Technical Memorandum: Drivers, Spatial Assumptions, and Travel Parameters

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. This memo describes the trend drivers and the related assumptions that were developed uniquely for the RCS Hampton Roads exploratory scenario planning. Each section relates back to the scenario narratives as the basis for assumptions and describes the means by which assumptions were derived, and the resulting spatial assumptions in the land use model, and the economic and technology driver assumptions incorporated in the travel demand 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. This memo describes the role of industry clusters and place types in the development of spatial Suitability Factors for growth in the three Greater Growth scenarios.

Drivers Implemented in the Land Use Model

Environmental Driver – Sea Level Rise

As described above, the primary environmental driver that was modeled for the future was potential sea level rise. Based on working group input, the project team decided to use 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 Appendix 1. 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.

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 will follow the same approach in that it will model 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 will reflect that assumption as well and will model only the growth from the 2045 baseline that shows up in the inundated areas. In addition, the TDM will 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 is currently underway. 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

[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.

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, the project team created economic profiles of each scenario, as summarized in Figure 1.

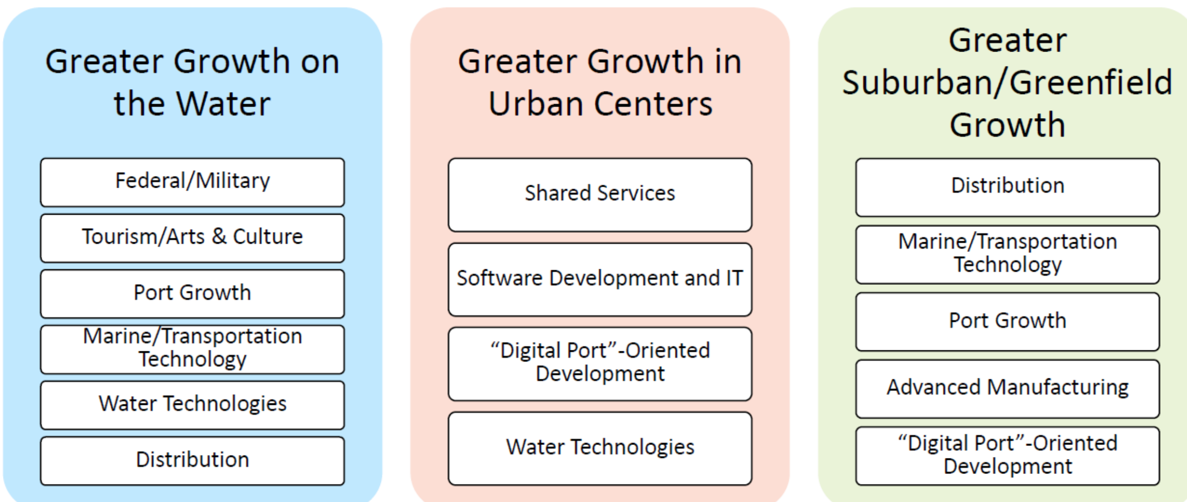

Figure 1. Sectors and industries assigned to each of the three Greater Growth Scenarios, based on the project team's analysis of economic development strategies and likely direction for regional job growth.

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

- **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

As described in the *Scenario Planning White Paper* (Nov, 2019), the employment composition of the three Greater Growth Scenarios is one important 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). Rather, given the overall scenario planning goal of stress-testing the transportation system, the project team emphasized the ability to develop and assign Suitability Factors that would produce meaningful differences in the scenarios in terms of spatial patterns of growth, travel behavior or trip generation.

The primary mechanism by which spatial differentiation of growth occurs in the land use model is through Suitability Factors. These 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 assignment of place type preferences and other Suitability Factors was based on scenario drivers—specifically on the rough composition of job growth, as well as lifestyle preferences, in each scenario narrative.

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. 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]

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.

Defining Suitability Weighting Factors

For each Suitability Factor, the project team started by considering different site selection preferences of industry clusters listed above. In the land use model, each Suitability Factor can have different "weights" assigned to it, allowing fine tuning of the attractiveness of different factors. The project team tuned each Suitability Factor – both spatial and place type based – specifically to amplify spatial differences between scenarios in order to produce a good diversity

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[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).

of growth patterns between the scenarios. For 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 RCS project's emphasis on scenario differentiation and narrative consistency shaped the project team's use of suitability weighting factors. The project team defined these factors in a fluid, iterative process in which initial Suitability Factors were tested using initial allocations of employment and population. The project team compared these initial allocations against the intended patterns of greater growth in each scenario and then revised Suitability Factors to better match the scenario narratives.

Many of the Suitability Factors were revised in response to the characteristics of available datasets and to the results of 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 water and greenfield 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 11 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 11 essentially translates the proposed scenario narratives to specific Suitability Factors that are used to define and model the difference between future scenarios. Suitability factors were developed based on relevance to the scenario narratives and availability of data. Weighting of suitability factors was developed through an iterative process, testing different weights to determine the optimum weighting that would best match each scenario narrative.

Table 11. 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	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); Greenfield and water scenarios purposely not weighted towards job centers to show greater differences between them and the 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

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	Greenfield
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 water scenario to support port-oriented growth. Detractor for population in water and greenfield scenarios because traditional dispersed residential development prefers locating away from major roadways. In the urban scenario, major roadways are not a detractor as they provide concentrated urban access.	M (jobs) Negative (pop)	N/A	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 urban 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

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	Greenfield
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 water scenario, this factor is only applied to population, to support the scenario narrative of more dispersed population than employment.	H	L	H
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 urban 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 water scenario.	H	M	N/A
Shoreline Proximity	**Existing**	**Water.** Population drawn to coastal amenities in 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

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	Greenfield
Urbanized Waterfront Proximity	**Existing**	**Water and Urban.** Employment growth strongly attracted by urbanized coastal areas in water scenario; Some employment attraction to urbanized waterfront in urban 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 urban 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 urban scenario; existing density attracts future greater growth density.	N/A	H	N/A
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

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 previously discussed in the *Economic Trends and Opportunities Memo*). These assumptions are shown in Table 2.

Table 2. 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 3 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 3. 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 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 4. 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 2 and Table 5. 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.

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[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 4. 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 2. Port of Virginia Containerized Volumes – Total and by Truck, Under Each Scenario

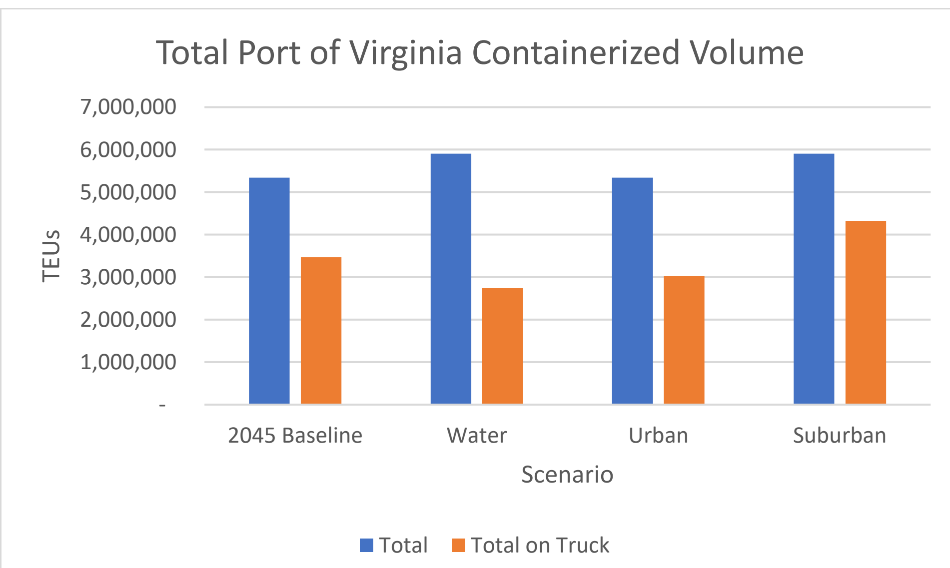


Table 5. Containerized Volumes by Terminal and Mode Under Each Scenario

	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. Figure 3 provides a brief technology-oriented narrative for the scenarios.

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-occupant vehicles (ZOVs)
- Changes in effective roadway capacity
- Reduction in vehicle accidents/improvement in travel time reliability

Appendix 2 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 occupant vehicle (ZOV) 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.

[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.

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 3. Baseline and Greater Growth Scenario Technology Narratives.

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

Figure 4 that follows shows the relative difference between the baseline and greater growth scenarios for these measures in accordance with the scenario narratives. Tables 6 through 8 show the actual values used for the first three measures for each scenario.

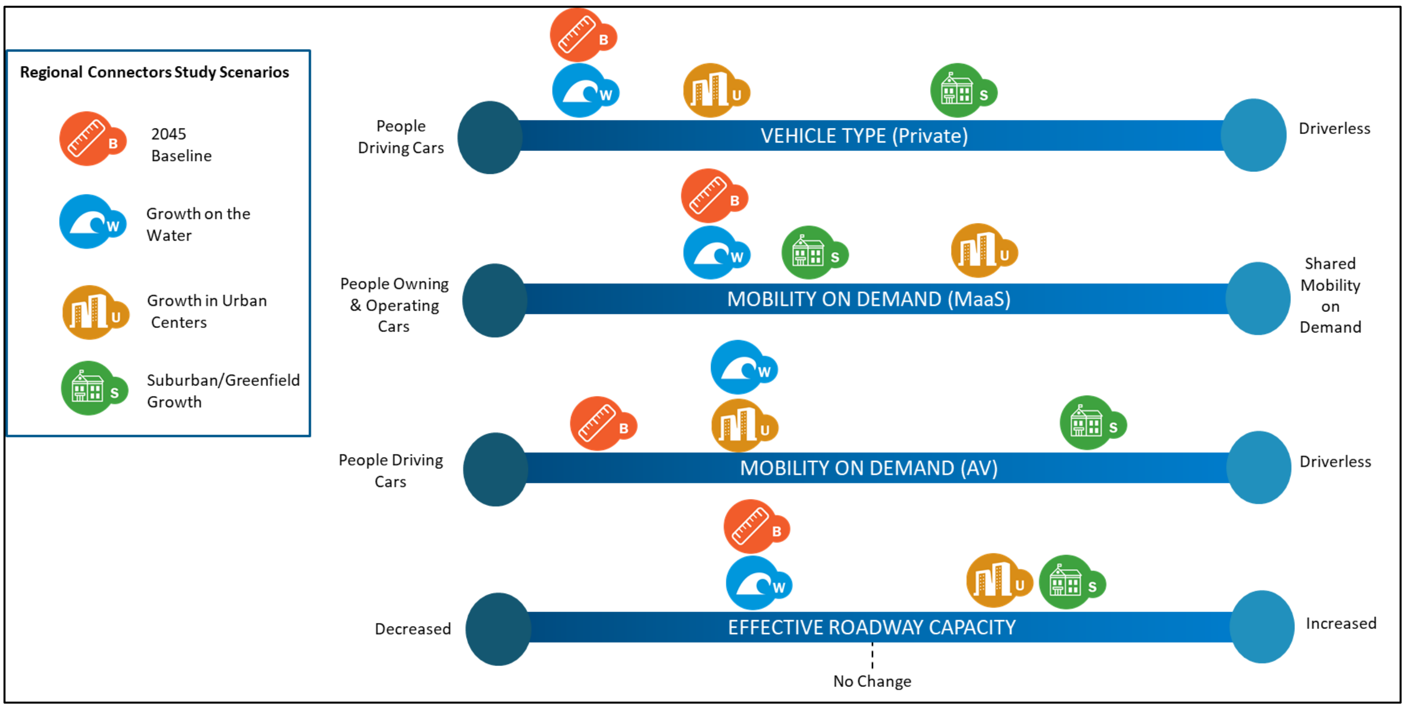


Figure 4. Technology Measures for Baseline and Greater Growth Scenarios.

Table 6. 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 7. 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 8. 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 9 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 3.

Roadway Capacity - 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 5 shows the assumption that a 35% increase in capacity on interstates and freeways will result.

Passenger Car Equivalent (PCE) - Amount of roadway capacity a specific type of vehicle uses. PCE for passenger cars = 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 9. 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 vehciles

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-occupant vehicles (ZOVs) on the roadway network. ZOVs can arise as a result of privately-owned AVs or those that are shared through MaaS and operated by transportation network companies. ZOVs 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 10 describes these behaviors and how they are accounted for in the travel demand model.

Table 10. Types of Zero-Occupant 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 11 shows the level of ZOV 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 ZOV trip generation will be greater for this area type than others. Depot locations for shared AVs are in four locations in downtown Norfolk.[8]

Table 11. 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 12 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. The values in Table 8 are default values associated with the travel demand model.

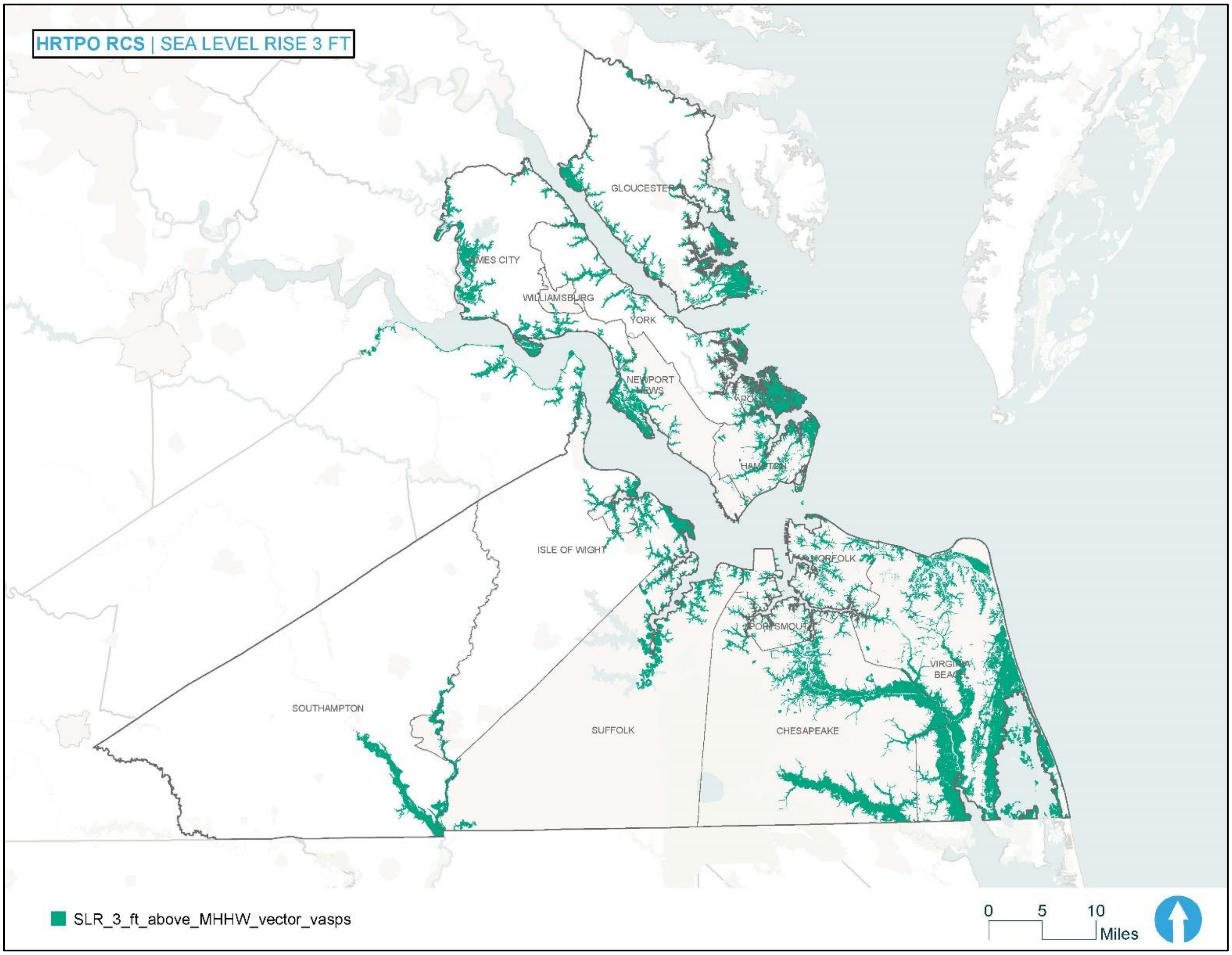
[7] Based on "reasonable assumptions" by the developer of the HRTPO Travel Demand Model.

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

Table 12. 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%	

Appendix 1: Areas of Inundation with Three Feet of Sea Level Rise



Source: Hampton Roads Planning District Commission, see https://www.hrgeo.org/datasets/slr-3-ft-above-mhhw for data and https://www.hrpdcva.gov/uploads/docs/11_Attachment_Proposed%20Sea%20Level%20Rise%20Planning%20Policy%20and%20Approach%20100518.pdf for methodology.

Appendix 2: 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.
ZOV Trip Generation (New Step)	- Add vehicle trips to account for new trip legs with driverless vehicles.	- 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.