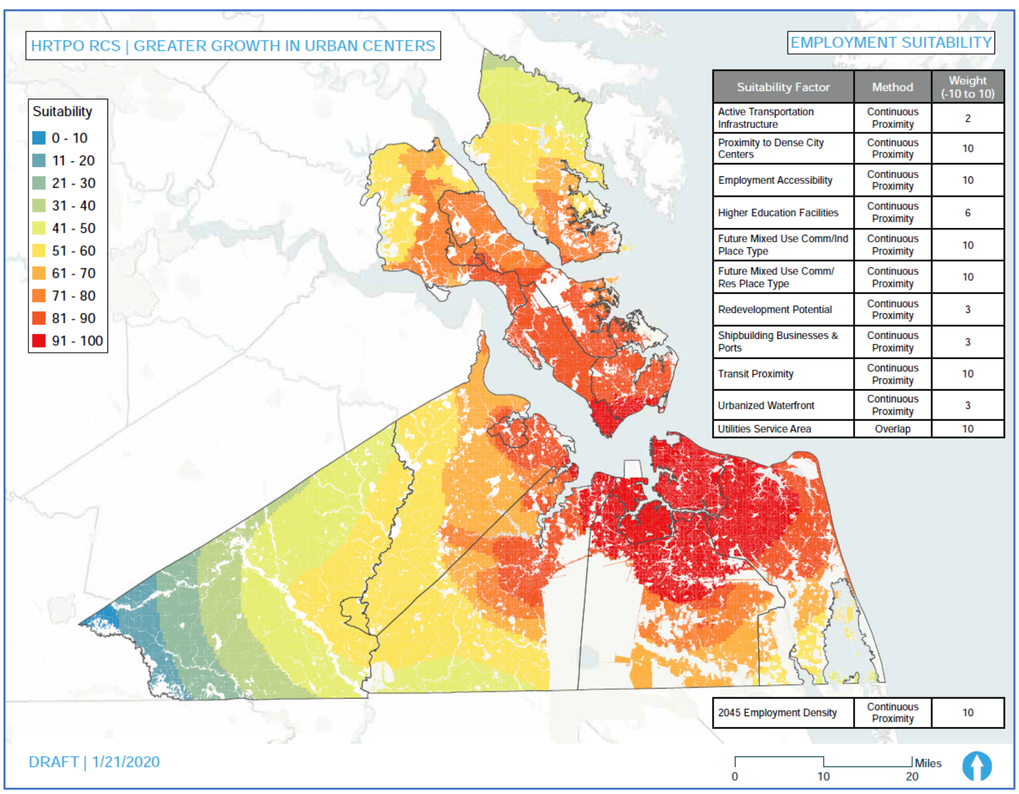


Figure 38. *Final Suitability Factor mapping for employment suitability for the Greater Growth in Urban Centers scenario*

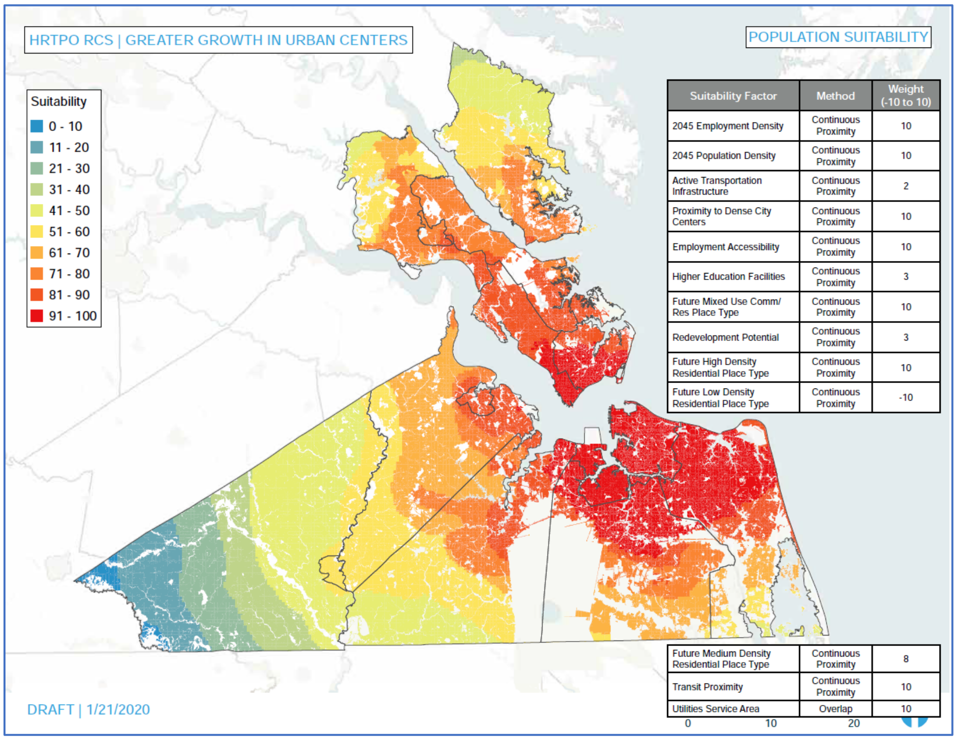


Figure 39. *Final Suitability Factor mapping for population suitability for the Greater Growth in Urban Centers scenario*

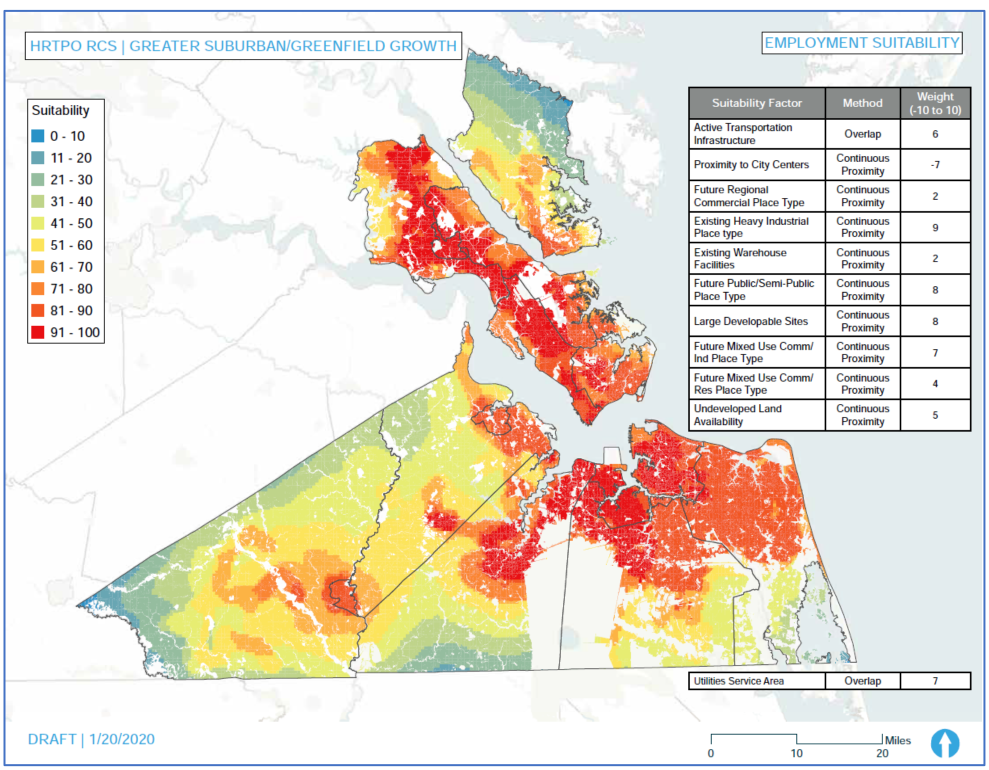


Figure 40. *Final Suitability Factor mapping for employment suitability for the Greater Suburban/Greenfield Growth scenario*

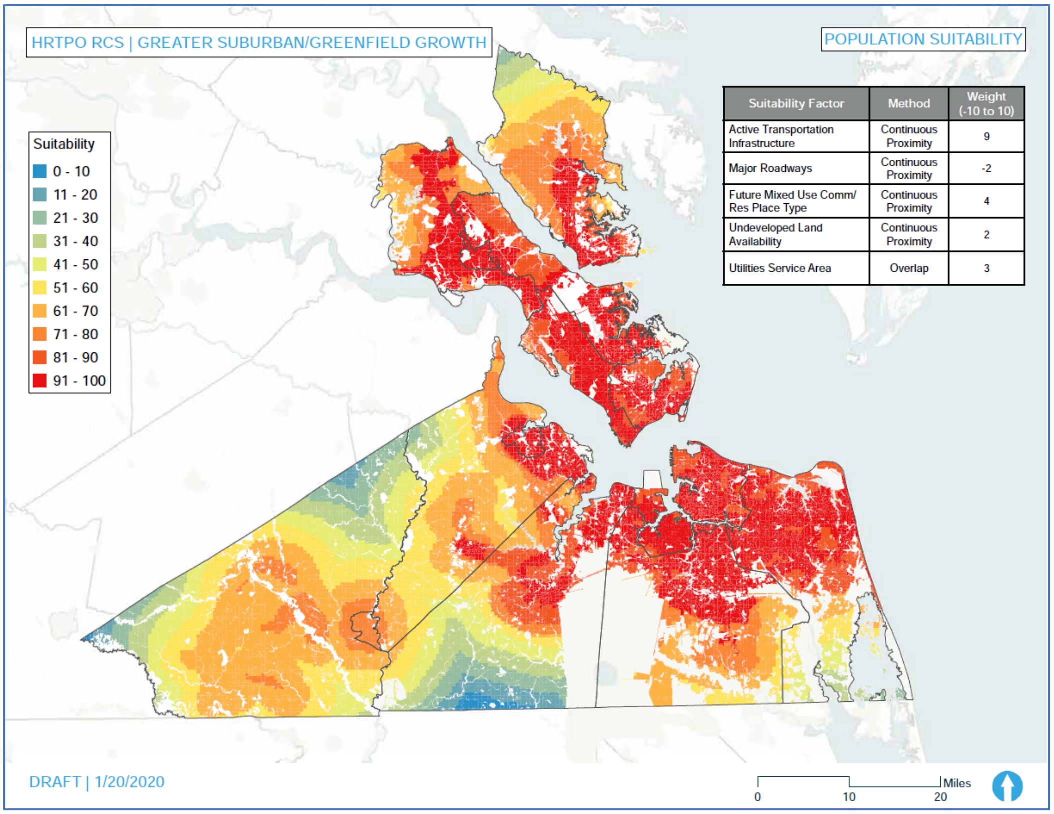


Figure 41. *Final Suitability Factor mapping for population suitability for the Greater Suburban/Greenfield Growth scenario*

Capacity Mapping

As described above in Chapter 6, capacity in the model is defined as the difference between the ultimate buildout possible in a polygon, minus the existing development in the polygon. The buildout potential is the product of the acres and the maximum density of a Place Type polygon. CommunityViz calculated the capacity for each polygon in the model based on this formula. The outcome of the capacity calculation was two maps, one for population capacity and one for employment capacity. These did not differ by scenario since capacity is the same for each scenario. The allocator tool used these maps to assign available growth to each polygon in each scenario. The scenarios differed based on their relative suitability, not on the basis of their capacity. Shown below are the maps that document the capacity for growth for both population and employment capacity.

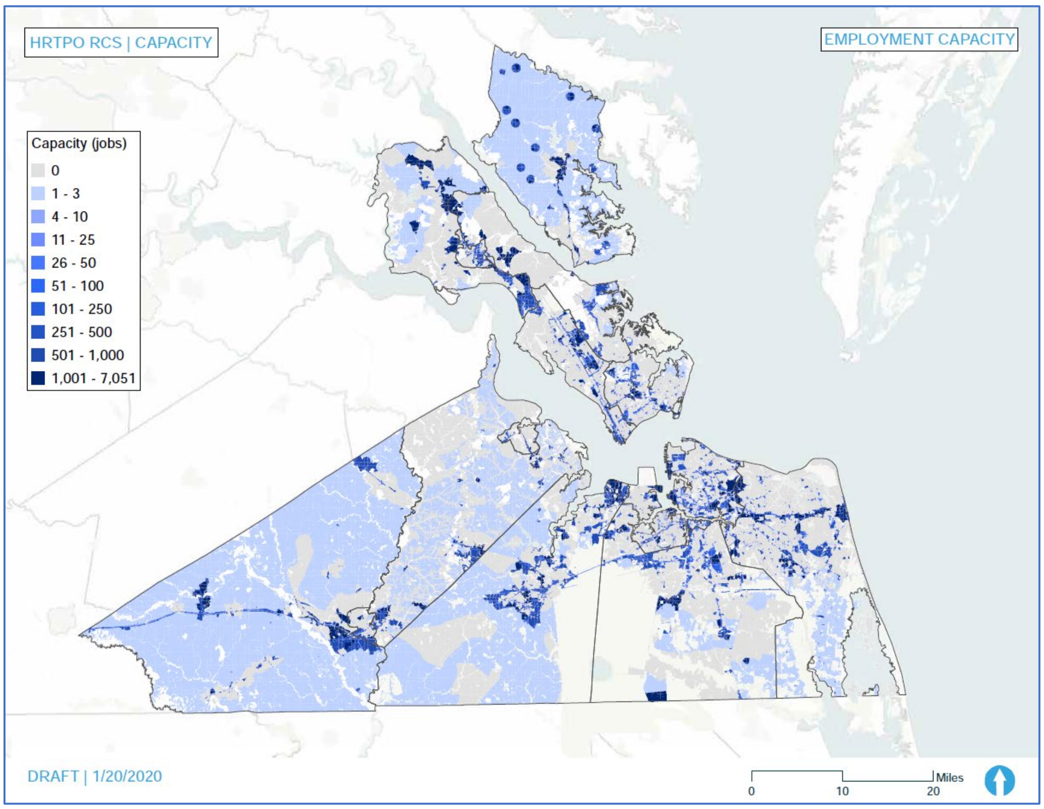


Figure 42. *Final Capacity mapping for employment for all the scenarios*

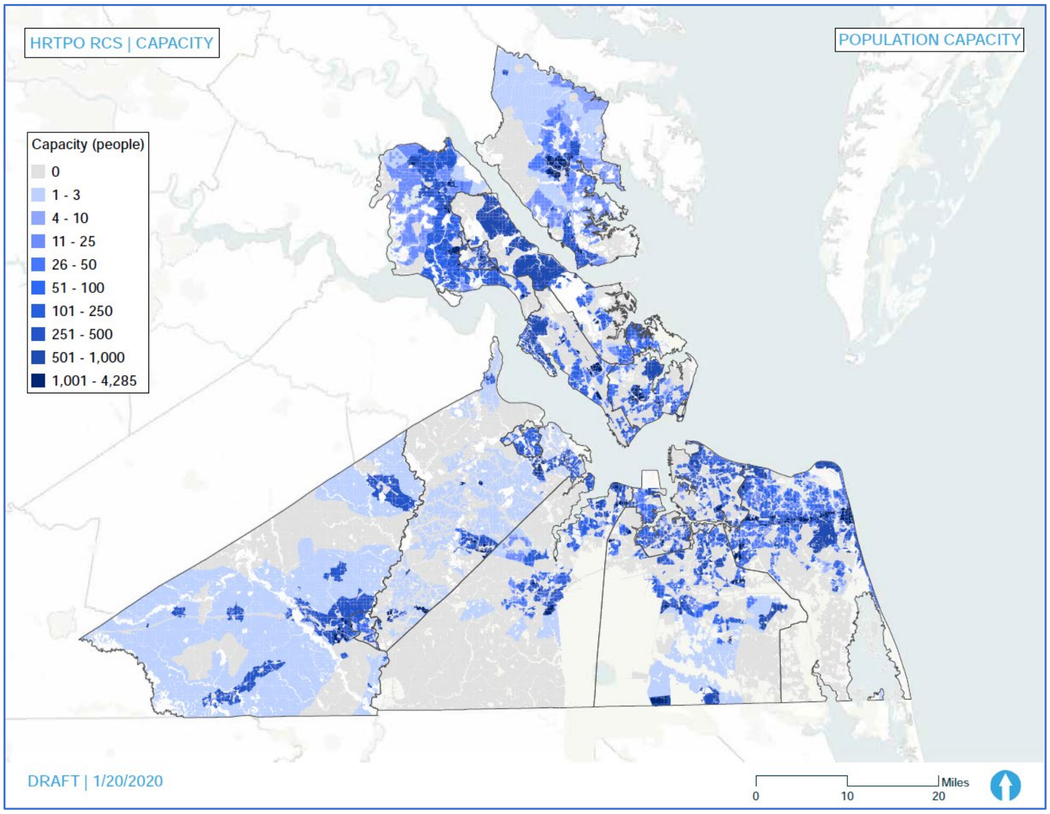


Figure 43. *Final Capacity mapping for population for all the scenarios*

Land Use Allocation Mapping

Upon completion of the suitability factors and weights, the CommunityViz Allocator was run on each greater growth scenario to create a pattern of future growth according to each scenario narrative. As described in Chapter 6, this was an iterative process, using a series of iterative runs of each scenario while slightly adjusting the suitability factor weighting for each scenario so that the pattern of growth more closely matched the intended narrative of each scenario. The result of this process was to produce three distinctively different patterns of growth, each keyed to one of the scenarios with the respective set of drivers described in the scenario narratives.

CommunityViz and GIS mapping tools also allowed visualizations of the allocations for each scenario for both population and employment. Shown below are the maps for each scenario for both population and employment allocation.

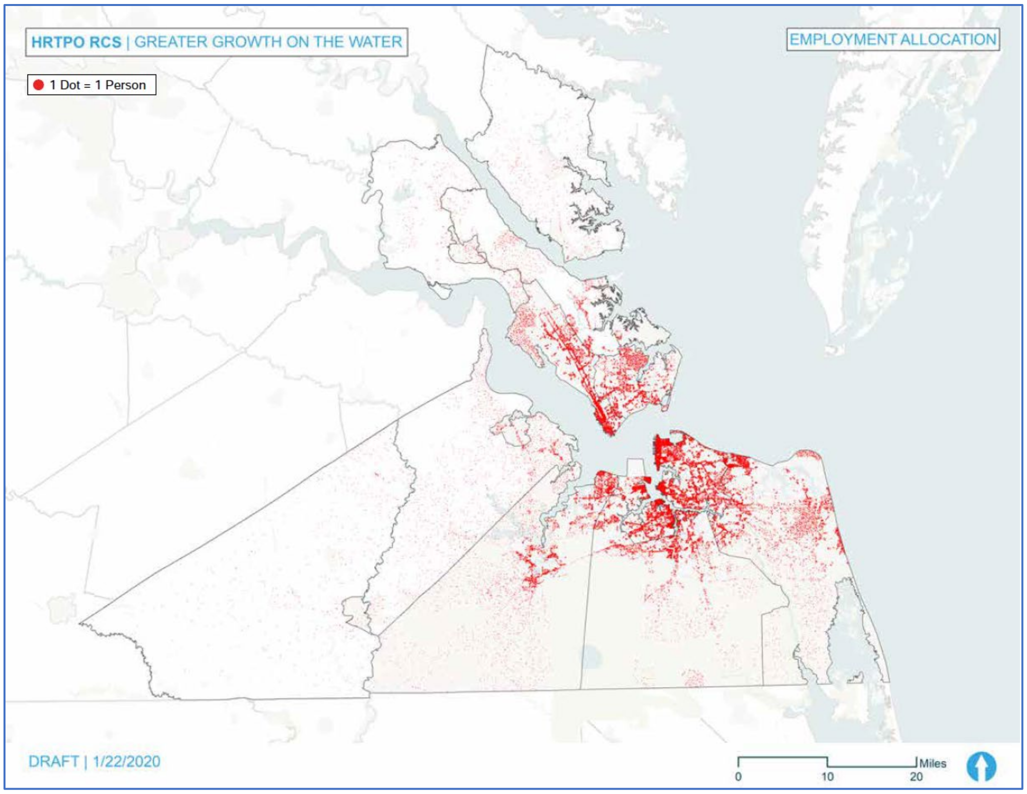


Figure 44. *The final allocation map for employment for the Greater Growth on the Water scenario*

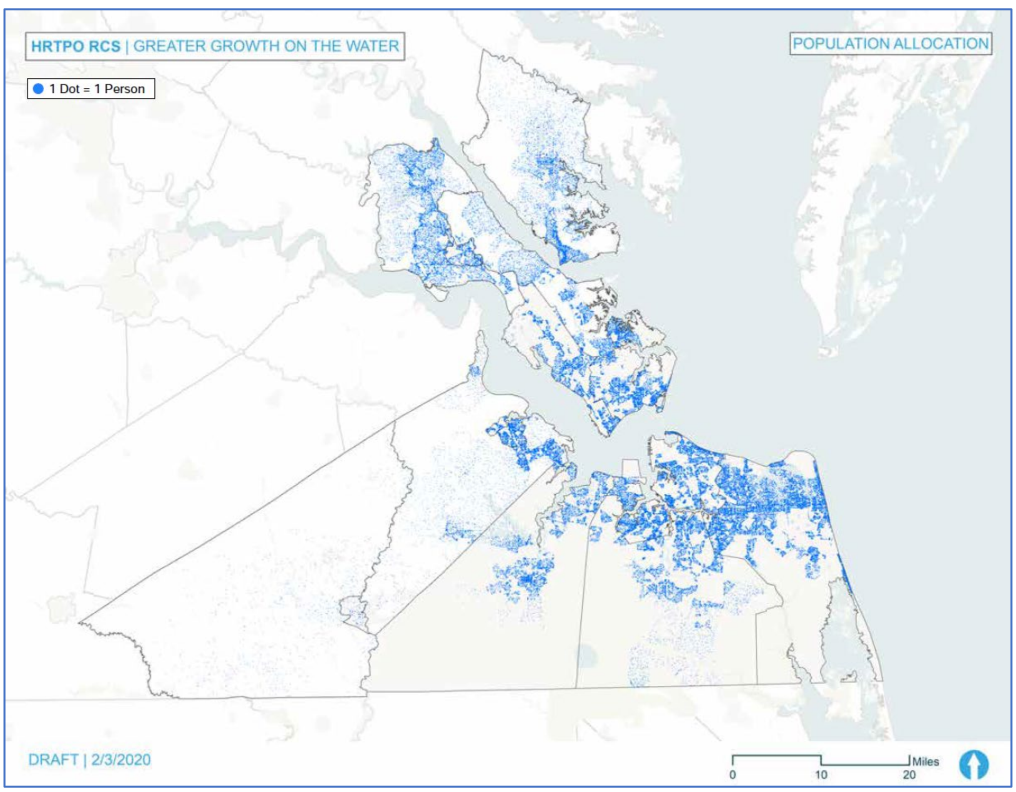


Figure 45. *The final allocation map for population for the Greater Growth on the Water scenario*

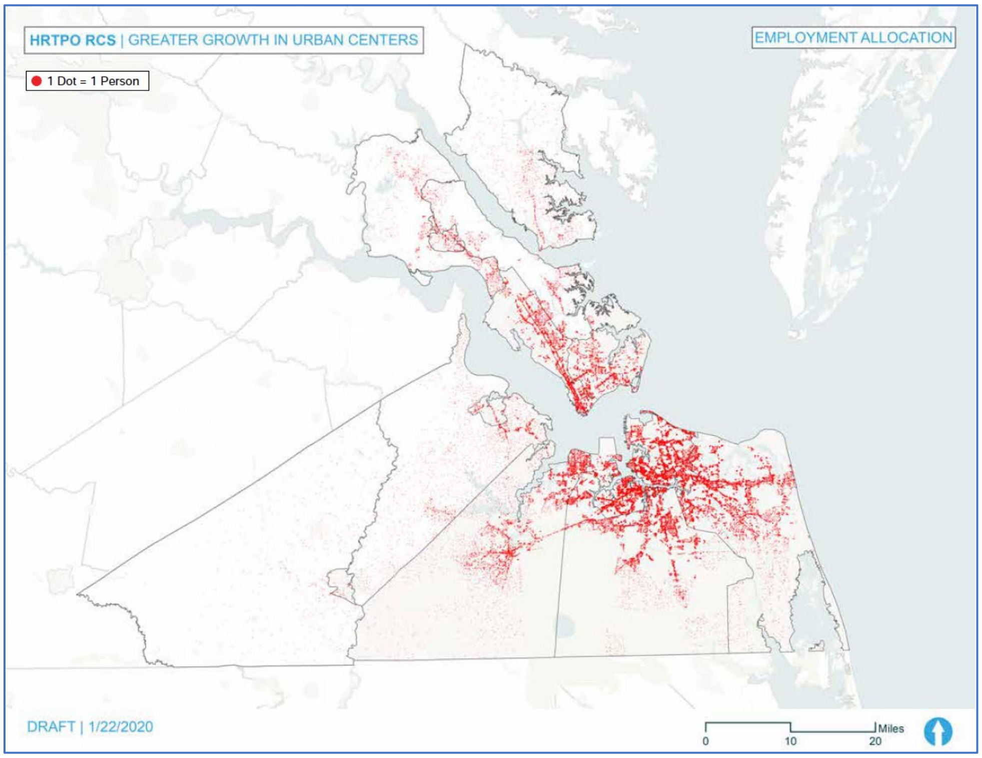


Figure 46. *The final allocation map for employment for the Greater Growth in Urban Centers scenario*

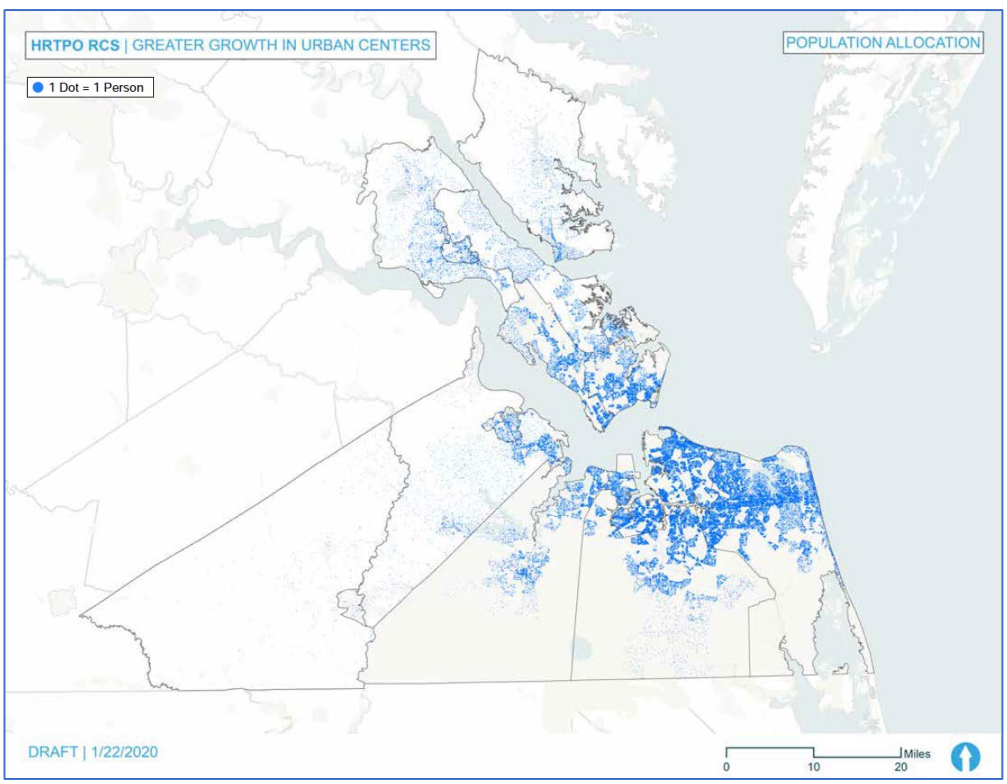


Figure 47. *The final allocation map for population for the Greater Growth in Urban Centers scenario*

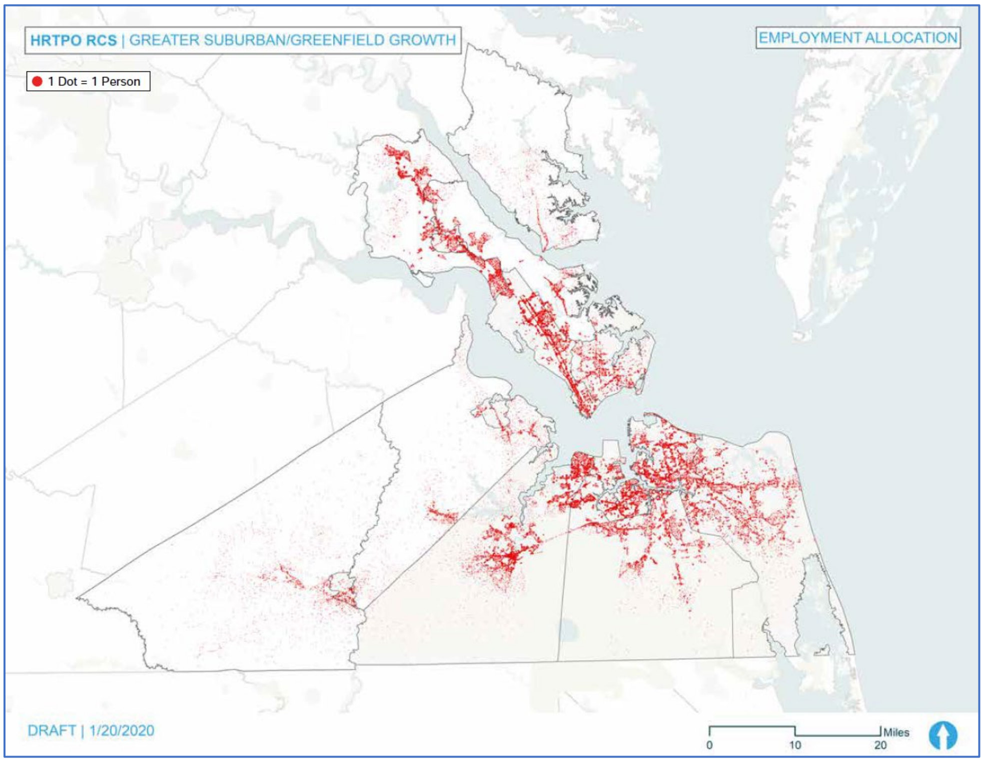


Figure 48. *The final allocation map for employment for the Greater Suburban/Greenfield Growth scenario*

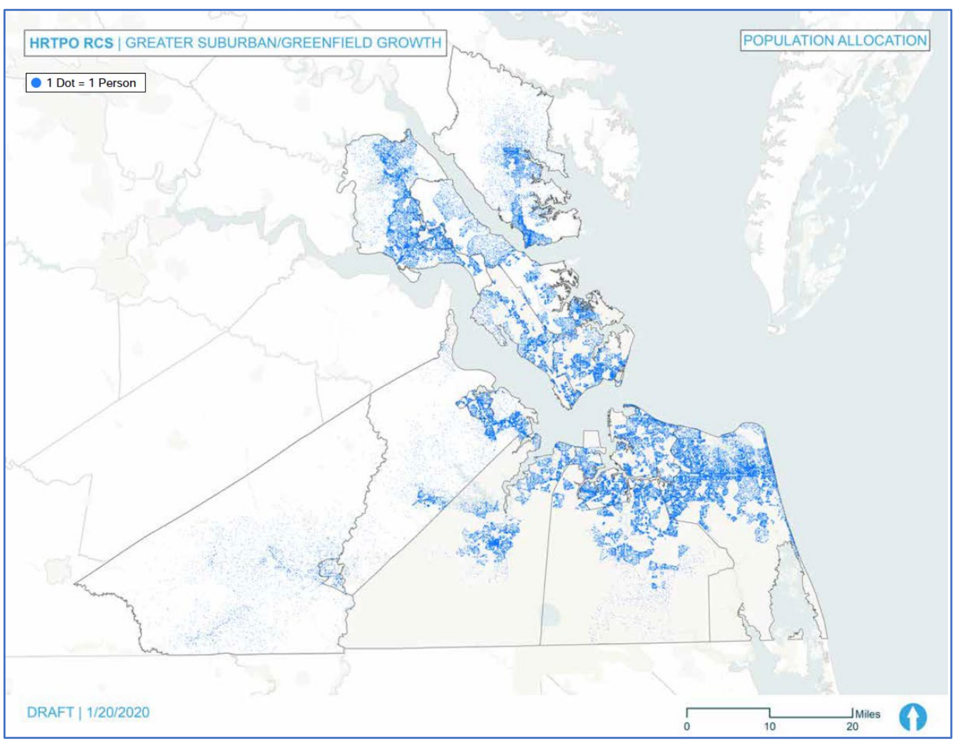


Figure 49. *The final allocation map for population for the Greater Suburban/Greenfield Growth scenario*

Documentation of Land Use Model Performance Measures

According to the Performance Measures matrix described above, a series of performance measures derive solely from the land use model. There are many more performance measures in the modeling that derive from the TDM and TREDIS models as well. The performance measures coming out of the land use model are the following:

- Population in multi-family housing
- Population near key destinations
- Population near transit stops
- Population in urban Place Types
- Population on generally undeveloped land (per 2016 Land Cover Data)
- Population near flood-prone areas
- Jobs near key destinations
- Jobs near transit stops
- Jobs near flood-prone areas

Based on the final land use scenario allocations in the land use model, the land use performance measures showed sufficient variation between the scenarios to validate the basic scenario narratives that were originally developed. These performance measure results for the three greater growth scenarios are summarized below.

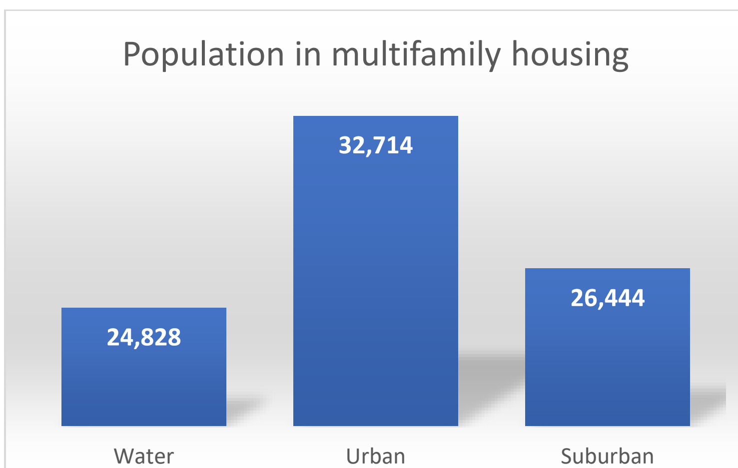


Figure 50. *Population in Multifamily Housing for the greater growth scenarios*

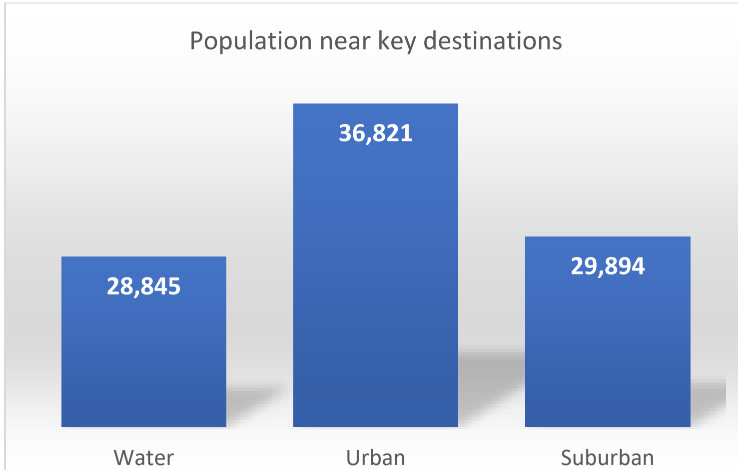


Figure 51. *Population Near Key Destinations for the greater growth scenarios*

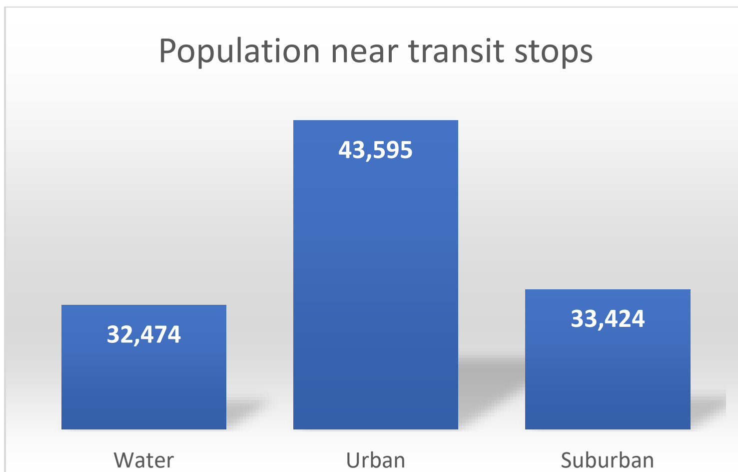


Figure 52. *Population Near Transit Stops for the greater growth scenarios*

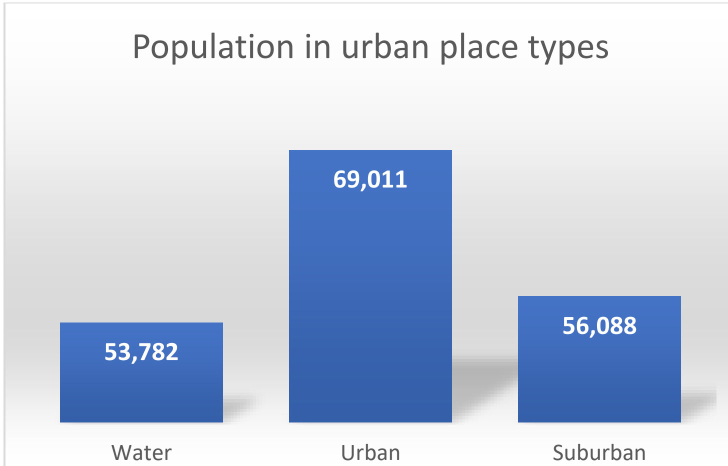


Figure 53. *Population in Urban Place Types for the greater growth scenarios*

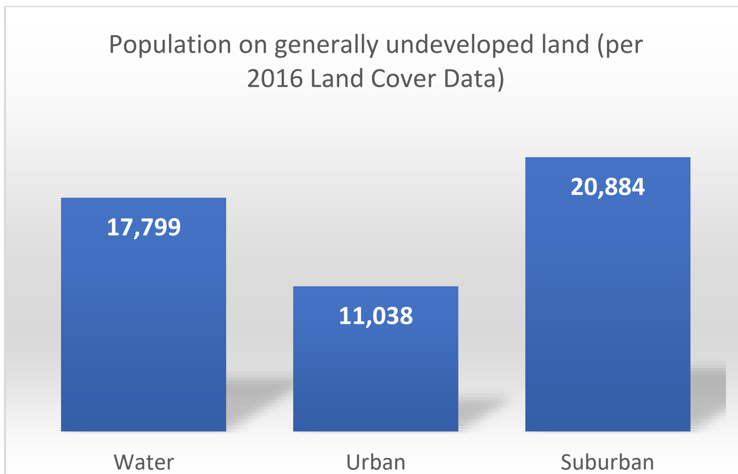


Figure 54. *Population on Generally Undeveloped Land for the greater growth scenarios*

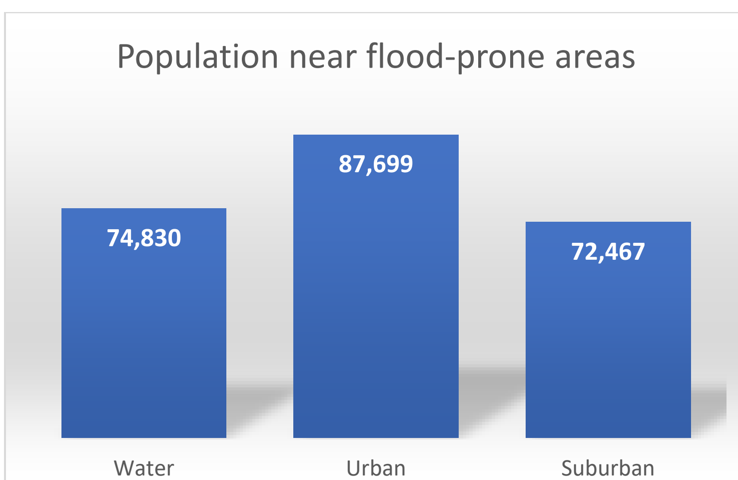


Figure 55. *Population Near Flood Prone Areas for the greater growth scenarios*

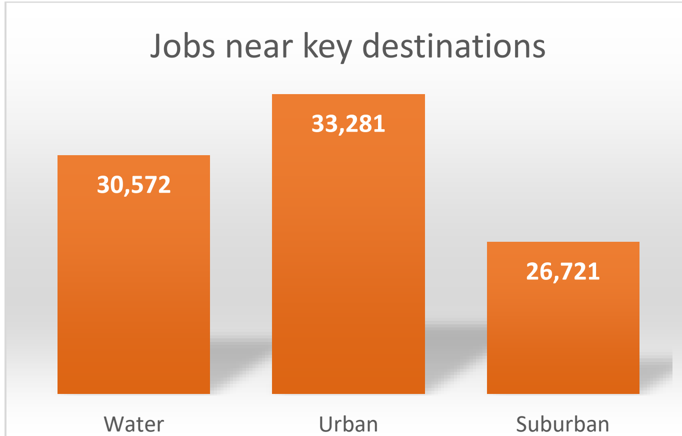


Figure 56. *Jobs Near Key Destinations for the greater growth scenarios*

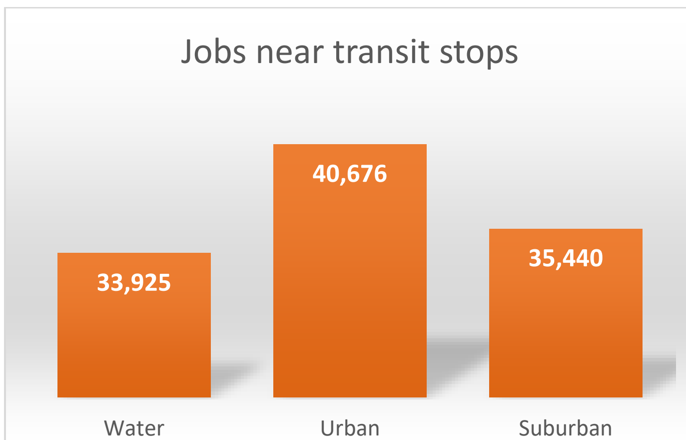


Figure 57. *Jobs Near Transit Stops for the greater growth scenarios*

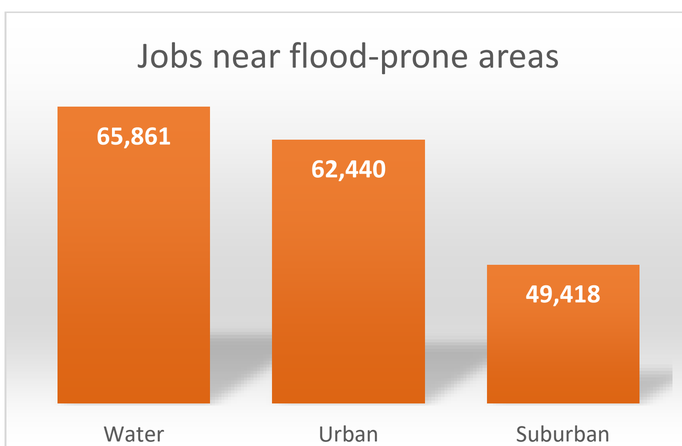


Figure 58. *Jobs Near Flood Prone Areas for the greater growth scenarios*

Documentation of Land Use Outputs for the Travel Demand Model

After completion of the land use allocation for each greater growth scenario, the outputs from the land use modeling become inputs to the TDM. These inputs are used to apply a unique set of socioeconomic data by TAZ from the land use model so that it can be run in the TDM.

TDM Input Tables

The land use model outputs were translated into TDM Input tables that contained all the data types needed to run the TDM. The TDM Input tables are used by the TDM to distribute travel across the region according to the socioeconomic data provided from the land use modeling.

TAZ15Int	H1V0	H1V1	H1V2	H1V3	H2V0	H2V1	H2V2	H2V3	H3V0	H3V1	H3V2	H3V3	H4V0	H4V1	H4V2	H4V3	POP	HH	AUTOS
1	0.510638	0.817021	0.544681	0.102128	0.170213	0.680851	0.851064	0.340426	0.068085	0.408511	0.476596	0.306383	0.068085	0.27234	0.851064	0.340426	16	6.808511	10.89362
2	2.202128	3.523404	2.348936	0.440426	0.734043	2.93617	3.670213	1.468085	0.293617	1.761702	2.055319	1.321277	0.293617	1.174468	3.670213	1.468085	69	29.3617	46.97872
3	1.085106	1.73617	1.157447	0.217021	0.361702	1.446809	1.808511	0.723404	0.144681	0.868085	1.012766	0.651064	0.144681	0.578723	1.808511	0.723404	34	14.46809	23.14894
4	0.638298	1.021277	0.680851	0.12766	0.212766	0.851064	1.06383	0.425532	0.085106	0.510638	0.595745	0.382979	0.085106	0.340426	1.06383	0.425532	20	8.510638	13.61702
5	0.606383	0.970213	0.646809	0.121277	0.202128	0.808511	1.010638	0.404255	0.080851	0.485106	0.565957	0.36383	0.080851	0.323404	1.010638	0.404255	19	8.085106	12.93617
6	0.825112	1.701794	0.721973	0.103139	0.309417	1.03139	1.547085	0.206278	0.206278	0.876682	0.825112	0.103139	0.154709	0.618834	0.567265	0.515695	23	10.3139	14.33632
7	0.765957	1.225532	0.817021	0.153191	0.255319	1.021277	1.276596	0.510638	0.102128	0.612766	0.714894	0.459574	0.102128	0.408511	1.276596	0.510638	24	10.21277	16.34043
8	0.925532	1.480851	0.987234	0.185106	0.308511	1.234043	1.542553	0.617021	0.123404	0.740426	0.86383	0.555319	0.123404	0.493617	1.542553	0.617021	29	12.34043	19.74468
9	0.542553	0.868085	0.578723	0.108511	0.180851	0.723404	0.904255	0.361702	0.07234	0.434043	0.506383	0.325532	0.07234	0.289362	0.904255	0.361702	17	7.234043	11.57447
10	0.446809	0.714894	0.476596	0.089362	0.148936	0.595745	0.744681	0.297872	0.059574	0.357447	0.417021	0.268085	0.059574	0.238298	0.744681	0.297872	14	5.957447	9.531915
11	0.829787	1.32766	0.885106	0.165957	0.276596	1.106383	1.382979	0.553191	0.110638	0.66383	0.774468	0.497872	0.110638	0.442553	1.382979	0.553191	26	11.06383	17.70213
12	1.946809	3.114894	2.076596	0.389362	0.648936	2.595745	3.244681	1.297872	0.259574	1.557447	1.817021	1.168085	0.259574	1.038298	3.244681	1.297872	61	25.95745	41.53191
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	1.363229	2.811659	1.192825	0.170404	0.511211	1.704036	2.556054	0.340807	0.340807	1.44843	1.363229	0.170404	0.255605	1.022422	0.93722	0.852018	38	17.04036	23.6861
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1.434978	2.959641	1.255605	0.179372	0.538117	1.793722	2.690583	0.358744	0.358744	1.524664	1.434978	0.179372	0.269058	1.076233	0.986547	0.896861	40	17.93722	24.93274
22	1.337188	2.80037	1.403145	0.371785	0.5037	1.840888	2.692414	1.007401	0.20148	1.278446	1.549491	0.802313	0.20148	0.875486	2.135893	1.146531	47	20.14801	32.34117
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 59. *A portion of the TDM Input Table showing the first few data columns for each TAZ*

The TDM Input tables have a series of data columns that provide data for each TAZ. Below is a list of the data columns with a brief explanation of each column.

- TAZ15Int – the unique TAZ identifier
- H1V0, H1V1, H1V2, H1V3, etc. - percent of 1,2,3 etc. person households by 1,2,3, etc. vehicles per household
- POP – total population in the TAZ
- HH - total households in the TAZ
- AUTOS - total autos in the TAZ
- TOTEMP - total employees in the TAZ
- RETEMP - total retail employees in the TAZ
- NRETEMP – total non-retail employees in the TAZ
- BA_OFF - total office employees in the TAZ
- BA_IND - total industrial employees in the TAZ
- BA_OTH - total other employees in the TAZ
- AVGAUTO – average number of autos per household in the TAZ
- GQ – presence of Group Quarters in the TAZ (Y=yes, N=no)
- GQ_TOT – total population in Group Quarters in the TAZ

B: Documentation of Transportation Model Elements

During the course of applying a regional travel model to a specific study, adjustments to the regional model are often necessary in order to address the particular objectives of the subject study. Such was the case with the Hampton Roads travel model and the Regional Connectors Study. While many adjustments during the Regional Connectors Study were made to the regional model to improve model performance, this appendix describes significant enhancements to the model that are unique to this study.

Travel Time Reliability

The "stock" updated Hampton Roads travel model as delivered by VDOT[13], and used in this study, contains "penalties" that discourage cross-harbor travel. These penalties were instituted so that traffic estimates produced by the model are close to those observed in 2017; but they do compromise the model's capability to forecast future demand – especially where transportation improvements could significantly increase cross-harbor capacity. The penalties contained in the model have the potential to "throttle" future cross-harbor demand because they do not change moving into the future and do not recognize increases in capacity that the RCS will consider.

One of the factors that the penalties account for is travel time reliability. The greater the level of congestion on cross-harbor travelers, the more unreliable the travel time required to get to their destination. Travelers react to this unreliability by building in extra time, or "buffer" time, to ensure on-time arrival. This extra time manifests itself as part of the penalty applied in the stock model. However, in the future, the amount of buffer time will change with the level of congestion associated with crossing the harbor, precipitated by changes in demand and available roadway capacity.
In order to forecast the change in buffer time into the future, this Study introduced travel time reliability as an explicit variable in the model. Its inclusion provides a means to dynamically account for an aspect of cross-harbor travel behavior and potentially lessen the dependency on applying static penalties to discourage cross-harbor travel.

Implementation

As congestion increases, the variance in travel time on a day-to-day basis increases, making travel times less reliable. Travelers program in extra travel time (buffer time) to ensure on-time arrival. This additional time added to the actual travel time introduces "perceived time" into the travel model's trip distribution process:

Perceived Time = Actual Time + Buffer Time

This additional time makes certain destinations less attractive in the trip distribution step of the model depending on the level of congestion and the individual travel path from any given origin to destination. Implementation of travel time reliability into the travel model generally proceeded as follows:

[13] January 2020 release.

1. Identification of travel paths that use the cross-harbor bridges and tunnels.
2. Determine percentage of vehicle-miles traveled (VMT) in congested conditions for each travel path.
3. Calculate buffer time for each path based on congested VMT. Figure 60 shows the relationship between the percentage of congested VMT and the buffer time index[14] associated with each travel path.
4. Add buffer time to actual travel times for each travel path yielding perceived times.
5. Feed perceived times into the travel model.
6. Re-validate the travel model using observed travel pattern and traffic count data – focus on cross-harbor travel.
7. Examine impact on the need for cross-harbor adjustments.

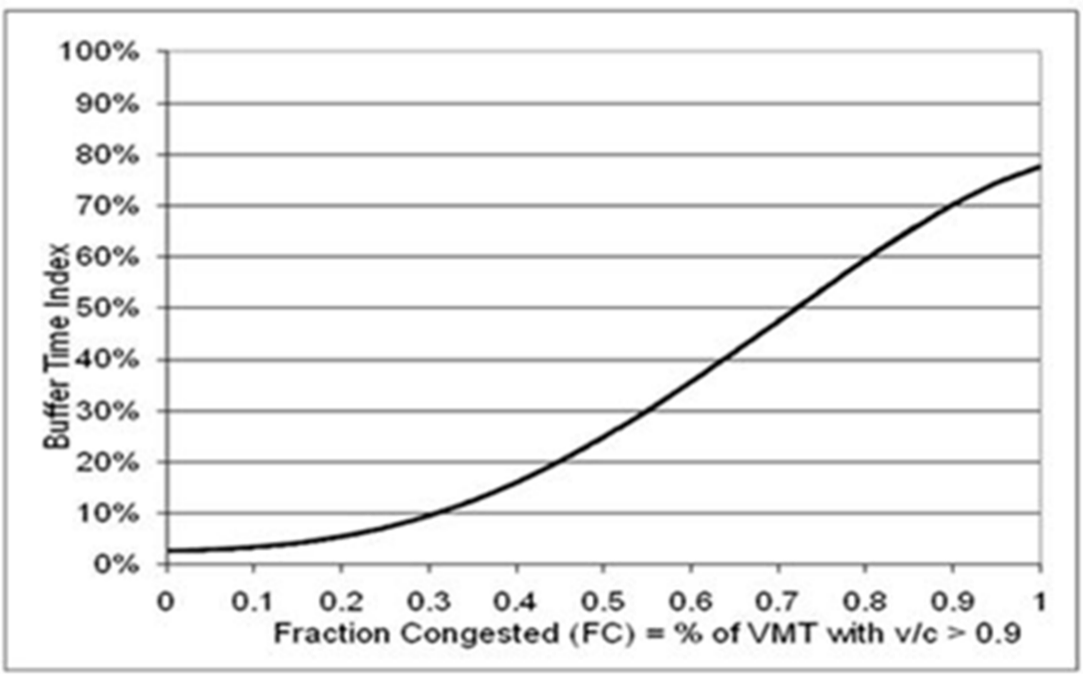


Figure 60. *A portion of the TDM Input Table showing the first few data columns for each TAZ.*
Source: TREDIS Technical Documentation

Revised Cross-Harbor Adjustments

Cross-harbor adjustments in the stock model consisted of distance penalties on the Monitor Merrimac Memorial Bridge-Tunnel and the Hampton Roads Bridge-Tunnel. Jurisdiction-to-jurisdiction adjustment factors were also used in the stock model's trip distribution step to discourage cross-harbor travel. After accounting for the effect of travel time reliability, travel model re-validation revealed a diminished need for the more significant adjustments present in the stock model:

- No need for the bridge distance penalties.
- Reduced need for jurisdiction-to-jurisdiction adjustment factors as applied to commuters.

[14] BTI = Perceived Time/Actual Time

Table 27 shows the reduced need for these factors by comparing the magnitude of adjustment for the stock model with the travel model after accounting for travel time reliability ("adjusted") for specific movements that were heavily penalized in the stock model.

Table 27. *Jurisdiction adjustment factors*

Movement	Stock Model	Adjusted Model
Newport News to Norfolk	-4.00x	-2.22x
Hampton to Norfolk	-6.67x	-1.96x

* - a value of '1.0' indicates no adjustment

The Newport News to Norfolk movement was originally adjusted to be 4-times less attractive (-4.00x). After accounting for travel time reliability, the adjustment required for validation is reduced by almost 50%. Similarly, the adjustment required for the Hampton to Norfolk movement has been reduced by 70%.

Port Trip Generation

The internal-external truck trip generation process in the stock model does not reflect the unique trip characteristics of the ports. The travel model as provided by VDOT apportions internal and external trips based on the distance of a trip generator to the regional model boundary. The closer to the boundary, the greater the number of trips apportioned as external. The ports are at the center of the region and thus get assigned a relatively large percentage of internal trips when using the stock model. This is contrary to observed behavior based on vFreight data for Year 2018. Table 28 shows the percentage of internal trips estimated by the stock model vs. this observed data. Observed data shows that a small percentage of trips generated at the ports are actually internal to the region.

Table 28. *Port zones internal trip adjustment*

Type	2018 vFreight Data			2017 Model Estimate	
	Volume[1]	Internal	Internal Target[2]	Stock Model	Adjusted Model
Imports	7,100	10.6%	9.0%	84.3%	9.0%
Exports	7,479	7.4%			

[1]Annual containerized tons
[2]Weighted average of imports and exports

The vFreight data was used to develop a revised internal target for the ports and the stock model was adjusted accordingly.

Zero-Passenger Vehicle Trip Generation

The Consultant team added the capability of estimating zero-passenger vehicles (ZPVs) associated with conventional mobility-as-a-service (MaaS) trips. The stock model only addressed ZPVs for autonomous vehicles. Technique used to generate and distribute vehicles is the same as used for autonomous MaaS trips in the stock model.

C: Documentation of Economic Model Elements

Truck Trip Data Adjustments

As discussed in the section *Adjusting Data to Focus on Efficiency of Trips Already Existing in the Baseline*, the Consultant team adjusted the TDM outputs to focus on the efficiency of existing baseline trips only. This was necessary in order to adjust for the changes to overall vehicle travel associated with the greater growth in population and employment. The project team followed parallel processes for passenger and truck trips.

Table 29 presents a summary of regional truck trip characteristics by scenario both before and after this scaling adjustment. Table 30 presents the same information for cross-harbor trips only. Both tables also present average trip length, speed, and occupancy. Because vehicle trip characteristics were scaled uniformly, this transformation had no effect on average trip length, speed, and occupancy. These characteristics are indicators of the changes the relative efficiency of truck travel across scenarios.

Table 29. *Summary of regional truck trip characteristics before and after scaling truck trips in the alternative scenarios to match truck trips in the baseline.*

	Scenario	Truck Trips	VMT	VHT	Length (mi)	Speed (mph)
Unadjusted Trip Characteristics	Baseline	108,943	3,243,469	78,823	29.8	41.1
	Water	113,873	3,191,943	80,813	28.0	39.5
	Urban	123,650	3,660,133	79,402	29.6	46.1
	Suburban	139,518	3,963,881	105,349	28.4	37.6
Adjusted Trip Characteristics	Baseline	108,943	3,243,469	78,823	29.8	41.1
	Water	108,943	3,053,768	77,315	28.0	39.5
	Urban	108,943	3,224,799	69,958	29.6	46.1
	Suburban	108,943	3,095,211	82,262	28.4	37.6

Table 30. *Summary of cross-harbor truck trip characteristics before and after scaling truck trips in the alternative scenarios to match truck trips in the baseline.*

	Scenario	Truck Trips	VMT	VHT	Length (mi)	Speed (mph)
Unadjusted Trip Characteristics	Baseline	21,300	1,152,032	34,039	54.1	33.8
	Water	21,111	1,072,596	31,375	50.8	34.2
	Urban	25,208	1,260,763	35,611	50.0	35.4

	Suburban	26,620	1,264,760	34,865	47.5	36.3
Adjusted Trip Characteristics	Baseline	21,300	1,152,032	34,039	54.1	33.8
	Water	21,300	1,082,220	31,656	50.8	34.2
	Urban	21,300	1,065,325	30,090	50.0	35.4
	Suburban	21,300	1,012,003	27,898	47.5	36.3

Drivers of Economic Results: Truck Trips

After the completion of all the adjustments to the TDM outputs described above (for passenger and truck travel), the travel data was ready to be entered into TREDIS to support a series of TREDIS economic modeling runs comparing the alternative scenarios to the baseline scenario for both all regional data and cross-harbor data only. The TREDIS methodology and results are described in greater detail in the first part of this document, in the sections *Economic Modeling Runs* and *Economic Modeling Results and Interpretation (TREDIS Output)*.

The remainder of this section describes the truck travel characteristics that contributed to these economic results. To that end, Table 31 summarizes directional changes in performance metrics that drive the economic analysis results for truck trips regionwide. Table 32 presents the same information for cross-harbor truck trips only. In both tables, green cells indicate positive change (i.e., faster trips, leading to greater efficiency), while red cells indicate negative change (i.e., lower vehicle occupancy, leading to less efficiency).

***Table 31**. Trends in regional truck TDM performance by scenario (all regional truck trips)*

Performance (Average Regional)	Greater Growth on the Water	Greater Growth in Urban Centers	Greater Suburban/ Greenfield Growth
Trip Length	↓	↓	↓
Speed	↓	↑	↓
Congestion	↑	↓	↑

***Table 32**. Trends in cross-harbor truck TDM performance by scenario (cross-harbor truck trips only)*

Performance (Average Regional)	Greater Growth on the Water	Greater Growth in Urban Centers	Greater Suburban/ Greenfield Growth
Trip Length	↓	↓	↓
Speed	↑	↑	↑
Congestion	↑	↓	↑

Overall, the trends in regional truck travel performance are directionally consistent with the overall trends observed in travel in each of the alternative scenario. As with passenger travel, truck trip length decreases in each alternative scenario, relative to the baseline. Furthermore, truck trip speeds increase in the urban scenario, but decrease in the Greater Suburban/Greenfield Growth and Greater Growth on the Water scenarios, relative to the baseline.

The trends in truck travel support the intended scenario narratives and demonstrate good differentiation across scenarios. In the Greater Growth on the Water scenario, slower speeds and more congestion reduce the efficiency of regional freight movement. However, as trip lengths go down, both overall truck VMT and VHT decreases. Shorter truck trip lengths also reduce truck VMT in the other two scenarios. The Greater Growth in Urban Centers scenario demonstrates the greatest overall gains in travel efficiency through not only shorter truck trips, but also faster trips and less congestion. Finally, the Greater Suburban/Greenfield Growth scenario, like the Greater Growth on the Water scenario, is characterized by slower and more congested truck travel, but shorter truck trips, leading to a reduction in truck VMT. In the Greater Suburban/Greenfield Growth scenario, slowing of travel speeds are enough to outweigh decreases in truck trip length, leading to a net increase in truck VHT.

Performance for cross-harbor trips is generally consistent with regional differences across the scenarios, with two notable points of divergence. While regional average truck speeds only improve in the Greater Growth in Urban Centers scenario, among cross-harbor trips, truck travel speeds increase for all three alternative scenarios. The result is a reduction in both truck VMT and truck VHT for all three alternative scenarios, relative to the baseline, with the greatest reductions in the Greater Suburban/Greenfield Growth scenario. However, cross-harbor truck trips are routed on more congested roadways in the Greater Growth on the Water and Greater Suburban/Greenfield Growth scenarios, relative to the baseline. In these two scenarios, trucks may be able to choose routes across that harbor that are on average faster than in the baseline, but that are more subject to unreliability in travel time.

Adjusting Crash Rates to Account for Technology Adoption

One RCS performance measure for the three greater growth scenarios is the cost of forecast crashes. By linking the TREDIS economic model to the TDM outputs as described in Part I, TREDIS is able to use VMT forecasts to calculate the user cost associated with these crashes. However, because each of the scenarios included a different level of CAV use, it would be inappropriate to assume that crash rates would remain consistent across the scenario. To estimate the cost of crashes accurately, TREDIS required adjusted crash rates that account for the CAV technology adoption associated with each scenario. This section details the economic analysis team's approach for connecting the assumed CAV adoption levels to the TDM in order to observe the impact of this technology on the cost of crashes under each scenario.

With 93% of motor vehicle crashes nationwide attributed to human error (e.g., slow reaction time, poor sight, aggressive driving, drowsy driving), the adoption of CAVs has significant potential to lower crash rates.[15] Some researchers even estimate that by 2050, CAVs could eliminate 90% of human error-caused crashes, or an 84% overall reduction in the crash rate.

To account for this trend, this estimated effect needs to be applied to initial crash rates for the Hampton Roads region. Table 33 presents regional crash rates for Hampton Roads. These figures are taken from the HRTPO document *The State of Transportation in Hampton Roads 2017*.[16] Crash rates are presented separately for fatalities, injuries, and crashes because of the different costs associated with each crash severity.

Table 33. *Crash rates in Hampton Roads region per 100 million VMT as reported in State of Transportation in Hampton Roads 2017*
Data source: Virginia DMV

Crash Rate (Per 100M VMT)	2010	2011	2012	2013	2014	2015	AVG
Fatalities	0.89	0.86	0.81	0.84	0.88	0.84	0.85
Injuries	90	96	104	107	104	103	101
Crashes	155	165	174	177	176	175	170

Similarly, Table 34 provides crash rates for bus and truck modes by severity for the Commonwealth of Virginia in 2017. Crash counts are from *2017 Virginia Traffic Crash Facts*, with bus and truck VMT estimates from NTD's Monthly Module Adjusted Data Release, October 2019[17] and VDOT's 2017 modal VMT estimates[18] respectively. In 2017, bus crashes represented 0.4% of all traffic crashes, 0.4% of all traffic injuries, and 0.24% of all fatalities. Crashes involving large trucks represented 1.8% of all traffic crashes, 0.5% of all injuries, and 1.4% of all fatalities.

[15] Kockleman et al 2016. "Implications of Connected and Autonomous Vehicles on the Safety and Operations of Roadway Networks." FHWA/TX-16/0-6849-1. https://library.ctr.utexas.edu/ctr-publications/0-6847-1.pdf

[16] https://www.hrtpo.org/uploads/docs/State%20of%20Transportation%202017%20-%20Final%20Report.pdf

[17] Vehicle revenue miles filter for Virginia and for commuter bus (CB) and bus (MB).

[18] https://www.virginiadot.org/info/2017_traffic_data_daily_vehicle_miles_traveled.asp

Table 34. 2017 modal crash rates in Virginia, as reported in 2017 Virginia Traffic Crash Facts

Crash Rate (Per 100M VMT by Mode)	Bus	Truck
Fatalities	0.42	1.00
Injuries	45.55	18.28
Crashes	68.21	32.01

Kockleman et al. (2016) performed a comprehensive analysis of the potential crash, congestion, and other impacts of CAVsin Texas in order to monetize these impacts at various levels of market penetration.[19] This study was selected as the basis for this methodology because it is among the first to rigorously anticipate the safety impacts of CAV adoption and, as such, is highly regarded and frequently cited. Although crashes and crash rates may differ between Texas, Hampton Roads, and any other state or region, this memo assumes that the safety effect anticipated by Kockleman will similarly reduce crashes in Hampton Roads in a proportional manner.

Table 35 summarizes the crash rates anticipated by Kockleman at three levels of CAV penetration.[20] It also calculates the percent reduction in crashes at each severity level according to the three levels of CAV penetration. Crash reduction increases along with penetration, ranging from approximately 7% crash savings at the 10% penetration to roughly 80% crash savings at the 90% penetration level, depending on severity.

Table 35. *Impact of CAV use on crash rates, as estimated by Kockleman 2016*

	CAV Penetration			
	0%	10%	50%	90%
Fatalities/100M VMT	1.3	1.2	0.7	0.3
% Reduction	-	*7.7%*	*41.1%*	*76.9%*
Injuries/100M VMT	85.7	79.9	49.9	14.7
% Reduction	-	*6.8%*	*41.9%*	*82.9%*
Crashes/100M VMT	164.4	151.1	89.0	25.3
% Reduction	-	*7.7%*	*41.1%*	*76.9%*

[19] Kockleman examines the potential benefits from Level 3 (limited self-driving) to Level 4 (full self-driving) automation, assuming CV technology.

[20] Kockleman does not report crash rates, but rather the total number of crashes at each penetration level. In order to calculate a rate, this count of crashes was divided by total Texas VMT (urban and rural), as reported in FHWA's 2016 Highway Statistics Report, available at https://www.fhwa.dot.gov/policyinformation/statistics/2016/ps1.cfm. This VMT data was multiplied by VMT growth rate factors for urban and rural VMT at each CAV penetration level reported in Kockleman (p. 125).

Combining the previous tables, Table 36 presents anticipated future crash rates in Hampton Roads at three levels of CAV penetration for three different modes. At the highest level of penetration, fatalities per 100 million passenger VMT falls as low as 0.2, injuries to 17.3 and crashes to 26.2, with similar savings for truck and bus.

Table 36. *Anticipated crash rates in Hampton Roads Region, 2045.*

		CAV Penetration			
Mode	**Crash Type (/100M VMT)**	0%	10%	50%	90%
Passenger Vehicles	Fatalities	0.85	0.78	0.50	0.20
	Injuries	101	94.10	58.73	17.29
	Crashes	170	156.25	92.10	26.19
Bus	Fatalities	0.42	0.39	0.25	0.10
	Injuries	45.6	42.49	26.51	7.81
	Crashes	68.2	62.68	36.95	10.51
Truck	Fatalities	1.00	0.92	0.59	0.23
	Injuries	18.3	17.05	10.64	3.13
	Crashes	32.0	29.41	17.34	4.93

The three greater growth scenarios each entail a different level of CAV penetration: lowest in Greater Growth on the Water, higher in Greater Growth in Urban Centers, and higher still in Greater Suburban/Greenfield Growth. The crash rates associated with each scenario depend on the corresponding CAV penetration, as summarized in Table 37, and provided by the travel demand modeling team. For automobiles, a weighted average CAV adoption rates is calculated for the different markets (internal, internal-external, and external-external), using the share of overall automobile VMT as the weighting factor.

Table 37. *CAV adoption by mode (proportion of vehicles)*

Mode		**2045 Baseline**	**Growth on the Water**	**Growth in Urban Centers**	**Suburban /Greenfield Growth**
Autos	*% of Auto VMT*				
Internal	*65.0%*	30%	30%	40%	75%
Internal-External	*34.8%*	20%	20%	25%	45%
External-External	*0.2%*	25%	25%	30%	60%
Weighted Avg.	*100%*	**26.5%**	**26.5%**	**34.8%**	**64.5%**
Bus	*n/a*	**20%**	**20%**	**25%**	**45%**
Trucks	*n/a*	**40%**	**40%**	**50%**	**70%**

By applying the appropriate crash rate modifications at the penetration levels shown above, Table 38 accounts for the impact of CAVs on vehicle crash rates. These crash rates are consistent with those presented in Table 19 in Part I of this document.

Table 38. *Modified crash rates reflect CAV adoption by scenario, extrapolated from Tables 12 & 13.*

Mode & Severity	2045 Baseline	Growth on the Water	Growth in Urban Centers	Suburban /Greenfield Growth
Autos (Penetration)	***26.5%***	***26.5%***	***34.8%***	***64.5%***
Fatal Crash Rate	0.66	0.66	0.61	0.39
Injury Crash Rate	79.51	79.51	72.17	43.71
Overall Crash Rate	129.79	129.79	116.48	68.21
Bus (Penetration)	***20%***	***20%***	***25%***	***45%***
Fatal Crash Rate	0.36	0.36	0.34	0.27
Injury Crash Rate	38.50	38.50	36.50	28.51
Overall Crash Rate	56.25	56.25	53.03	40.17
Trucks (Penetration)	***40%***	***40%***	***50%***	***70%***
Fatal Crash Rate	0.67	0.67	0.59	0.41
Injury Crash Rate	12.24	12.24	10.64	6.89
Overall Crash Rate	20.36	20.36	17.34	11.14

Part III. Appendices

A. Economic Trends and Opportunities Memorandum
B. Draft Goals and Objectives Memorandum
C. Glossary of Terms
D. CommunityViz Resources
E. Transportation Performance Measures Definitions
F. MetroQuest Survey Results

Appendix A. Economic Trends and Opportunities in the Hampton Roads Region – Technical Memo

Note: This Technical Memorandum was developed in November 2019 as an early analysis of growth and economic trends in the region and was used as one of the components of building the regional control totals for greater growth and the three scenario narratives for the greater growth scenarios.

Introduction

To support development of economic drivers for use in the construction of scenario narratives, the project team reviewed and analyzed several sources of information on economic trends and opportunities for the Hampton Roads region. This memo summarizes the information reviewed in this effort and explains how this information provides the understanding of current and forecast economic conditions (including key trends and drivers of future economic conditions) necessary to support informed scenario analysis.

The following principles, developed in concert with HRTPO and the Regional Connector Study working group, were used to guide the economics research:

- **Exploring Greater Growth:** HRTPO's 2045 growth forecasts represent a baseline from which to pivot the scenario analysis. The alternative future scenarios will be developed to explore the implications of plausible *additional* growth.
- **A Focus on Different Economic Futures:** Incremental growth is to be held constant across the three alternative scenarios in order to focus on the implications of different visions of economic futures.
- **Relevance to Land Use and Travel Behavior:** Alternative economic futures used to structure the scenarios should be sufficiently different so as to result in different spatial patterns and types of development, with associated implications for travel patterns and modal reliance.

This memo is organized into the four areas of analysis:

- **Economic Risks and Opportunities:** This section reviews economic trends and performance in the region to identify risks and opportunities that should shape the scenario planning process.
- **Alternative Growth Rates:** This section reviews historic and forecast economic (job) growth for the region in order to select an appropriate level of incremental employment growth to test in alternative scenarios (and from which other demographic indicators are drawn).

- **Existing Industrial Base and Anticipated Growth Industries:** This section refines the growth outlook from the first section to add greater detail on an industry sector-basis, anticipating which sectors could be expected to absorb job growth in future possible scenarios.
- **Outlook for Ports and Freight:** Because of the importance of maritime trade to the overall regional economy, this section provides detail on possible alterative port growth assumptions to provide differentiation between scenarios in terms of port competitiveness, truck/rail mode split, and growth in freight transportation.

Finally, the conclusion section explains how the project team distilled this information on economic trends into the three distinct alternative scenarios analyzed according to the methodology presented in the *Scenario Planning Methodology White Paper*.

Economic Risks and Opportunities

The Hampton Roads economy has faced several challenges in the past decade and a half. According to data published in HRPDC's 2018 Hampton Roads Regional Benchmarking Study, the region lost about 50,000 civilian jobs during the Great Recession (approximately July 2007-February 2010). Although the economy has since recovered this job loss, the region has only gained 3,600 jobs since 2007, despite growing in population by 82,000 in the same period.[21] The region has also lost approximately 30,000 military personnel since peaking around 130,000 personnel in 2003.[22] As is the case nationwide, Hampton Roads is currently experiencing decelerating population growth, an aging population, and decreasing labor force participation.

Beyond these high-level trends, the Hampton Roads Regional Benchmarking Study highlights several risks faced by the region, as revealed through benchmarking comparisons to other regions and the United States as a whole. These include:

- Weak growth
- An economy that remains highly reliant on military and civilian defense employment
- Income and wages that lag behind the United States as a whole

The employment to population ratio in Hampton Roads has not returned to its pre-recession peak. This sustained period of weak employment growth may signal underlying economic issues. In particular, employment in Hampton Roads is highly reliant on military personnel, federal civilians, and private employees in industries related to the Department of Defense (DoD), with a striking military location quotient of 8.14 (Figure A-1).[23] Government employment constituted 25 percent of regional employment in 2013, of which half is uniformed military personnel and DoD civilians. However, regional government employment has experienced a gradual decline over the past several decades and even more so since the last recession. Furthermore, since the 1980s, regional employment has constituted a diminishing share of national employment due to declining military spending relative to economic growth. In the last decade,

[21] Hampton Roads Regional Benchmarking Study, 13th Edition. Hampton Roads Planning District Commission (HRPDC). October 2018, pp. 24-28. Weblink.

[22] Ibid, p. 42.

[23] Local quotients identify comparative advantages by comparing regional employment distributions to national employment distributions. An LQ of greater than one suggests a comparative advantage.

minimal enterprise growth and job creation in the Hampton Roads market have limited competitive economic growth within private industries. As such, the Hampton Roads Region has been confronted with the difficult challenge of developing well-paying employment opportunities that simultaneously meet the needs of existing regional employers (particularly in the military sector) while also supporting a greater strategic diversity of industry clusters in the region.

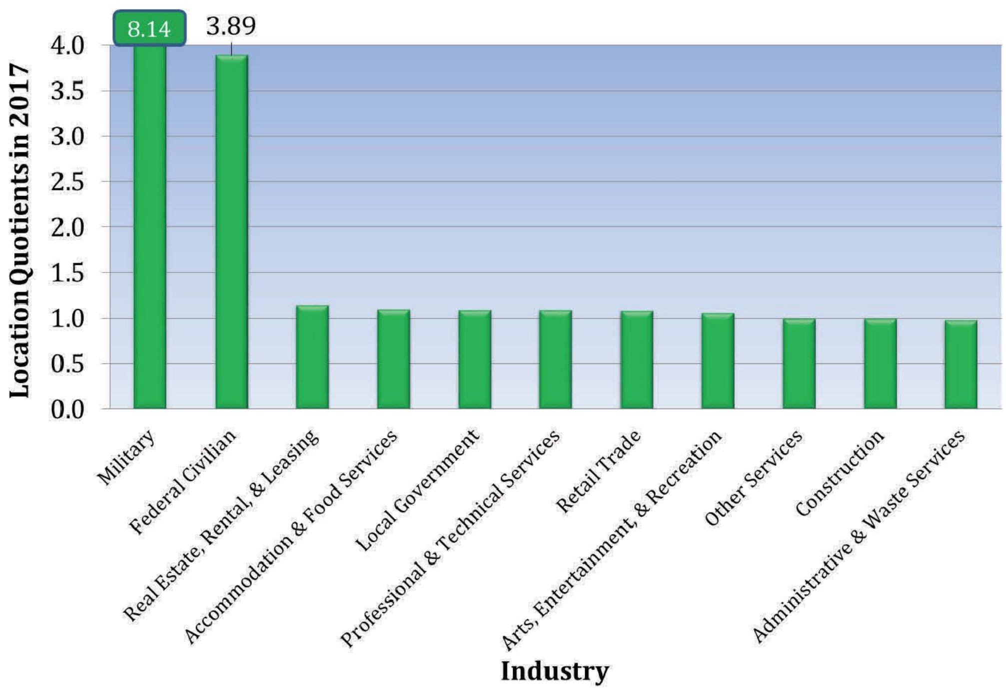


Figure A-1. *Current industry clusters – Hampton Roads Location Quotients by industry.*
Source: Bureau of Labor Statistics, HRPDC Regional Benchmarking Study.

Despite these job growth challenges, the regional unemployment rate (including employed military personnel) declined to 3.0 percent in July 2017 and Hampton Roads' labor market continues to be very tight. Nonetheless, regional per capita incomes are $3,000 lower than the U.S. metropolitan area average, as of 2016. Average weekly wages have lagged the U.S. average since 2011. Additionally, income from wages and salaries have declined since the beginning of the Great Recession, even as total incomes have grown as the result of growth in other income categories, particularly personal transfers (i.e., government benefits).

While the Hampton Roads Region has experienced some growth since 2010, that growth has been slight compared to many similar sized metropolitan areas, as well as the average growth for U.S. metropolitan areas. Gross product growth (the value of all the goods and services produced within a geographic in a year) in Hampton Roads has lagged employment and labor income. Between 2001 and 2007, real gross product grew at annualized rate of 3.3 percent; however, since the recession, the regional economy has declined by an annualized rate of 0.24 percent when controlling for inflation. From 2014 to 2017 annualized growth in gross product in the Hampton Roads Region has lagged nearly all other metropolitan areas with population between 1 and 4 million.

Dependence on a handful of industries is frequently identified as a risk to the Hampton Roads regional economy. The HRPDC's Regional Economic Development Strategy identifies the need for a regional transformation that overcomes such dependency.[24] To do so, the report recommends a two-fold strategy:

1. Maintaining and growing three pillars of the regional economy (federal, port/maritime, and tourism/arts & culture), and
2. Nurturing regional assets that have the most realistic chance of diversifying the economy.

Similarly, HRTPO's 2019 State of the Region Report[25] identified the following strategies for combating industry dependency in Hampton Roads:

- Diversifying the economic base and developing new industry for the future
- Gaining public support for and appreciation of the economic value of our regional assets
- Maintaining and growing the three pillars of the regional economy – the Port, Tourism and our Federal assets
- Building on defense-related competencies that can be utilized in other industries
- Leveraging technologies developed at local colleges, universities and federal labs as well as commercial entities
- Improving commerce derived from industry, all of which is dependent on transportation infrastructure; we must make it easier for people and products to move within the region
- Significantly increasing quality of life for residents by leveraging the variety of attractions, arts and culture, venues and performances and recreational opportunities that exist in the region

Alternative Growth Rates

In the context of the risks and opportunities described above, the scenario planning process seeks to explore potential greater growth trajectories that could shape future transportation needs in the region. To construct these alternative scenarios, the project team first addressed two basic questions. First, what amount of additional employment growth over the 2045 baseline forecast is both plausible and sufficiently significant to test the impact of greater growth on regional connectors? Second, what might the composition of this growth look like? This section addressed the first question, while the next section addresses the second.

[24] Hampton Roads Regional Economic Development Strategy (REDS), Hampton Roads Planning District Commission (HRPDC). September 2015. Weblink.

[25] As quoted in ibid. p. 34.

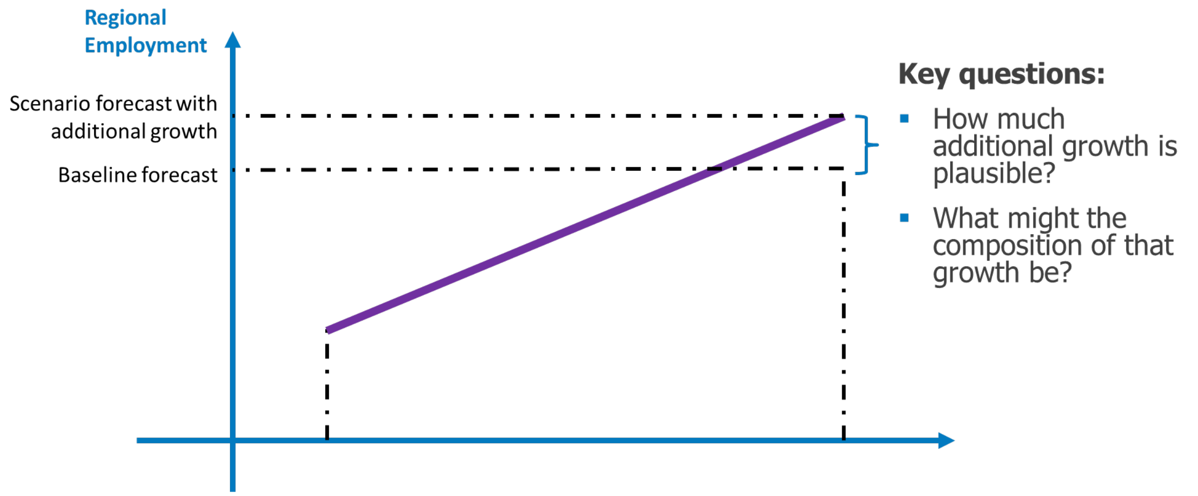


Figure A-2. *Stylized representation of incremental regional employment growth above HRTPO's 2045 baseline. This amount of growth will be held constant across all alternative scenarios, although the location and composition will vary.*

To answer the first question, the project team followed an approach that leveraged alternative forecasts to provide guidance on the range of uncertainty inherent to long-term forecasting. The goal was to identify a single level of growth that offered a sufficient increment to "move the needle" in the land use and travel demand modeling, but also provided a believable narrative for the region's economy. This level of growth will serve as a constant control total for the alternative greater growth scenarios. This level of growth is not meant to predict actual future growth, but rather to establish a level of additional growth against which to stress test the regional transportation system and ultimately the connector alternatives. The analysis focused on first on the potential for additional employment in order to explore possible future scenarios where the region becomes more competitive. Additional population growth would then follow from that employment growth – as greater demand for labor drives in-migration.

The project team considered the following inputs to identifying an appropriate control total for employment:

- Retrospective employment growth in the region, compared to Virginia and the United States
- HRTPO's 2045 Baseline forecast
- Alternative future growth forecasts for the region, the state, and the country
- Exploration of what a major "shock" to the economy—e.g., the opening of an employer the size of Amazon's "HQ2" in the region—might look like in terms of changes in growth trajectory and added regional employment
- Travel model sensitivity testing

Beginning with the first step, the project team found that, relative to HRTPO, employment in the Commonwealth of Virginia has grown significantly faster, and the U.S. as a whole has grown slightly faster in the aggregate, as shown in Figure A-3. Whereas the Hampton Roads region grew at an average annual rate of 1.35 percent from 1980 to 2010, Virginia grew 1.78 percent annually, and the United States grew 1.4 percent annually. The next 30 years of employment growth are forecast to be slower at all three geographies, as discussed below.

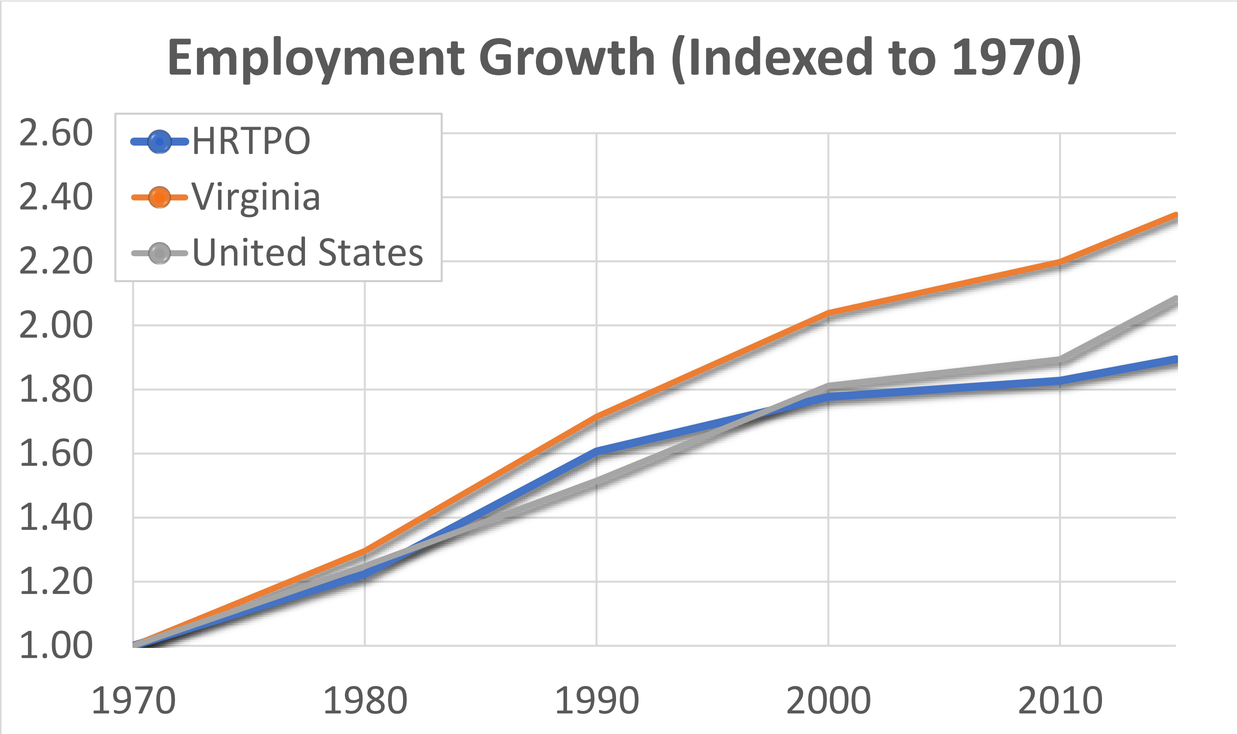


Figure A-3. *Regional, state, and national employment growth since 1970.*
Source: Bureau of Economic Analysis (HRTPO data as reported in 2045 Socioeconomic Forecast Report[26])

Continuing further in the process of choosing a control total growth rate, the project team considered HRTPO's 2015 employment (just over 1.0 million jobs) and the baseline employment growth through 2045 (approximately 81,000 jobs), as shown in the first column of Figure A-4. These forecasts were generated using a REMI© model customized to the Hampton Roads region. The project team also compared these numbers to regional, state, and national growth rates from Moody's Analytics (columns 2 through 4 in Figure A-4).[27] Finally, the project team illustrated the effect of a major employer opening in the region using expected employment estimates from the recent announcement of the Amazon "HQ2" location in Northern Virginia. That project is currently estimated at 25,000 new jobs, but incentives from the Commonwealth of Virginia are approved for up to 37,850 jobs.[28] These job ranges are shown in columns 5 and 6 of Figure A-4. The last column in Figure A-4 illustrates potential multiplier (indirect and induced) effect on top of the higher estimate of direct jobs, based on research published by Chmura Economics.[29] This multiplier effect represents an upper bound estimate as it is based on multiplier effects calculated for the entire Virginia economy, rather than a single region.

---

[26] Hampton Roads TPO. Hampton Roads 2045 Socioeconomic Forecast and Transportation Analysis Zone Allocation. February 2019. Weblink.

[27] Moody's Analytics is another widely recognized provider of economic and industry research services, including region-specific long-range growth forecasts. Weblink.

[28] Schrott, Missy. "Northern Virginia Amazon HQ2 plans still on track." Alexandria Times. February 21, 2019. Weblink; SB 1255 Major Headquarters Workforce Grant Fund, Virginia's Legislative Information System, Weblink.

[29] Implied multiplier of 2.37 calculated based on the ratio between 25,000 direct jobs and 59,308 total jobs as cited in: Chmura, Chris. Economic Impact: How much will Amazon's new second headquarters benefit Virginia? Chmura. Weblink.

With input from the working group, the project team chose to focus on the plausible greater growth boundaries of 12 to 21 percent growth in employment above 2015 levels as established by the more optimistic regional and Virginia growth forecast from Moody's. The "catalyst" effect of a major new employer is of a similar magnitude, further validating this range of consideration.

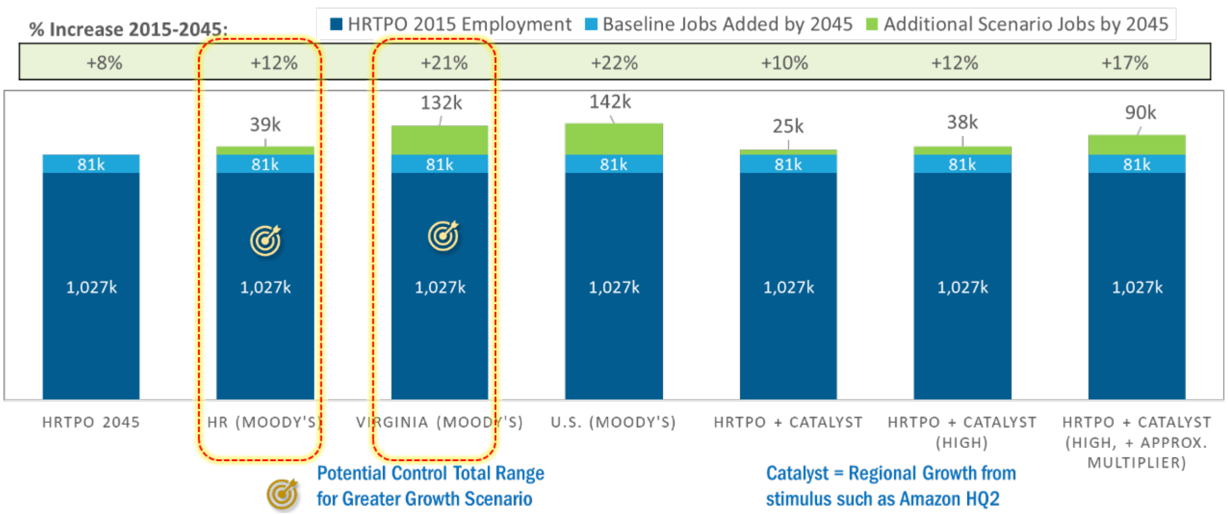


Figure A-4. *Comparison of HRTPO 2045 employment forecasts (i.e., 2015 employment plus baseline job growth) to multiple forecasts of stronger job growth. Based on input from the working group, the project team ultimately decided to set a control total growth rate in between the forecasts circled in orange (i.e., 12-21%).*

Finally, the project team performed travel demand model sensitivity analysis to test the approximate effect of alternative control totals for greater employment growth on vehicle-hours level of travel at various levels of congestion, as shown in Figure A-5. Considering the substantial regionwide congestion under the 2045 Baseline with the existing and committed network (shown in the callout box in Figure A-5), the project team's sensitivity testing in the travel model showed that 12 percent growth above 2015 has only a mild effect relative to the baseline, while 21 percent growth above 2015 shows a much more significant (i.e. non-linear) increase in severe congestion.

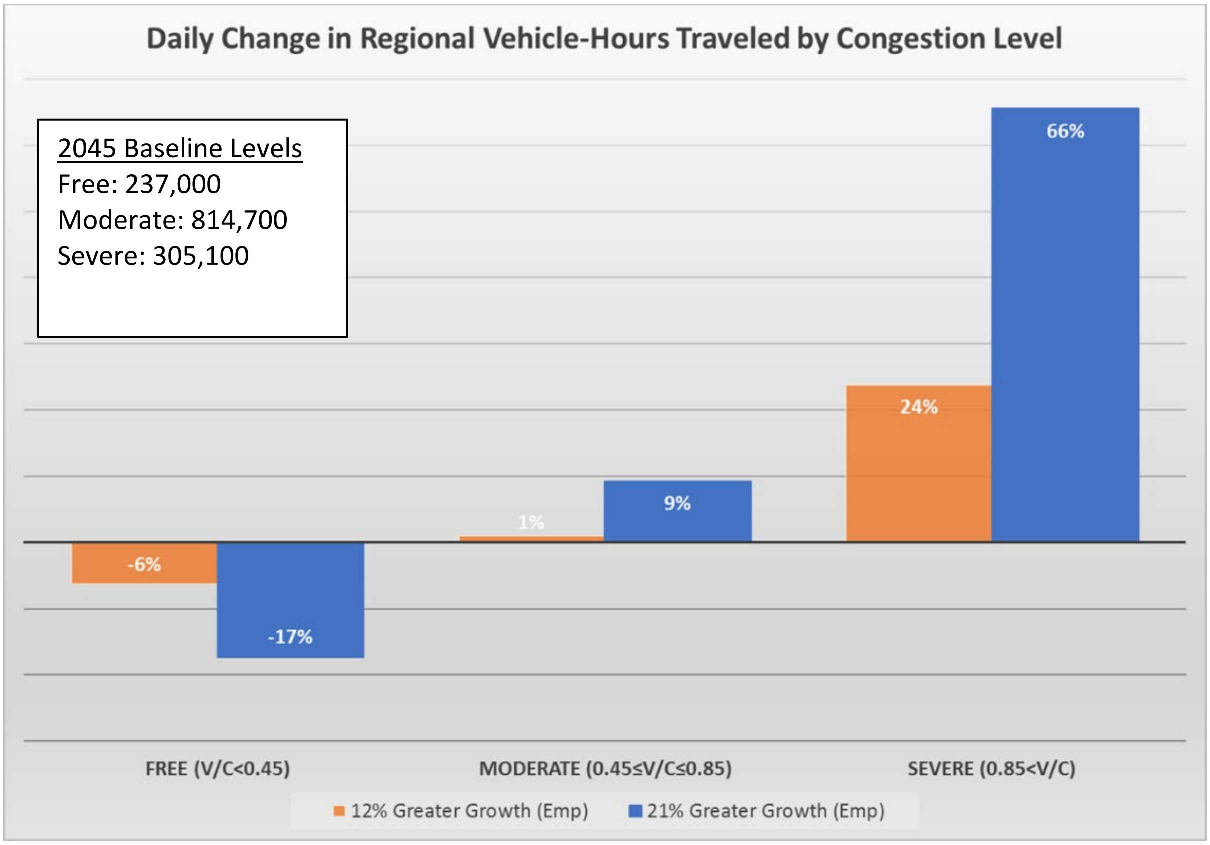


Figure A-5. *Effect of two levels of employment growth (12% and 21% above 2015 levels) on congestion in 2045*
Derived from Hampton Roads Model (Ver. 1.2), September 2014

The project team reviewed these inputs with the working group and steering committee and considered various goals and risks of selecting each possible control total, including the overall goal of providing enough differentiation between the scenarios. The goal was to set a growth rate that was not too low (which could dilute differences between scenarios) nor too high (which could result in widespread, severe congestion that would mask differences between scenarios). Furthermore, a 21 percent employment growth would imply that the region would keep pace with Virginia (and Northern Virginia) over the next 30 years, which seemed implausible given the risks and challenges presented in the previous section, as well as historic precedent. For that reason, the project team proposed a middle ground growth rate of 16 percent growth above 2015 employment, which roughly doubles the 2045 baseline employment growth forecast (i.e., it adds approximately 81,000 jobs for a total of 162,000 jobs over 2015 employment). This level of "greater growth" will subsequently be tested and refined if needed through the scenario modeling process.

Existing Industrial Base and Anticipated Growth Industries

As noted in the introduction to the previous section, in addition to setting an employment growth level, the project team was tasked with understanding how future economic development in the Hampton

Roads region might affect industrial patterns of long-term regional growth, including employment by sector, in several alternative future scenarios. To help answer that question, the following section summarizes economic development opportunities in the Hampton Roads Region, including information on identified target industries, their potential for growth, and major implications for regional industrial patterns of long-term growth.

To begin, the project team reviewed HRTPO's 2015 profile of socioeconomic data and its 2045 regional socioeconomic forecasts. Figure A-6 provides an overview of the industry growth changes projected in the region between 2015 and 2045 according to HRTPO. Certain trends are immediately evident. First, the largest sources of employment growth forecast between 2015 and 2045 are *Health Services* and *Other Professional and Related Services*. Second, there is forecasted contraction of the region's dominant sector, *Government*, which according to its definition includes both the military and federal civilian employment as well as local government.

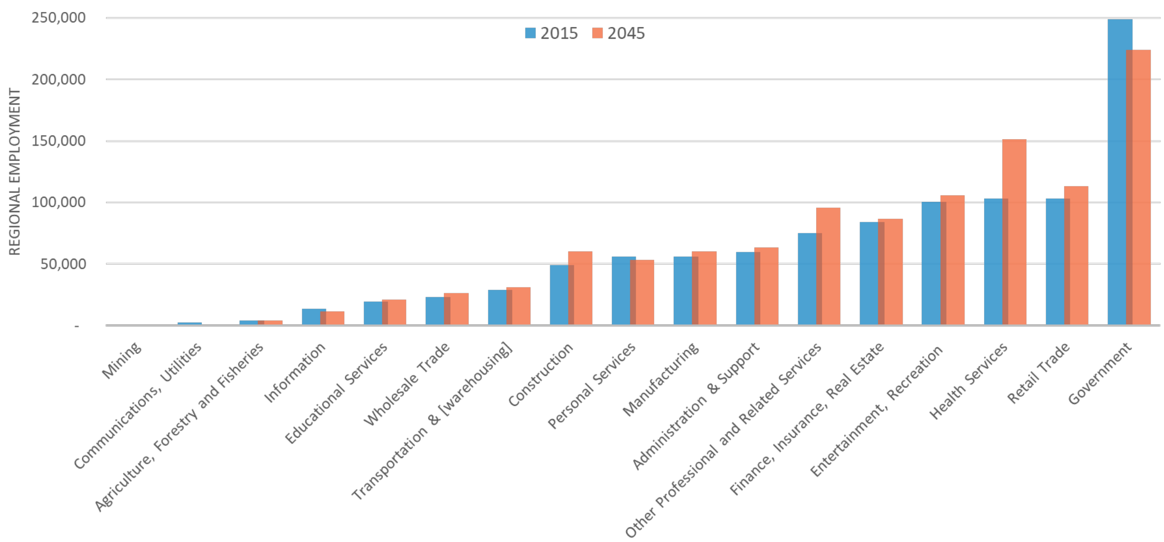


Figure A-6. *Forecast change in regional employment by sector, 2015-2045 Baseline.*
Source: HRTPO 2045 Forecast (developed using REMI).

In terms of present-day civilian employment, the three largest industry sectors in the Hampton Roads Region are professional and business services (including many government contractors), healthcare and social assistance, and leisure and hospitality, with the fastest job growth in recent years seen in healthcare and social assistance. From 2007 to 2017, the sectors with the sharpest loss in employment have been local government, manufacturing, and construction, largely due to a weak real estate market.

Looking forward, the Hampton Roads Economic Development Alliance's (HREDA) Go-to-Market Strategy[30] identifies five target business sectors for economic development in the Hampton Roads region: shared (business) services, software and information technology (IT), transportation technology, distribution, and food and beverage processing. The project team considered these sectors alongside the established pillars of the regional economy (federal, port/maritime, and tourism/arts & culture) as identified by HRPDC's

[30] 2019 Business Plan: Delivering Process Improvement and Competitive Priorities for the Region of Hampton Roads, Virginia Hampton Roads Economic Development Alliance (HREDA). September 2019. Weblink.

most recent Regional Economic Development Strategy (REDS) and Regional Benchmarking Study. Based on input from the working group, the project team also considered the following sources of information to identify potential opportunities for economic diversification in the Hampton Roads region:

- The 2017 Go Virginia Region 5 Growth and Diversification Plan[31]
- Documentation of opportunities associated with a potential "digital port" to take advantage of a new transatlantic data cable landing at Virginia Beach[32]
- Bureau of Labor Statistics on national industry trends[33]

This information provided a basis for defining potential scenario economic drivers that are specific to the Hampton Roads Region, with particular attention given to different potential economic diversification futures. From a synthesis of these sources, the project team identified nine target industry sectors or clusters to consider in creating three alternative greater growth scenarios:

- **Federal/military:** Includes armed services installations, civil servants supporting military operations, private defense contractors, and other federal agencies and contractors.
- **Maritime/transportation technology:** Specialized manufacture, assembly, and repair for maritime equipment, railcars, buses, trucks, sensors, aerospace, etc. Includes ship repair/shipbuilding, advanced materials and components, and unmanned systems/aerospace.
- **Water technologies:** Architecture, planning, and engineering for coastal areas/climate research. Includes engineering and technical consulting, as well as creative design.
- **Shared services:** High value internal support functions to corporate operations, including finance and human resources. Includes management and operations services.
- **Software development and IT:** Development of software applications, support and consulting services for U.S. and international markets. Includes cyber security, data analytics, and modeling and simulation.
- **Data port-oriented development:** Includes data centers and data analytics. Offers a mix of job opportunities includes software engineers and data scientists, but also jobs with lower educational requirement (sales, security, service, etc.).
- **Distribution:** Regional distribution/logistics centers for the eastern U.S. market. Includes port operations, logistics, and warehousing.
- **Advanced manufacturing:** Specialized food and beverage manufacturing, medical equipment manufacturing, or other manufacturing from employers with high R&D spending and >20% of jobs requiring a STEM education.
- **Tourism/arts & culture:** Includes hospitality, entertainment, culinary businesses, traveler engagement, arts & culture, sporting events, and outdoor recreation.

---

[31] Go Virginia Region 5 Growth and Diversification Plan Biennial Update 2019. Prepared for the Region 5 Council by The Dragas Center for Economic Analysis and Policy at Old Dominion University. August 2019. Weblink.

[32] Glose, Bill. Transatlantic Cables Anchored in Virginia Beach Make the Area a Digital Port. The Business Magazine of Coastal Virginia. 2018 August 22. Weblink; Moss, Sebastian. Globalinx Data Centers moves forward with Virginia Beach campus. Data Center Dynamics. 2019 January 25. Weblink; Sawers, Paul. Google announces its first private transatlantic subsea cable, stretching from Virginia to France. Venture Beat. 2019 July 17. Weblink; Virginia Beach Dept. of Economic Development. Transoceanic Fiber Cables to Connect North America to Brazil and Europe from Virginia. Accessed 2019 February 22. Weblink.

[33] U.S. Department of Labor, Bureau of Labor Statistics, Employment Projection Data Tables, Industries. Tables 2.1-2.7. Accessed, November 2019. Weblink.

These nine industry clusters together represent potential growth opportunities for the Hampton Roads Region that are both grounded in existing regional strengths and represent opportunities for economic diversification.

Outlook for Ports and Freight

The final economic driver for the project team to consider in its construction of scenarios was the regional outlook for port activity and related surface transportation freight flows. In this area, the project team reviewed expected trends at Port of Virginia facilities, including container volume growth and landslide mode share forecasts from the Port of Virginia's 2065 Master Plan.[34] The goal of considering port-related scenario drivers is both to address uncertainty in port growth trends by exploring greater growth and to understand the implications of alternative growth trajectories for the regional transportation network. Therefore, the scenario process considers not only the magnitude of goods movement through regional port terminals, but also opportunities for mode shift away from the road network. Adding a port element to the scenarios also is intended to help explore the spatial implications of different patterns of regional growth alongside port-related travel demand, in order to "stress test" the transportation system under plausible alternative futures.

Figure A-7 shows the Port of Virginia's containerized volume forecasts for each the four major terminals in the region. The scenario development process focuses primarily on containerized volumes as these are represented as a distinct lever within the HRTPO travel demand model and also represent the greatest opportunities for growth. As shown in the charts, between 2015 and 2045, overall volumes are expected to more than double in the baseline scenario—which is built into HRTPO's baseline 2045 travel demand model. The Port of Virginia has also developed a high demand forecast that would add another 11 percent on top of that baseline growth.

Figure A-8 shows the mode share for port flows in 2015 as well as forecast mode share in the 2045 baseline. Between 2015 and 2045, rail mode share across all terminals is forecast to hold steady at 32 percent, barge share is forecast to drop from 4 percent to 3 percent, and truck traffic is forecast to remain the dominant mode for handling goods movement in and out of the port terminals. There is some differentiation at the terminal level based on differences in landside transportation capacity. While this is the baseline forecast mode split, the Port of Virginia's has established a long-term target of achieving a 50% landslide rail mode share. Achieving this goal depends on a number of exogenous factors such as overall market conditions, relative costs across modes, and where and when the railroads (particularly Class I railroads) choose to make rail capacity investments. Scenario planning offers the opportunity to explore these uncertainties.

[34] Data provided by the Port of Virginia.

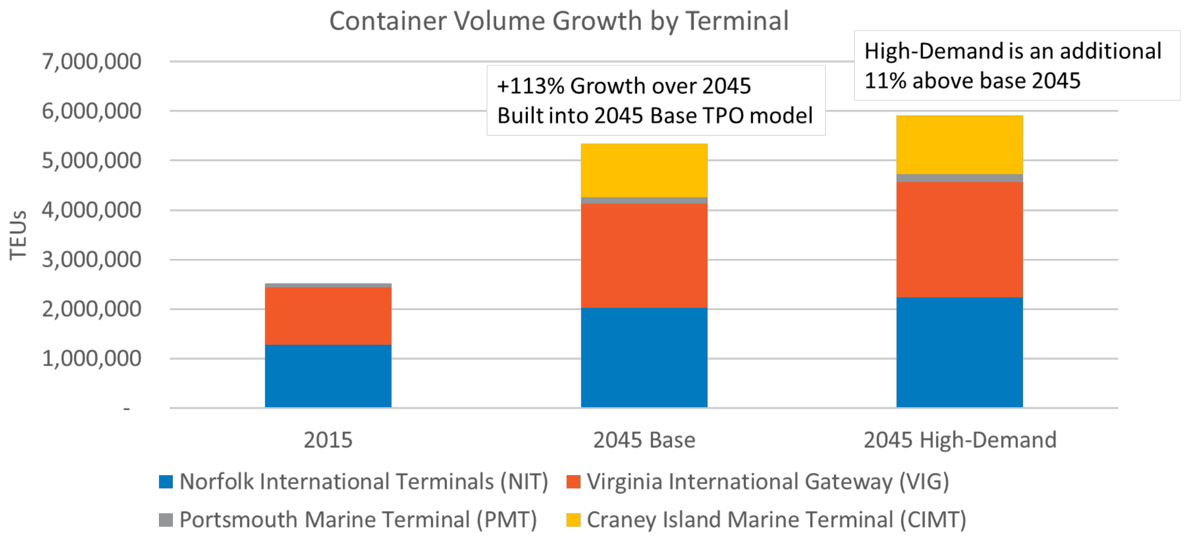


Figure A-7. *Container volume forecasts at four different Port of Virginia terminals*
Source: Port of Virginia.

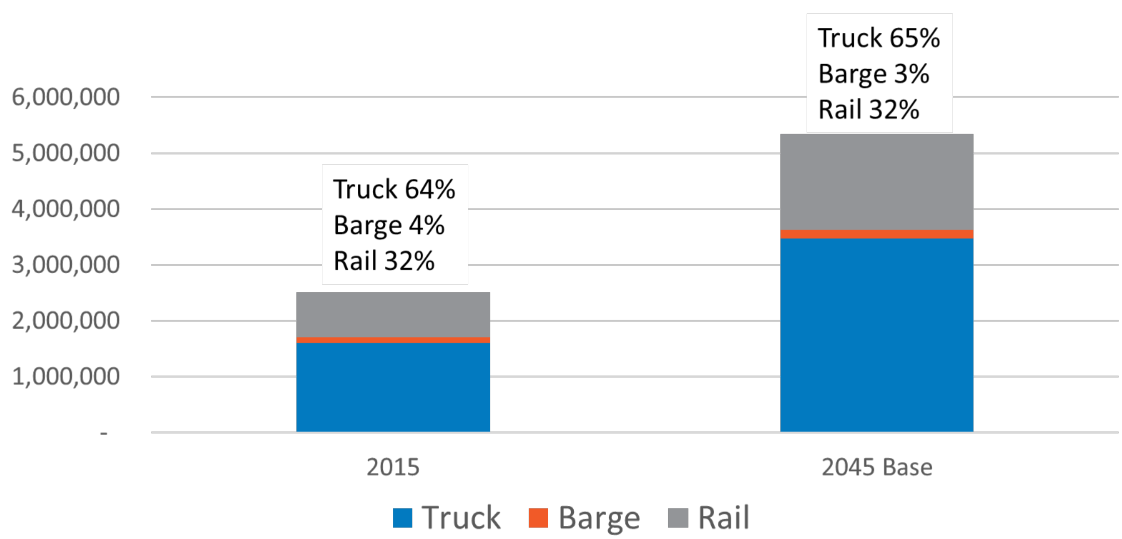


Figure A-8. *Forecast landslide mode share at Port of Virginia*
Source: Port of Virginia.

Considering these possible outcomes at the Port of Virginia, the project team decided to incorporate the following port drivers into the scenario definitions: Containerized volumes (TEUs) at the port terminals and rail, barge, and truck mode share for associated landside traffic. These drivers are aligned with the industry drivers in the following section.

Conclusion: Relevance to Scenario Development

Bringing together the analysis and literature review from the preceding sections, this conclusion defines three greater growth scenarios that are unified in their level of employment growth (16 percent over 2015 regional employment), but divergent in their other characteristics, particularly employment composition and port activity. The population control total is also uniform across the three scenarios and will be derived based on the employment total using HRTPO's REMI economic model.

As described in the Scenario Planning Methodology White Paper, the employment composition of the three greater growth scenarios is one important way that the land use allocation model can allocate the increment of additional growth differently for each scenario. In selecting industry composition, the exact breakdown of employment is not as important as defining scenarios that will meaningfully differ in terms of spatial patterns of growth and travel behavior or trip-generation. The mechanism by which this happens is the assignment of Place Type preferences and employment suitability factors (e.g., port access, access to highway ramps, proximity to institutions of higher education) that are based on the rough expected composition of job growth in each scenario. Some of these location factors may be tuned specifically to amplify spatial difference between scenarios, but their definition begins by considering different site selection preferences of industries in each of the three scenarios.

To support the definition of these suitability factors, the project team developed the economic profile of each scenario presented in Figure A-9. Greater Growth on the Water involves growth in water-oriented sectors, with the Port of Virginia becoming even more competitive in terms of annual container volume. Core sectors represented include the Military, Port Employment, and Tourism (i.e., sectors that already thrive in the region), while target sectors include Maritime and Transportation Technology, Water Technologies, and Distribution (i.e., sectors primed for growth in the region). Greater Growth in Urban Centers involves employment growth from significant economic diversification in industries with low space requirements per employee, likely in urban settings. Target sectors here include Shared Services, Software Development and IT, Data Centers, and Water Technologies. Finally, Greater Suburban/Greenfield Growth involved growth in suburban/exurban areas. In this scenario, the Port of Virginia becomes more even more competitive and a Virginia Beach data port brings additional jobs. Core sectors include marine/transportation technologies, with target sectors such as advanced manufacturing and distribution.

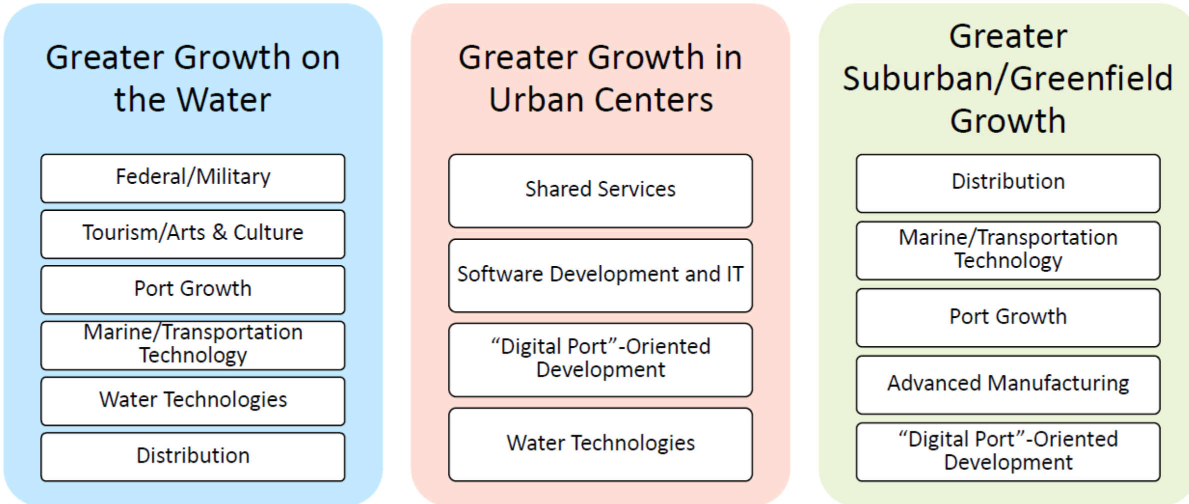


Figure A-9. *Sectors and industries assigned to each of the three greater growth scenarios, based on the project team's analysis of economic development strategies and likely direction for regional job growth.*

Table A-1 further shows how three combinations of port drivers correspond to the three different greater growth scenarios. The first scenario pairs greater port volume growth with success in achieving mode shift away from trucking, to mitigate the burden placed on the road network. The second scenario does not see greater containerized volume growth above the 2045 baseline but does achieve some limited modal diversion. This scenario is intended to allow exploration of the baseline 2045 port growth with overlap between urban and port growth pressures. The third scenario has both greater volumes at the port and an increased reliance on trucking. This scenario will allow exploration of truck-intensive growth effects on the network.

Table A-1. *High-level combinations of port scenario drivers for greater growth scenarios*

Port Driver	Greater Growth on the Water	Greater Growth in Urban Centers	Greater Suburban / Greenfield Growth
Containerized volume (TEUs)	↑	–	↑
Rail mode share	↑↑	↑	↓
Barge mode share	↑	–	–
Truck mode share	↓	↓	↑↑

Given these profiles, the construction of these three scenarios allows the project team to test three different futures and answer the questions outlined in Figure A-10.

SCENARIO NARRATIVES

GREATER GROWTH ON THE WATER

- » Growth in water-oriented activity
- » Growth in regional military activity
- » Port of Virginia becomes even more competitive with freight more multimodal
- » More dispersed housing locations
- » Moderate assumptions for CAV adoption & network adaptation

GREATER GROWTH IN URBAN CENTERS

- » Significant economic diversification
- » Low space requirements per job
- » Large role for "digital port"
- » New professionals prefer to live/work in urban settings
- » High level of CV adoption & low auto ownership or high TNC mode

GREATER SUBURBAN / GREENFIELD GROWTH*

- » Growth is suburban / exurban, but growth includes walkable mixed use centers
- » Port of Virginia becomes even more competitive
- » "Digital port" brings additional jobs
- » Housing is more suburban
- » High level of AV adoption & network adaptation

WHAT THESE WILL HELP US TEST

- Test greater cross-harbor travel in particular
- Test more urban & multimodal travel patterns
- Test more overall regional travel

NOTE: Sea Level Rise assumed as 3 ft. in all Scenarios

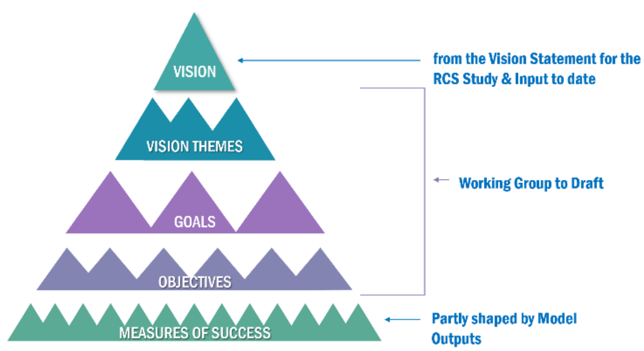
** The term "Greenfield" refers to growth in currently undeveloped areas*

Figure A-10. *Summary of three greater growth scenarios, with intention for analysis. Also includes technological factors discussed in the Scenario Planning Methodology White Paper*

Appendix B. Draft Goals and Objectives Memorandum

Note: The RCS Scope of Work included the development of a vision statement and goals, objectives, and performance measures for the modeling process. This occurred in the spring and early summer of 2019 through a series of meetings with the RCS Working Group, with review by regional stakeholders. The RCS Steering Committee approved the study performance measures on July 2019. This Technical Memorandum was created as an interim document to summarize the input received on the project Vision, Goals and Objectives in March, 2019.

Background



The following discussion of Draft goals and objectives for the HRTPO Regional Connectors Study is based on input from the March 28th, 2019 Working Group meeting. It incorporates results from the earlier regional survey conducted in Phase 1 as well as discussion and feedback from the Working Group meeting.

The March 28th Working Group meeting resulted in a basic affirmation of the project Vision as stated in the "Guidance for Scope of Work" of the Regional Connector Study Request for Proposal. It also resulted in a series of Vision Themes derived from the Vision statement that formed the basis for initial Goals for the study. Below are the results of the Working Group discussions along with a fist draft at developing a Draft Goals and Objectives Framework for review by the Working Group. These Draft Goals and Object are intended to feed into the modeling efforts for the Regional Connectors Study, which will then help to shape Measures of Success.

This document will be sent to the Working Group for their review and comment prior to their next work session on April 17th, 2019.

Part 1: Input From Working Group Meeting

Vision Statement

Below is the Vision Statement as defined in the RCS Study RFP:

"This study should establish a regional long-term vision that investigates 21st century transportation

options that connect the Peninsula and the Southside across the Hampton Roads Harbor that enhance economic vitality and improve the quality of life in the region."
(from the "Guidance for Scope of Work" of the Regional Connector Study RFP)

Vision Themes

The March 28th discussion included a list of seven vision themes, to help guide development of goal statements. These vision themes included:

1. Economic Vitality
2. Out-Region Connectivity
3. In-Region Connectivity
4. Safety
5. Multimodal Accessibility
6. Congestion Relief
7. Quality of Life

Draft Goals

In the March 28th discussion, based on Working Group discussions, the Vision Themes were further refined into a series of 10 goal categories that could start to suggest potential goals for the study:

1. Economic Vitality
2. Connectivity
3. Adaptability
4. Resilience
5. Environment
6. Safety
7. Congestion Relief
8. Accessibility
9. Reliability
10. Quality of Life

Draft Objectives

Also, in the March 28th meeting, the Working Group members were asked to brainstorm initial draft Objectives under each one of the Goal categories that were developed. These were not intended to be final objectives, given the short time in the meeting for brainstorming but were intended to get the discussion started for further refinement in this document, for written feedback after review of this document and for affirmation in the April 17th meeting.

Their ideas were recorded on sticky notes and the results of their input are summarized below, verbatim as they were written:

Economic Vitality

- Sustain and develop industry and technology sectors
- Maintain port competitiveness
- Sustain existing economic strengths and support upcoming/future economic opportunities
- Capitalize on freight to create local and regional development and redevelopment opportunities

Connectivity

- Improve access and frequency of transit throughout the region
- Regional multimodal connectivity (including transit)

Adaptability

- Ability to change to new technology
- Adaptability to emerging technology implementation
- More smart road/technology research and implementation (locally)
- Encourage progressive adaptability – 5H – drones – air space

Resilience

- Maximize resources – military, waterways, ocean and diversity
- Provide alternative routes to aid congestion and or unplanned instances, i.e., wrecks, infrastructure failure (use of technology as a factor?)

Environment

- Environmentally and economically responsible water quality requirements (tourism and seafood industries)
- Optimize modes to benefit air and water quality

Safety

- Roads high enough for hurricane evacuation flooding
- Military readiness in times of massive activation

Congestion Relief

- Provide alternatives to existing Hampton Roads harbor crossing
- Connectivity + travel time reliability

Accessibility

- Access to oceanfront and affordable housing
- Regional accessibility – limit recurring congestion, limit non-recurring congestion (reliability) and connectivity in network
- Transit dependent population - mobility

Reliability

- Limit travel delay
- Resilient system
- Reliability – more VDOT emergency response → area expansion (major local roads?)

Quality of Life

- Network context – facility context is appropriate for regional types

- Natural resources or resources – maximize
- Appropriate freight network – truck movements are effectively served on appropriate facilities (shouldn't degrade livability/safety)

Part 2: Draft Goals & Objectives Framework For Review

In this part of the document, the consultant team has – with the Working Group's direction – attempted to put the input received from the March 28th meeting into a draft Goals & Objectives Framework for review and comment by the Working Group. We have taken the initial objectives brainstormed by the Working Group in the meeting and added to them using input and information from stakeholder interviews, the public survey and our understanding of the purpose of the Regional Connector Study as a whole. We have also fleshed out the Goal categories into more complete Goal statements in sentence form for consideration.

The following draft Goals & Objectives Framework is specifically associated with the Regional Connectors Study. These goals and objectives should support the study vision statement, while also guiding work on the study. The purpose of this draft framework is not to limit the Working Group but simply to stimulate its work and discussion prior to and in their next meeting by providing additional "food for thought." Space is provided in the right hand column for their comments.

A. Economic Vitality Support a diverse and resilient regional economy that sustains existing industry and builds on new economic opportunity. **Economic Objectives:** Sustain existing industry and technology sectors. Develop new industry and technology sectors. Invest in the Port of Virginia as an economic anchor for the region. Capitalize on the region's freight networks to create inter- and intra-regional economic opportunities.	

B. Connectivity Invest in transportation facilities that will increase transportation connectivity throughout the Hampton Roads region, connecting intra- and inter-regional markets. **Connectivity Objectives:** Maintain and improve transportation connectivity with outside markets. Maintain and improve intra-regional transportation connectivity, especially between the peninsula and southside. Improve transit frequency and coverage throughout the region. Increase multi-modal connectivity within region.	

C. Adaptability Plan for and invest in a transportation system that can readily adapt to any possible future scenarios. **Adaptability Objectives:** Research and anticipate emerging technologies and their effects on the regional transportation system. Implement smart transportation strategies that incorporate new technologies.	

D. Resilience Strengthen the region's ability to avoid, mitigate and recover from hazards, adversity and unexpected trends. **Resilience Objectives:** Support a more diverse economy and population, through transportation capital investments that bring access and connectivity. Develop transportation solutions that support the region's assets, such as the military, natural resources and diverse communities. Establish alternative transportation routes, to aid congestion and or unplanned events, such as traffic accidents, infrastructure failure, natural hazards, etc.	

E. Environment Support and implement policies to protect natural resources and air and water quality in the Hampton Roads region. **Environmental Objectives** Quantify the environmental impacts of new growth and development on the region's natural resources. Invest in environmentally sustainable modes of transportation, to contribute to higher air and water quality for the region. Invest in transportation technologies for public systems that protect local natural resources.	

F. Safety Invest in a transportation system that helps to ensure the safe movement of people, goods and services throughout the Hampton Roads region. **Safety Objectives:** Invest in transportation facilities that will decrease the occurrence of traffic accidents, especially along critical connectors. Invest in a resilient transportation system that allows for safe evacuation during hurricane and other major flood events. Design a transportation system to ensure military readiness in times of massive activation.	

G. Congestion Relief Invest in a transportation system that helps support reliable travel and minimizes travel under congested conditions throughout the Hampton Roads region. **Congestion Relief Objectives:** Provide alternative transportation options to the existing Hampton Roads harbor crossings. Invest in transportation improvements that more efficiently maximize the existing roadway capacities. Establish policies and regulations for land use patterns that minimize the need for auto-dependent trips, reducing volumes on critical connectors.	

H. Accessibility Develop a transportation system that maximizes access to travel options and desired designations. **Accessibility Objectives:** Improve access to the oceanfront for the region's residents and visitors. Improve the housing diversity and affordability in the Region to improve commuting options. Invest in transportation improvements equitably, in affluent and nonaffluent neighborhoods, while mitigating negative effects of new infrastructure. Provide multi-modal solutions to transportation needs throughout the region. Improve access between the region's residents and businesses for economic opportunity, especially in areas where water features create barriers.	

I. Reliability Design a reliable and predictable transportation network that serves the entire Hampton Roads region. **Reliability Objectives:** Invest in transportation improvements that will improve the predictability and reliability of travel times. Support land use patterns that place less demand of the existing transportation network. Develop a transportation network that can quickly adapt to changing conditions. Expand the coverage area and reliability of emergency response service, with a balanced emphasis on safety and restoration of roadway capacity.	

J. Quality of Life Develop a transportation system and land use policies that maximize safety, efficiency, community integrity and individuals. **Quality of Life Objectives:** Ensure that new transpiration investments are appropriate to the surrounding community and the region. Protect the region's natural resources. Provide greater access to natural resources, rural and urban areas. Ensure that freight operations help to support, not degrade, the region's communities.	

Appendix C. Glossary of Terms

2045 Baseline Scenario: The Baseline Scenario uses the forecasted growth for the region in the 2045 Regional Travel Demand Model. It consists of the 2045 socioeconomic forecast that was approved for the region by the HRTPO Board allocated into a total of over 1,500 TAZs. For the purposes of scenario planning, the 2045 Baseline Scenario is used to compare against the three greater growth scenarios.

Accessibility: The collective ability of travelers to access specified types of destinations (such as jobs) within a reasonable travel time by the specified mode of travel (automobile, transit, etc.) on the transportation network.

Attributes: A term used in the CommunityViz land use model – refers to a piece of information describing a map feature. In the RCS land use model, the attributes of the parcel layer polygons in the model included population, employment and Place Type.

Allocator 4 Tool: A term used in the CommunityViz land use model - refers to the version of allocator that sets up supply/demand allocation based on capacity and desirability of features (see Land Use Allocation).

Attractor: The Allocator 4 tool available in CommunityViz is used to model the spatial pattern of the greater growth scenarios in this project.

Bottlenecks: Congestion hot spots that create upstream congestion, such as lane reductions or busy interchange weaving areas.

Capacity: A term used in the CommunityViz land use model - simply the capacity to accommodate future growth that is controlled by the available capacity for additional density in each Place Type polygon. It is the difference between the maximum density allowed in a Place Type polygon and the actual density already accounted for by existing development in the polygon. There are separate capacities for population and for employment.

Circuity: The difference between the distance of a route traveled on the network and the straight-line distance between origin and destination.

CommunityViz®: The consultant team used this software to conduct land use modeling for the Regional Connectors Analysis. CommunityViz Scenario 360 software is an extension of ESRI's ArcGIS"® software. This tool facilitates the visualization and comparison of alternative development scenarios.

Control Total: A term used in the CommunityViz land use model – the total growth that is allocated in a scenario. There are separate control totals for employment and for population.

Delay: The difference between congested and uncongested travel times.

Detractor: A term used in the CommunityViz land use model – a factor that acts to repel or detract from growth in the allocation process. An example of a detractor is the proximity of major interstate highways to low density housing – major highways are generally not attractive places to locate homes.

Development Factor: A factor used in the modeling process to correlate the development totals within the land use model's parcel dataset with the development totals within the travel demand model's TAZ dataset. Population and employment totals in the parcel dataset were multiplied by a development factor so that they would all total up to the same number as in the TAZ that contained the parcels.

Drivers: The drivers represent forces such as demographic change, economic trends, or technological advances, which can all affect land use patterns in different ways.

E+C (Existing plus Committed): The overall transportation network used in the travel demand model for the 2045 Baseline scenario – represents the existing network plus the projects that are financially committed in the LRTP.

GIS: stands for Geographic Information Systems – the computer mapping system used to collect and analyze spatial data in the land use model and in many planning applications.

Greater Growth Scenario: The three greater growth scenarios are the alternative future land use scenarios that were developed interactively by the Working Group and approved by the Steering Committee. They represent the alternative future land use patterns against which the transportation investment alternatives will be tested. They are termed "greater growth" because they represent an increment of growth greater than the 2045 baseline growth projected in the regional travel demand model.

Hampton Roads Planning District Commission: The Hampton Roads Planning District Commission (HRPDC), one of 21 Planning District Commissions in the Commonwealth of Virginia, is a regional organization representing this area's seventeen local governments. Planning District Commissions are voluntary associations and were created in 1969 pursuant to the Virginia Area Development Act and a regionally executed Charter Agreement.

Hampton Roads Transportation Planning Organization: The Hampton Roads Transportation Planning Organization (HRTPO) is the body created by the Hampton Roads localities and appropriate state and federal agencies to perform the duties of an MPO under the federal regulations.

Indicator: Also "performance Indicator" or "performance measure" – a numeric measure used to compare scenarios, such as "total vehicle miles traveled" or "percent of population near transit."

Intersect: a term used in GIS to indicate when one spatial layer is laid over another and a geometric operation is performed on them. For an example, the TAZ layer was intersected with the parcel layer so that the two layers could be analyzed with respect to one another (i.e. each parcel was associated with a specific TAZ).

Land Use Allocation: A term used in the CommunityViz land use model – indicates the placement of people and jobs across the region in a scenario. The Allocator tool automatically allocates a control total of people and jobs to parcels in each scenario based on the suitability and capacity values of each parcel.

Lookup Table: A term used in the CommunityViz land use model – the Lookup tables are the datasets that summarize the characteristics of each Place Type in terms of land uses, densities, occupancy, capacity for people and jobs, etc.

Mode Share Index: The profile of the share of travel for each mode (automobile, transit, bike, etc.) for a particular area such as a traffic analysis zone (TAZ).

Performance Measures: see *Indicator*

Place Types: A term used in the CommunityViz land use model – Place Types are a series of land uses that characterize the type of development that is associated with each parcel in the land use model, such as "mixed use residential" and "neighborhood commercial." The 21 general land use categories from the Regional Land Use Map were adopted as the Place Types for the land use modeling in the scenario planning process.

Place Type Suitability Factors: A term used in the CommunityViz land use model – Place Type factors are one category of Suitability Factors that are growth attractors based on a Place Type. For example, the High Density Residential Place Type is used as a suitability factor selected to attract population growth in the Greater Growth in Urban Centers scenario.

Productivity: The economic value of time lost or gained through travel, such as time spent in traffic congestion or time gained in higher-speed travel or shorter commutes

Project Prioritization Tool: A tool used by the HRTPO in an objective and data-driven project prioritization process to assist the HRTPO Board in selecting transportation projects that will benefit the region while maximizing the use of scarce financial resources. The HRTPO Project Prioritization Tool is designed to score candidate transportation projects based on their technical merits and regional benefits.

Randomizer: A feature of the CommunityViz land use model – the randomizer is a setting in the model that creates a user-determined degree of randomization to the spatial pattern of growth after an allocation. Randomization is used to create a smoother pattern of growth across a region.

*RCS***:** the Hampton Roads Regional Connectors Study

Regional Land Use Map: First developed in 2011 by the HRPDC and updated since then, the map synthesized the existing and future land use maps from the comprehensive plans of the region's sixteen jurisdictions into a single set of land use categories that were agreed to and adopted by the HRTPO Board. This unified existing and future land use map provides a common language for analyzing, planning and envisioning land use patterns and growth across the region.

Reliability: The predictability of travel times; for example, the amount of extra time that must be allowed for a certain trip to accommodate the worst level of recurring congestion

REMI Regional Economic Model: REMI is the model used by the HRPDC to forecast population and employment. The Commission's REMI model was purchased in 2001 and is updated on an annual basis. National, state and local data are collected from a variety of sources and specifically calibrated for the Hampton Roads Region.

Resilience Test: A term used to characterize the purpose of scenario planning and testing in the RCS. The scenarios create a series of plausible potential alternative futures for the region against which to test the candidate projects. By seeing which candidate projects perform best against all potential scenarios, we are testing the potential "resilience" of those projects against a variety of possible future conditions.

Scenario Planning: Scenario planning can be defined as the process of planning for the future by analyzing existing trends and organizing them into a series of plausible future scenarios to explore their consequences. Scenario planning is useful in understanding the potential impacts of current and proposed policies in the face of these potential futures. With respect to land use planning, scenario planning provides a method for exploring potential future land development patterns and alternative forecasts of population and jobs in a locality or region.

Scenario Narrative: The description of a scenario in words that is used as the basis for constructing data and numerical assumptions to characterize that scenario in the modeling process.

Spatial Suitability Factors: A term used in the CommunityViz land use model – spatial suitability factors are one category of Suitability Factors that are growth attractors based on a specific geographic feature. Spatial attractors are specific places, objects, boundaries, or systems that attract growth toward them or repel growth away from them. For example, the high demand transit network is used as a spatial suitability factor to attract population growth in the Greater Growth in Urban Centers scenario.

Steering Committee: The steering (or policy) committee for the RCS is comprised of elected officials from the seven local jurisdictions.

Suitability: Suitability is essentially a way of characterizing site suitability or desirability for growth across the region. The suitability feature of CommunityViz allows users to specify the factors that should be considered for attracting or repelling growth.

Suitability Factor: A term used in the CommunityViz land use model –Suitability Factors are specific geographic features or Place Types that are used in the model to attract or repel growth. For example, regional employment growth may be attracted to spatial features such as highway interchanges or to Place Types such as the Regional Commercial Place Type.

Suitability Map: A generalized heat map of the relative attractiveness of different parts of a region, based on the Suitability Factors and Weights built into a scenario.

Suitability Score: The relative attractiveness score of a polygon, based on the combined total of all of the Suitability Factors and Weights applied to that polygon.

Suitability Weight: A term used in the CommunityViz land use model – a user-defined number for each Suitability Factor from -10 to +10 that directs the attractiveness of a Suitability Factor. Suitability Factors and Weights were used to direct growth in each scenario in a pattern that matched the scenario Narratives.

Translational Layer: A term used in GIS – represents a geospatial data layer used to convert or "translate" one geography into another. For example, a layer used to translate the TAZ geography into the parcel-based geography in the land use model.

Transportation Analysis Zones (TAZs): The unit of geography most commonly used in conventional transportation planning models to subdivide a region and study travel behavior by providing socio-economic and other data in each TAZ.

Travel Demand Model: A program or set of computer programs and data which are used for travel forecasting. The traffic forecasts in the model are based on forecasted land use, demographics, and travel patterns unique to the region.

TREDIS®: Transportation Economic Development Impact System is a computer software used to determine benefit-cost analysis, economic impact analysis and financial impact analysis for transportation planning purposes.

Virtual Future: A term used in land use modeling to describe the geospatial dataset that defines a land use scenario at a specific point in the future. In the RCS, the Virtual Future is synonymous with the 2045 Baseline Scenario – i.e. the land uses and control totals for growth that are built into the regional travel demand model for the year 2045.

Virtual Present: A term used in land use modeling to describe the geospatial dataset that defines pattern of population, employment and land uses on the ground currently. In the RCS, the Virtual Present is synonymous with the 2015 existing conditions – i.e. the land uses and control totals for growth that are built into the regional travel demand model for the year 2015.

Working Group: The Working Group for the RCS is comprised of technical staff from seven local jurisdictions and other key regional stakeholders (US Navy, US Coast Guard, Virginia Port Authority, Federal Highway Administration, US Army Corps of Engineers, Virginia Department of Transportation, and HRTAC).

Appendix D. CommunityViz Resources

CommunityViz software developed by City Explained, Inc. is one of the most widely used land use modeling programs in the world. It was used for the land use modeling in the RCS. CommunityViz Scenario 360 software is built on the platform of ESRI's ArcGIS" ® software. CommunityViz is particularly useful for its flexibility, allowing a great degree of user customization, and for the built-in features that facilitate the visualization and comparison of alternative development scenarios.

Listed below is a series of links to explanatory narratives on the CommunityViz website to explore the different features of the modeling software:

General information on CommunityViz:
https://communityviz.city-explained.com/

Case Studies using CommunityViz for scenario planning:
https://www.city-explained.com/projects.html

Scenario360 Suitability Wizard:
https://communityviz.city-explained.com/communityviz/s360webhelp4-1/Decision_Tools/Suitability_Wizard/Working_with_the_Suitability_Wizard.htm

Scenarios:
https://communityviz.city-explained.com/communityviz/s360webhelp/Scenarios/About_scenarios.htm

Suitability Analysis:
https://communityviz.city-explained.com/communityviz/s360webhelp4-1/Decision_Tools/Suitability_Wizard/About_Suitability_Analysis.htm

Allocation:
https://communityviz.city-explained.com/communityviz/s360webhelp/Allocator_5/Allocator_5_Welcome.htm

Lookup Tables:
https://communityviz.city-explained.com/communityviz/s360webhelp/ArcMap/Editing_a_lookup_table.htm

Indicators:
https://communityviz.city-explained.com/PDFs/articles/WhitePaperIndicators.pdf

Attributes:
https://communityviz.city-explained.com/communityviz/s360webhelp/Attributes/About_attributes.htm

Appendix E. Transportation Performance Measures Definition

Measure	Description
Freight network - total delay	Daily congested VHT minus free flow VHT for the defined freight network.
Freight traffic on secondary streets	Daily (truck VMT/total VMT) for minor arterials, collectors, and local roadways.
Traffic volumes at at-grade rail crossings	Daily vehicle volume totaled over all at-grade rail crossings.
Accessibility to major tourist attractions	For any given TAZ, a scaled ratio of off-peak home-based other and non home-based trips attracted to specific TAZs with tourist activities to the total regional home-based other and non home-based trips attracted to these TAZs.
Mode Share Index	Mode share (as a % of all daily person trips) for each mode.
(Change in) Transit ridership	Percent change in daily transit boardings versus the Baseline scenario.
Average trip length by purpose (does not include ZOVs)	Average trip distance (miles) by trip purpose (business, commuter, personal) for conventional vehicles and CAVs.
(Change in) cost of emissions	Percent change in VMT versus the Baseline scenario.
Delay on cross-harbor trips	Daily congested VHT minus free flow VHT for each of the harbor crossings.
Circuity of cross- harbor trips	Ratio of the estimated (travel model) path distance taken by cross-harbor trips and the “straight-line” distance between their origin and destination.
Reliability for cross- harbor trips	Buffer time required to ensure on-time arrival in response to congestion for trips crossing the harbor (methodology discussed in Appendix “B”).
Cross-harbor accessibility	For any given TAZ, a scaled ratio of peak period home-based work trips crossing the harbor to total regional home-based work trips crossing the harbor.
Accessibility to labor	For any given TAZ, a scaled ratio of peak period home-based work trip attractions to total regional home-based work trip attractions.
Performance of the transit-serving roadway network	Average daily congested speed (mph).
Regional delay	Daily congested VHT minus free flow VHT for all roadways in the region.

System reliability	VMT w/ daily volume-to-capacity ratio > 0.90.
Bottlenecks on identified priority military routes (daily peak period conditions)	Percentage of military route lane-miles w/ PM volume-to-capacity ratio > 0.90.
Bottlenecks on identified evacuation routes (daily peak conditions)	Percentage of evacuation route lane-miles w/ PM volume-to-capacity ratio > 0.90.
Trips by automated vehicles	Percentage of daily CAV trips
Travel using facilities with adaptive technologies	Percentage of VMT on managed lane facilities.
(Change in) Person trip demand	Percent change in daily regional person trips versus the Baseline scenario.
(Change in) Internal truck trip demand	Percent change in daily regional internal truck trips versus the Baseline scenario.
(Change in) External truck trip demand	Percent change in daily regional external truck trips versus the Baseline scenario.
Induced internal trip demand from technology (w/ ZOVs)	Percent change in daily internal passenger vehicle trips versus the Baseline scenario.
Induced external trip demand from technology (w/ ZOVs)	Percent change in daily external passenger vehicle trips versus the Baseline scenario.

VHT – vehicle-hours traveled
VMT – vehicle-miles traveled
TAZ – traffic analysis zone
CAV – connected and/or autonomous vehicle
ZOV – zero-occupant vehicle

Appendix F. MetroQuest Survey Results

Participation

The Regional Connectors Study MetroQuest collected public input from February 10, 2021 to March 4, 2021. During this period, 70 participants completed the survey. An equal number of participants completed the survey in a web browser and on their smartphone.

Less than 30% of participants provided responses to the demographic data questions at the end of the survey. Out of 25 responses, 18 participants were White/Caucasian, five were Black/African America, and two identified as another race. One participant listed Hispanic/Latino as their ethnicity. Out of 26 responses, 16 participants were over 45 years old. Out of 25 responses, 16 participants' households made over $75,000. Of the 26 participants that provided their zip code, nine lived in Norfolk, eight lived in Virginia Beach, two lived in Chesapeake, two lived in Portsmouth, two lived in Suffolk, one lived in Hampton, and one lived in Newport News. One participant provided a zip code from the state of Georgia.

Scenario Assumptions

The first exercise on the MetroQuest asked participants either agree or disagree on the question "*Is this useful to explore?"* The question was asked following five explanatory tabs. The explanatory text, the participant responses, and a summary of their comments are described below.

Introduction: *Exploratory scenario planning is like a defensive playbook - envisioning and preparing for a wide range of future conditions that may occur. Each scenario has a set of parameters each with their own drivers that influence them. Scenario planning adjusts these drivers to produce variable outcomes.*

- 56 participants agreed this was useful to explore, 7 disagreed
- One commenter wrote: There wasn't a scenario that accounted for increased water taxi traffic

Scenarios: *The Greater Growth scenarios each have an equal additional amount of growth beyond the baseline HRTPO-approved 2045 Socioeconomic Forecast. That growth is allocated differently based on each scenario's drivers. The goal is to have distinctly different futures that enable stronger planning for what could happen in the future.*

- 51 participants agreed this was useful to explore, 6 disagreed
- One participant commented:
    - No military in any of the scenarios, seems incomplete without the military included in scenarios

Land Use: *"Suitability Factors" reflect assumptions about the additional growth in each scenario, acting as magnets for attracting or repelling growth in the computer model. This graphic shows the weighting of some suitability factors. The computer model then allocated available future growth according to these factors and created different patterns of growth for each scenario.*

- 44 participants agreed this was useful to explore, 5 disagreed

- Two participants commented:
    - One commenter wrote: Would like to have seen projections of new businesses and types in what areas and projected residential housing single and multiple in the area.
    - One commenter wrote: Lack of military in each scenario raises the question of suitability with such a large military in our community.

Technology: *The RCS used HRTPO's regional travel demand model to create a "baseline" for travel patterns and impacts in 2045. Scenario data was calculated using the baseline plus the land use model's population and employment growth data. All four scenarios include assumptions about future transportation technologies. These assumptions reflect the technology features noted in each of the scenario narratives.*

- 42 participants agreed this was useful to explore, 5 disagreed
- Three participants commented:
    - Scenarios talk to port growth, however Hampton Roads has seen growth in military and forecast is for additional growth in the future. Langley Air Force Base with aircraft, Naval Station is sure to receive my ship with a growing fleet. It's unclear to me how the military population and employment growth is address in this effort.
    - It seems like the assumptions for autonomous vehicles in the suburban growth scenario seem high, based on current trends.
    - I think consideration of more working from home or distributed offices should be considered in the analysis

Economics: *The economic drivers described in the scenario narratives such as industry growth and port activity were incorporated in the land use and travel models. The economic model then calculated potential changes in societal costs of travel based on the travel inputs by scenario shown here.*

- 44 participants agreed this was useful to explore, 4 disagreed
- One participant commented:
    - Military and DOD[35] are huge economic drivers in Hampton Roads, the study appears to be silent on DoD in the economic model. But rather focuses on port activity with the Port of Virginia and industry growth on a lessor level.

Scenario Outcomes

The second exercise on the MetroQuest asked participants either agree or disagree on the question "*Is this a useful range of outcomes?"* The question was asked following five explanatory tabs. The explanatory text, the participant responses, and a summary of their comments are described below.
Land Use Maps: *The land use maps to the left (suitability maps) show how the suitability factors were used to paint a picture of attractiveness to growth under each scenario. The land use allocation maps indicate the resulting patterns of additional growth in each scenario.*

- 27 participants agreed this was a useful range of outcomes, 10 disagreed
- Two participants commented:

[35] DOD: Department of Defense. Per this and related comments, the study team updated the description of scenario assumptions on the project website to further detail the assumptions with regard to the Navy and military employment across the region. These assumptions were not described in the MetroQuest survey, but were included in the project analysis.

    - Resiliency of existing national security assets and the missions/ operations of the Coast Guard, Navy, Army, Air Force and Marines appears to be missing from the study where land use constraints would be helpful to protect the assets.
    - More detail of specific areas would have been helpful.

Land Use Charts: *Each scenario produced important differences in land use patterns that are consistent with the Scenario Narratives. For example, the Greater Growth in Urban Centers scenario shows the most jobs near transit stops, and the Greater Suburban/Greenfield Growth scenario shows the most population growth on undeveloped land.*

- 28 participants agreed this was a useful range of outcomes, 8 disagreed
- Two participants commented:
    - No acknowledgment of military in scenarios raises questions for land use scenarios.
    - Development of public transportation is vital to Suburban growth and reduced transportation delays.

Transportation Maps: *The transportation performance results show important differences between the Baseline and Greater Growth scenario results in the patterns of congestion. Consistent with the scenario narratives, the Greater Urban Growth scenario has less congestion throughout the region, while Greater Growth on the Water and Greater Suburban Growth have more overall congestion, but different patterns of congestion.*

- 31 participants agreed this was a useful range of outcomes, 5 disagreed
- Four participants commented:
    - Means of public transportation is vital to Suburban growth and reduced transportation delays.
    - Unclear on the details of the scenario.
    - Sea level rise and climate change may impact bridge tunnel and road usages.
    - These scenarios may or may not be helpful when looking at the harbor crossing, but I really have to question how you generated these maps. How could Little Neck Rd be red in the suburban scenario when the land use maps showed almost no job or residential allocation in that part of the city?

Transportation Charts: *The transportation performance charts show that the scenarios produce different outcomes in the amount of travel, the time spent on travel, and the amount of delay that drivers are projected to experience. These results generally reflect the scenario narratives. For example, both land use and technology assumptions produce markedly less congestion in the Greater Urban Growth scenario.*

- 25 participants agreed this was a useful range of outcomes, 9 disagreed
- Two participants commented:
    - Unclear how transportation charts/scenarios appear to be developed without the military.
    - Means of public transportation is vital to Suburban growth and reduced transportation delays.

Economic Charts: *This graphic indicates that the Greater Growth on the Water scenario is similar or higher in societal costs compared to the 2045 Baseline scenario across all measures. The Greater Suburban Growth scenario raises both congestion and freight-related costs while reducing others, and only the Greater Urban Growth scenario has lower societal costs than the baseline across all measures.*

- 28 participants agreed this was a useful range of outcomes, 5 disagreed
- Two participants commented:
  - We are Urban residents for this reason
  - Again the scenario focuses on port transportation, what about military transportation routes? How are military commuters addressed?

Scenario Application

The third exercise on the MetroQuest asked participants to provide their opinions on several overarching items regarding the application of the scenario results. Their responses are below.

Plausible Futures: Questions and responses in this category bulleted below.

- The scenario results make sense to me as a plausible range of outcomes
  - Agree: 11
  - Somewhat Agree: 12
  - Neutral: 4
  - Somewhat Disagree: 1
  - Disagree: 0
- Please mark any scenario parameters that are not clear to you with regard to their plausibility (Select all that apply):
  - Land Use: 7
  - Transportation: 8
  - Technology: 6
  - Economics: 6

Important Trends: Questions and responses in this category bulleted below.

- The Greater Growth scenarios address future trends that are important to me.
  - Agree: 0
  - Somewhat Agree: 7
  - Neutral: 1
  - Somewhat Disagree: 1
  - Disagree: 0
- Please mark the scenario parameters that you feel are most important to testing future transportation investments (Select all that apply):
  - Land Use: 9
  - Transportation: 15
  - Technology: 7
  - Economics; 14

Regional Harbor Crossings: Questions and responses in this category bulleted below.

- The evaluation of regional harbor crossings will be strengthened by testing the crossings with the Baseline and Greater Growth scenarios.
    - Agree: 18
    - Somewhat Agree: 7
    - Neutral: 2
    - Somewhat Disagree: 1
    - Disagree: 0
- When regional crossing alternatives are evaluated, my top priority is to see improvements to:
    - Congestion across the harbor: 4
    - Overall amount of travel required: 2
    - Overall regional congestion: 12
    - Reliability of travel times: 5
    - Travel speeds during peak travel times: 3
    - Other Impacts:
        - Environmental, mission and operational impacts to existing and growth of military activities.
        - Economic
        - Sea level rise
        - Transportation equity and accessibility. Regionalism
        - Traffic lights plan. Why do certain traffic lights turn red and there are no other cars in other lanes. Why do traffic lights timed on major routes timed to turn red from one intersection to the next. Traffic cannot obtain approved speed because of stopping for traffic lights.
        - Safety alerts about delays due to accidents.