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How Might Virginia Age and Grow by 2040?

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John S. Miller, Ph.D., P.E.
Principal Research Scientist

Amy A. O'Leary, Ph.D.
Associate Director

Hillary D. Goldstein
Research Scientist

Aidan S. Barkley
Research Assistant

Benjamin D. Smith
Research Assistant

Final Report VTRC 16-R12

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530 Edgemont Road, Charlottesville, VA 22903-2454
www.VTRC.net

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16. Abstract:

The development of Virginia's Statewide Multimodal Transportation Plan for 2040, also known as "VTrans 2040," requires the identification of population forecasts, employment forecasts, and changes in population-related factors that might influence future travel demand. The research documented in this report fulfills that requirement.

Key findings are that Virginia's population is forecast to grow over roughly a quarter century from a 2012 population of 8.2 million to a 2040 population of 10.5 or 11.7 million, depending on the forecast source. The 14% difference between these two population forecasts is a degree of uncertainty that would be expected given previous comparisons of actual and forecast populations. The forecast growth varies by age group: the number of people age 65+ is projected to almost double over this period, with the fastest growing cohort within this age group being those age 85+. The forecast growth varies by location, with 4 of Virginia's 21 planning district commissions accounting for between 77% and 81% of the forecast growth from 2012-2040. Employment is forecast to grow by about 60% over this period. Changes in other population-related factors that influence travel demand include density (about one-half of Virginia's growth from 2012-2040 is projected to be in areas that will by 2040 have a transit-compatible population density), the use of alternative fuel vehicles, and vehicle ownership (which is not expected to increase).

These forecasts do not necessarily suggest a single policy response for all Virginia locations. For example, decreasing rates of licensure might suggest increased use of public transportation; however, this impact would presumably be less in areas with lower population density. As shown by the two sample stakeholder input exercises developed in Appendix D, a variety of responses to transportation policies is possible. Because knowledge of the forecasts noted in this report may help inform consideration of diverse transportation alternatives, it is recommended that the material available in the report continue to be shared with Virginia planners.

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FINAL REPORT

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DISCLAIMER

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

ACS	American Community Survey
Adult	age 20-64
Auto	automobile (a specific type of motorized vehicle)
AFV	alternative fuel vehicle
AIC	American Immigration Council
BTU	British thermal unit
CBD	central business district
CBSA	core-based statistical area
CNG	compressed natural gas
CTPP	Census Transportation Planning Package
E85	gasoline blend with 85% ethanol
FHWA	Federal Highway Administration
GAO	Government Accountability Office
HEV	hybrid electric vehicle
LEP	limited English proficiency
LNG	liquefied natural gas
Mature seniors	age 85 and over
Millennials	age 20-34 in 2012 (i.e., people born between 1978 and 1992 inclusive)
MPO	metropolitan planning organization
MWCOG	Metropolitan Washington Council of Governments
NILC	National Immigration Law Center
PDC	planning district commission

Senior	age 65 and over
U.S. EIA	U.S. Energy Information Administration
U.S.	United States
VEC	Virginia Employment Commission
Vehicle	A general term for a wheeled motorized transport unit; specific types of vehicles include automobiles, light duty trucks, and heavy trucks
VMT	vehicle miles traveled
VTrans	Virginia's statewide multimodal transportation plan
Weldon Cooper	The Weldon Cooper Center for Public Service
Woods & Poole	Woods & Poole Economics, Inc.
Youth	age 19 and under
Youthful seniors	age 65-74

EXECUTIVE SUMMARY

Introduction

This report provides socioeconomic forecasts and examples of how such forecasts may affect travel demand in support of VTrans2040, Virginia's 2040 statewide multimodal transportation plan, as required by the *Code of Virginia* (§ 33.1-23.03). The *Code of Virginia* charges the Commonwealth Transportation Board with assisting Virginia's Office of Intermodal Planning and Investment (see § 2.2-229, Item 2) with developing this plan at least every 4 years, with the plan being required to have at least a 20-year horizon and be multimodal in scope.

Because of this long-term focus, development of VTrans2040 requires consideration of how Virginia might change between the time when the plan was being developed (2014-2015) and the horizon year (2040). Accordingly, this report provides forecasts for how Virginia might change by 2040 in terms of population growth, employment growth, vehicle ownership rates, income growth, fuel prices, and land density. In response to an interest in alternative scenarios, the report provides information regarding possible impacts of how Virginia may change, such as the role of increased population density on Virginians' propensity to use transit. This report is thus not the plan itself but rather is one of many sources that may be considered in the development of the plan by the Office of Intermodal Planning and Investment's Multimodal Working Group. Participating agencies in this group include the Virginia Commercial Space Flight Authority, Virginia Department of Aviation, Virginia Department of Motor Vehicles, Virginia Department of Rail and Public Transportation, Virginia Department of Transportation, and the Virginia Port Authority (Office of Intermodal Planning and Investment, 2016).

This report answers three questions:

1. What population and employment growth is forecast for 2040?

2. What other changes in terms of factors that relate to population and also influence travel demand are expected by 2040?

3. How can changes in population growth or related factors be linked to travel demand and a societal outcome?

The findings are detailed in the body of the report, summarized in the "Conclusions" section of the report, and noted here.

Population and Employment Growth

Two sources forecast that Virginia's population will increase over the next 25 years. The Weldon Cooper Center for Public Service (hereinafter Weldon Cooper) (2012a) forecast Virginia growing from a 2012 population of 8.2 million to a 2040 population of 10.5 million; Woods & Poole Economics, Inc. (hereinafter Woods & Poole) (2014) forecast a 2040 population of 11.7 million. Most of the difference between these two growth forecasts—2.3 million versus 3.5

million—is accounted for by a difference of about 1.04 million for Northern Virginia, as shown in Figure ES1. A third set of forecasts for Northern Virginia by the Metropolitan Washington Council of Governments (MWCOG) (2013) is quite close to that of Weldon Cooper. That said, the 14% difference between the two statewide 2040 population forecasts is a degree of uncertainty that would be expected given previous comparisons of actual and forecast populations. A contributor to this uncertainty is the forecasting of future movement to Virginia: more than one-half of Virginia's growth from 2000-2010 was attributed to migration from other states or immigration from abroad (Virginia Department of Health, 2011), and changes in migration or immigration patterns will affect Virginia's population forecast.

The forecast growth in population varies by location. Four of Virginia's planning district commissions (PDCs)—Northern Virginia Regional Commission (hereinafter Northern Virginia PDC), Richmond Regional PDC, Hampton Roads PDC, and George Washington Regional Commission (hereinafter George Washington PDC) (the PDC that includes Fredericksburg and that is south of the Northern Virginia PDC)—account for 77% (according to Weldon Cooper, 2012a; see Figure ES2) or 81% (according to Woods & Poole, 2014) of the growth forecast from 2012-2040. Another way of describing this growth is that the proportion of statewide population in locations designated as "Central" or "Outlying" Hampton Roads, Northern Virginia, Richmond, defined by the U.S. Census Bureau (2013d, 2013e) as core-based statistical areas (CBSAs), is forecast to increase from slightly more than 65% in 2012 to slightly less than 69% in 2040, with decreases in small urban areas and jurisdictions not located in any part of a CBSA.

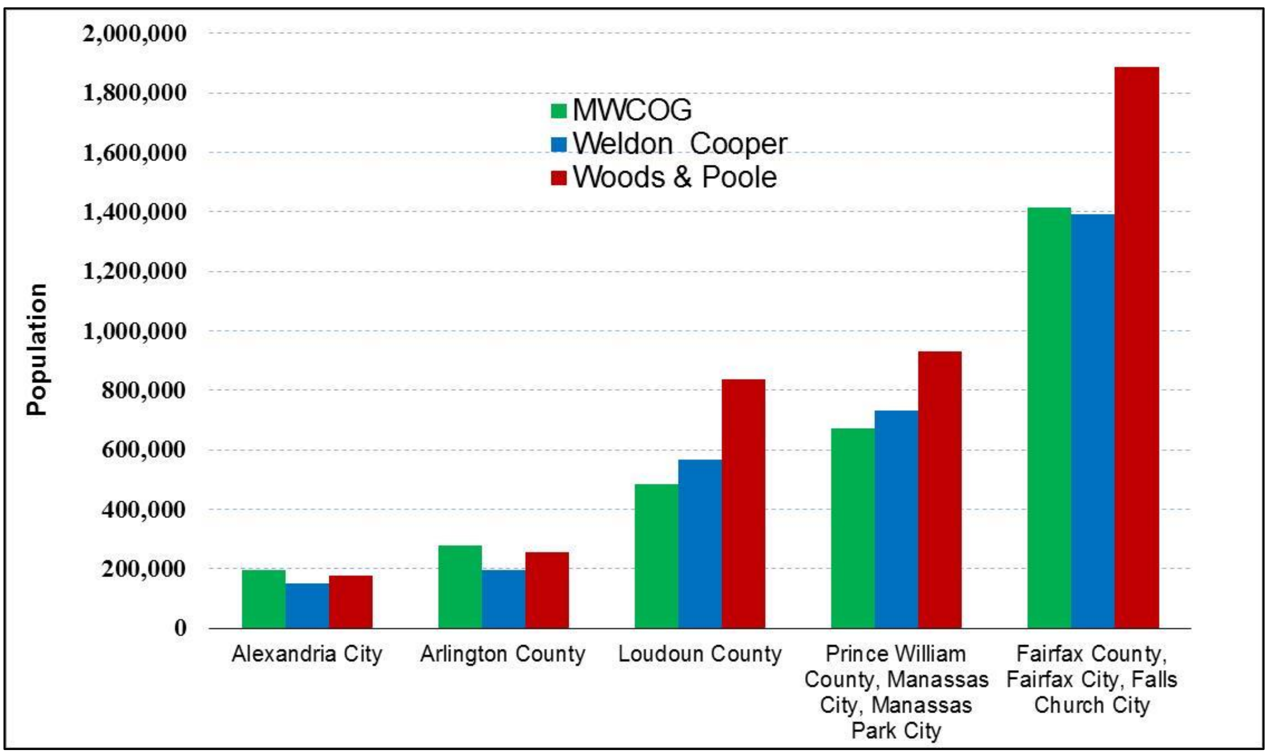

Figure ES1. Population of Localities in the Northern Virginia PDC: 2040. MWCOG = Metropolitan Washington Council of Governments. Data from MWCOG (2013), Weldon Cooper (2012a), and Woods & Poole (2014).

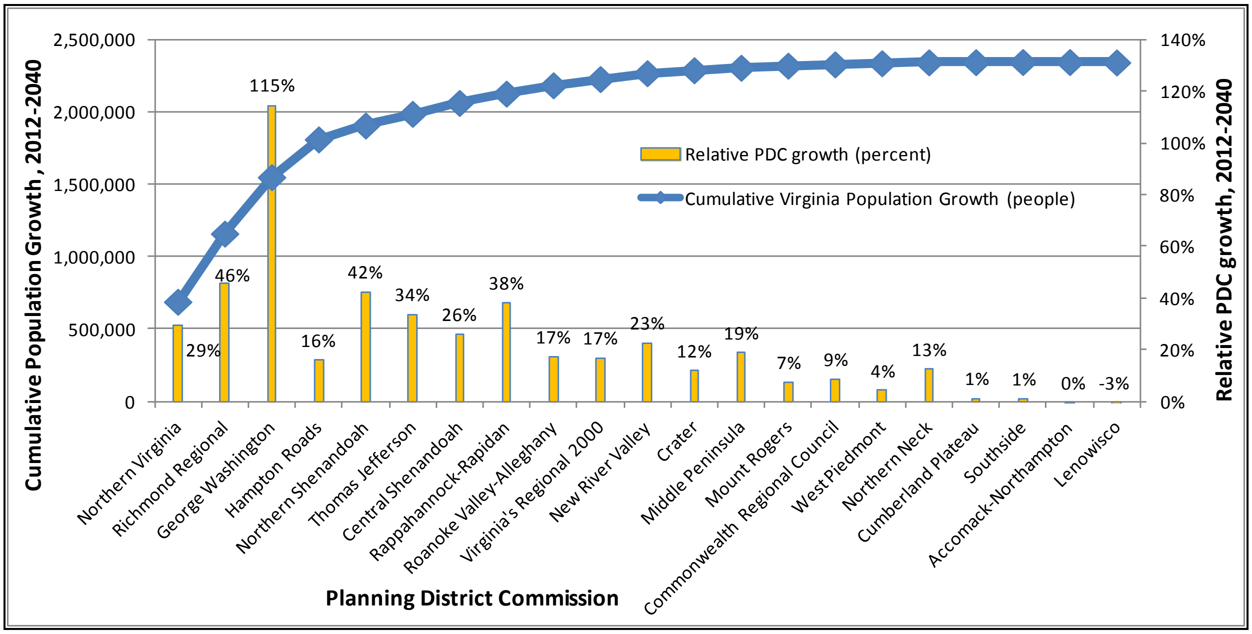

Figure ES2. Forecast Cumulative and Relative Growth in Virginia PDCs: 2012-2040. PDC = planning district commission. Data from Weldon Cooper (2012a).

Presently, Virginia jurisdictions with a population density of roughly 1,200/square mile or more tend to offer some type of daily, fixed route transit service with headways of 60 minutes or less. Based on this rough threshold, approximately one-half (i.e., 1.13 million) of Virginia's growth from 2012-2040 is projected to be in areas that will by 2040 have a transit-compatible population density, with the other one-half (1.21 million) being in jurisdictions that have a lower density.

The forecast growth in Virginia's population varies by age group. Based on forecast changes in age group data available from Weldon Cooper (2012a), the senior population (age 65 and over [65+]) may almost double (from 1.06 million to 1.90 million). Although the percentage of "youthful seniors" (i.e., age 65-74) may increase moderately (from 7.5% to 8.6%), the percentage of "mature seniors" (i.e., age 85 and over [85+]) may increase more dramatically (from 1.6% to 2.7%; see Figure ES3). The percentage of the population age 19 and under is expected to remain constant (accounting for roughly 25% of the population in 2012 and 2040), whereas the percentage of the population age 20-64 is forecast to drop (from 62% to 57%). If immigration were to cease, it would be expected that Virginia's age profile would be older than what is reported here.

Employment growth is also uneven by location. Woods & Poole (2014) suggested that employment may grow from roughly 4.9 million to 7.8 million jobs by 2040; of note is that the definition of *employment* by Woods & Poole (2014) differs from that of the Virginia Employment Commission (Geographic Solutions, Inc., 2014a, b, c). Woods & Poole (2014) pointed out that its employment numbers are often higher than those from other sources because (1) they include certain types of workers such as agriculture workers, the military, and proprietors that may be left out of other sources, and (2) they are collected based on where people work rather than where they live such that if a person has two jobs, both jobs will be counted, which is not always the case when employment data are collected at the point of

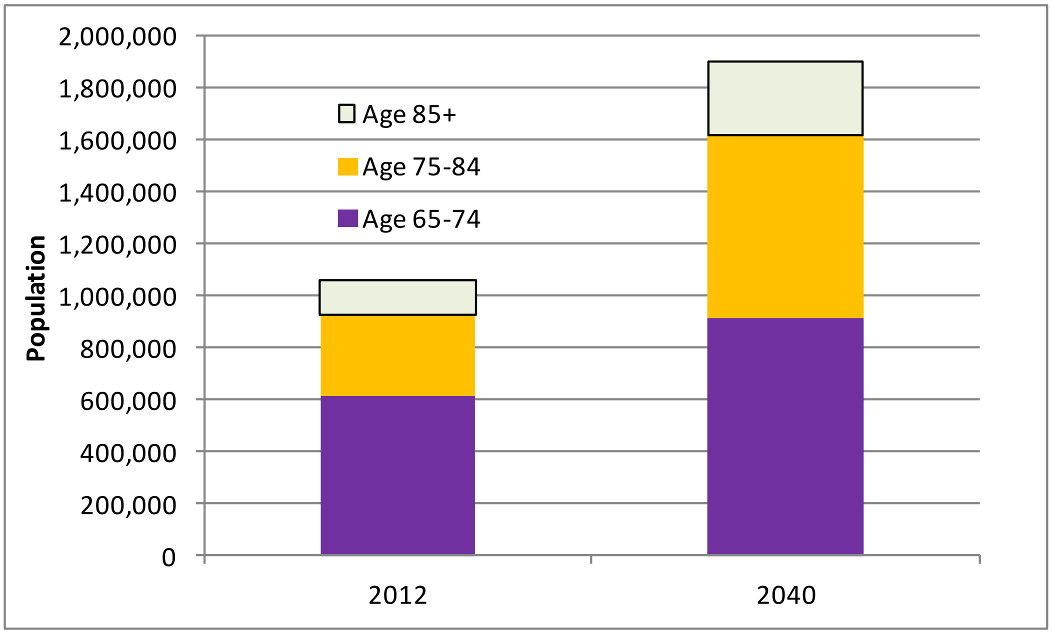

Figure ES3. Projected Change in Population Age 65+ by Age Group: 2012-2040. Data from Weldon Cooper (2012a).

residence. Thus, the salient observation is the forecast of an employment growth of roughly 60%. As is the case with population forecasts, there is considerable uncertainty with employment forecasts; some alternative methods to forecast employment considered by the authors of this report in Appendix B suggested an approximate empirical confidence interval of about 23% at the state level, meaning that one might expect actual employment to differ from forecast employment by as much as 23%. Analysis of data from Woods & Poole (2014) suggested that most (81.6%) of Virginia's employment growth from 2012-2040 may be in the same four PDCs with much of the population growth: Northern Virginia (48.2%), Richmond Regional (15.3%), Hampton Roads (14.1%), and George Washington (4.0%).

In short, these population and employment growth forecasts are useful as approximate indicators of where growth is projected to occur, with the understanding that there is more uncertainty for (1) smaller rather than larger geographical units and (2) employment rather than population. For example, when forecast and actual 20-year populations were examined for a set of six metropolitan regions throughout the United States, the 20-year forecast error for population [for the region] was an average of 7.3% (Transportation Research Board, 2007). By contrast, a 20-year retrospective analysis by the National Capital Region Transportation Planning Board (2013) suggested that jurisdiction-level employment numbers might have a larger average absolute error of 25%. This forecast uncertainty makes it more difficult to determine precisely where growth will occur within a given region. That said, analysis of data from the U.S. Census Bureau (2013f) and Wilson et al. (2012) showed that for 2000-2010, the area less than 5 miles from city hall accounted for less than 10% of the region's growth for the three large Virginia metropolitan areas of Virginia Beach–Norfolk–Newport News, Washington-Arlington-Alexandria, and Richmond.

Changes in Related Factors That Influence Travel Demand

In terms of how future populations may use vehicles for passenger travel, some national sources (e.g., British Petroleum [BP], 2014) suggested that vehicle ownership will not increase further but will remain flat. A review of related literature (e.g., Litman, 2014; Chatman and Klein, 2013) suggested that factors that could lead to decreased per capita ownership levels include uncertainty about employment, higher parking costs, concern about emissions, substitution of electronic communications for some trips, delayed driver's licensing, increase in people living in urban rather than rural areas, and the fact that some groups of immigrants use vehicles to a lesser degree than U.S.-born residents even after socioeconomic differences are accounted for. Nationally, relative to the 2007 peak vehicle miles traveled (VMT), Dutzik and Baxandall (2013) suggested three possibilities for 2040 VMT: an increase of 24%, an increase of 7%, and a decrease of 19%, with the uncertainty resulting from the question of whether the reduced driving behaviors of the millennial generation will abate, continue but only for that group, or extend to all age groups. (It should be noted that these percentages refer to total VMT rather than per capita VMT.)

Virginia data since 1990 appear to indicate some modest, and sometimes divergent, shifts in measures of vehicle use (American Association of State Highway and Transportation Officials [AASHTO], 2003; Federal Highway Administration, 2012; U.S. Census Bureau, 2000, 2011a, 2013a, b). For example, the percentage of Virginians age 15 and over with a driver's license dropped from 89% (1990) to 83% (2012), with more substantive decreases in the younger age groups. Vehicle ownership rates did not decline, although their rate of growth slowed, with an estimate of registered vehicles per person for year 2012 (0.845) being similar to that for year 2000 (0.842). The percentage of zero-vehicle households in Virginia decreased from 8.8% (1990) to 6.3% (2012). Evidence of changes in mode use is perhaps strongest in commuting data from the Northern Virginia PDC, where the authors of this report estimated an increase in public transportation mode share from 2000-2012 of 8.3% to 10.3%—about 2 percentage points. (Rather than a precise number, the estimate is a range because of some uncertainty regarding the mode share of taxis, as discussed in the body of the report.)

Another factor that may influence passenger VMT is how Virginia grows in terms of land development. Virginia-specific data as of 2014 show a negative correlation of -0.67 between vehicles available per capita and density. For example, the Virginia jurisdictions with a population under 250/square mile in 2012, such as Augusta and Hanover counties, had an average of 0.79 vehicles available per capita, whereas the jurisdictions with a population of 2,000-4,000/square mile, such as Newport News and Richmond, had 0.64 vehicles available per capita. At the national level, AASHTO (2013) reported that for commuters, the drive-alone mode share was 72% for households with one vehicle available and exceeded 80% for households with two vehicles available; in fact, the number of vehicles available is a key factor that explains commuting mode share (see Figure ES4). For example, 80% of people with a high household income ($60,000-$120,000) drive alone compared to 65% of people with a low household income (under $10,000). The difference (80% − 65% = 15%) is shown in Figure ES4.

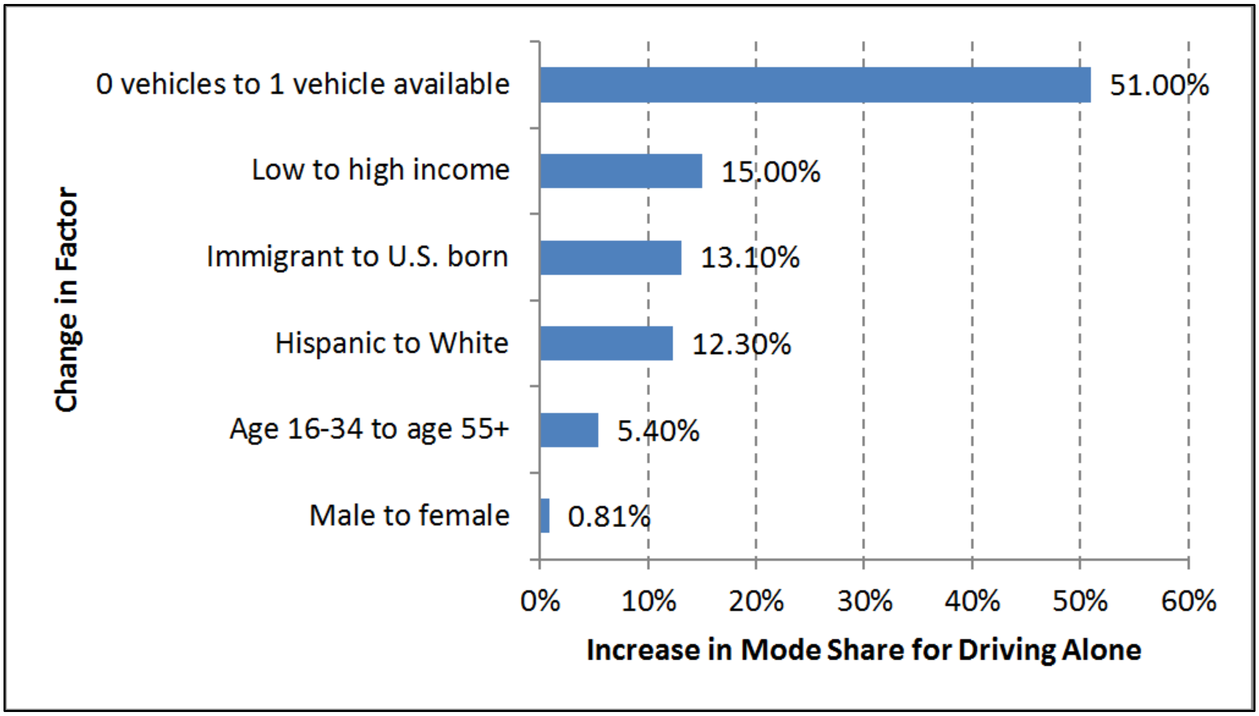

Figure ES4. Influence of Factors on Mode Share for Driving Alone in the United States. Data from AASHTO (2013). For example, AASHTO (2013) reported that 73.3% of persons "Ages 16-34" drove alone compared to 78.7% of persons "Ages 55+"; accordingly, the difference (5.40%) is reported in Figure ES4.

To be clear, this discussion of passenger travel omits a substantial contributor to VMT: freight movements. For example, at the national level, a decrease in freight travel explained almost one-half (43%) of the decline in total VMT since 2007 (Polzin and Chu, 2014), and looking to 2040, the U.S. Energy Information Administration (U.S. EIA) (2014) forecast that freight may account for one-third of energy consumed in the transportation sector. As might be expected, both passenger and freight travel are sensitive to forecast costs. One range of forecast gasoline prices for 2040 is $5.71 to $9.41 per gallon in 2012 dollars (Booz Allen Hamilton, 2014; Bureau of Labor Statistics, 2014); another range is $2.61 to $5.04 per gallon (U.S. EIA, 2014), the latter based on assumptions about economic growth in the Middle East and China and Canadian production costs for bitumen. That said, the use of alternative fuels is expected to grow: the U.S. EIA forecast that one-third of all vehicles sold in 2040 will be "micro hybrid" vehicles (hereinafter hybrid vehicles) in that they can use gasoline or diesel but not at idle. Other types of electric vehicles, such as plug-in hybrid vehicles, are expected to account for 7% of new light duty vehicle sales; vehicles that can be fueled by a blend of gasoline and up to 85% ethanol (E85) (also known as flex-fuel) are expected to account for 11% of light duty vehicle sales. The demand for alternative fuels is driven by several logistical factors. For example, TIAX LLC (Undated), in a report for the America's Natural Gas Alliance pointed out that the fact that liquefied natural gas (LNG) has a lower energy content (i.e., amount of energy per unit volume) than diesel fuel indicates that a gallon of LNG has only about 57% of the energy content of a gallon of diesel; thus for heavy vehicles, almost twice the density of fueling stations or additional fuel storage capabilities on existing trucks would be needed. That said, the U.S. EIA (2014) forecast that compressed natural gas (CNG) and LNG together will account for 3% of the British thermal units (BTUs) consumed in the transportation sector—a 20-fold increase relative to the most recent data available as of 2014.

A Reason for Being Interested in VMT Changes

One reason to quantify changes in VMT is to evaluate the societal costs of various alternatives, such as differing transportation investments. *Societal costs* refer to costs not borne by the motorist. Examples include environmental impacts (e.g., air pollution, greenhouse gases, noise, and water pollution); effects on other motorists (e.g., congestion and crashes); ancillary transportation services (e.g., retiming of traffic signals or other traffic control); and opportunity costs (e.g., the land that is used for transportation is land that does not generate economic value through other means). These costs are dependent on assumptions, and Litman (2009) suggested that such aggregate societal costs may range from $0.27 to $0.55 per VMT (see Figure ES5).

To be clear, a variety of policies influence VMT, and one related to Figure ES5 is detailed in Appendix D: the location of future population growth. Generally, higher density is associated with lower VMT and more transit use, with the understanding that the strength of this association varies by location. For example, some literature suggests that VMT reductions may be greater if the density of a higher density location is increased than if the density of a lower density location is increased. As an illustration, for a sample county in Virginia, Appendix D demonstrates how the societal costs of VMT associated with expected growth could be reduced by as much as 28% from the baseline scenario by altering where within the sample county the growth occurs. This reduction in VMT results in a reduction in annual societal costs of approximately $400 million.

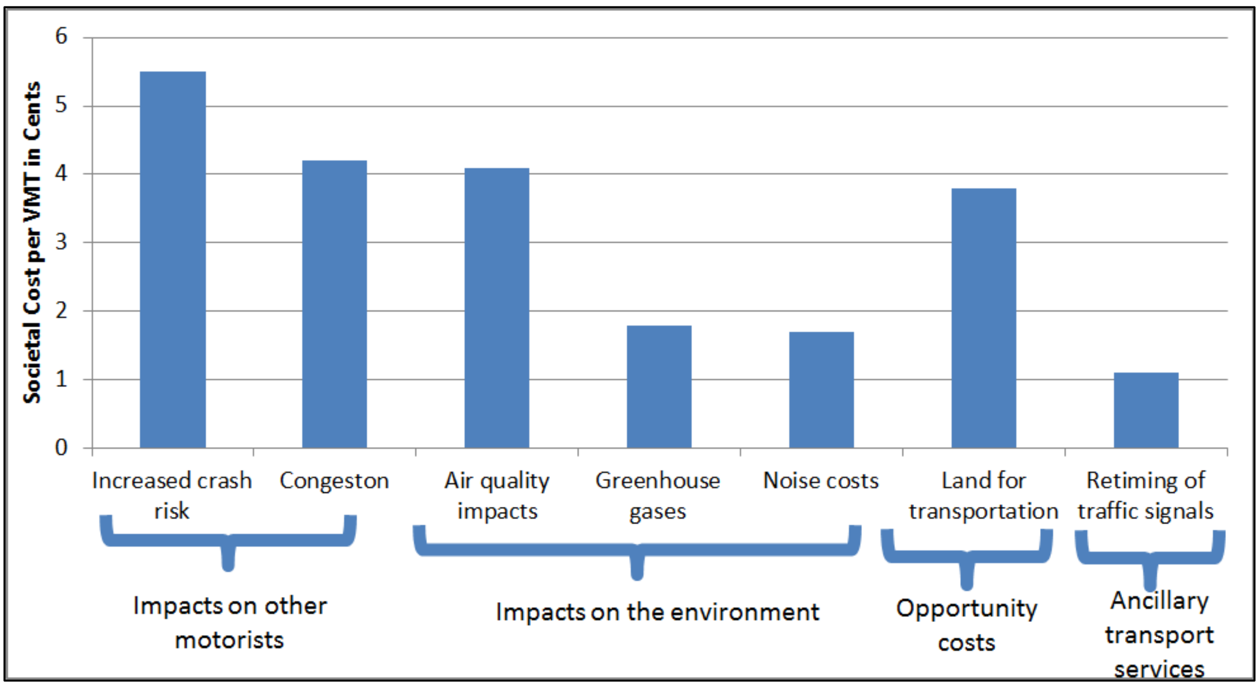

Figure ES5. Subset of Societal Costs for Travel by an "Average" Vehicle Identified by Litman (2009). Costs are in cents per vehicle miles traveled (VMT). (Litman [2009] identified other societal costs (e.g., costs to society not borne by the vehicle driver) that are not shown in Figure ES5; hence, the figure notes only a subset of those costs. Assumptions for this "Average" vehicle as noted by Litman include an average fuel efficiency of 21 mpg and an average occupancy of 1.5 persons per vehicle.)

SUMMARY OF FINDINGS

- More than one-third of Virginia's population growth (2014-2040) is forecast to be people age 65+, with the number of people age 85+ expected to increase by two thirds.

- Four of Virginia's 21 PDCs account for more than three-fourths of the state's projected population growth (2014-2040). The same 4 PDCs (Northern Virginia, Hampton Roads, Richmond Regional, and George Washington) are expected to account for four-fifths of the growth in employment.

- About one-half of the population growth is expected to be in transit-compatible areas, that is, areas where some form of public transportation appears feasible.

- For the previous decade (2000-2010), the area less than 5 miles from city hall accounts for less than 10% of the region's growth for the three large metropolitan areas in Virginia (Northern Virginia, Hampton Roads, and Richmond.)

- Uncertainty is present in any forecast; for example, state population forecasts from two sources varied by about 14%. Generally, there is less uncertainty for trend-based forecasts (such as births and deaths) and more uncertainty for behavioral forecasts (such as employment and carsharing).

- Migration and immigration are expected to influence population growth in the future; in the past, they accounted for more than one-half of Virginia's growth (2000-2010).

- Both the percentage of zero-vehicle households (6.3% in 2012) and the percentage of Virginians with a driver's license (87.3% in 2012) have dropped since 1990, but a consensus view is that vehicle ownership per capita is unlikely to increase in the United States.

- Fuel prices in the United States are forecast to range from $3.11 to $6.23 per gallon in 2012 dollars, and other ranges are possible.

- One reason to forecast location growth is to understand impacts on VMT and, by extension, the demand for other modes of transportation. For example, some literature (e.g., Meyer and Miller, 2013) suggests that jurisdictions with a population density of 500-2,000/square mile (e.g., Henrico County) tended to have 11.6% fewer VMT than jurisdictions with a population density less than 500/square mile (e.g., Page County).

- Another reason for quantifying changes in VMT is to evaluate the societal costs of alternatives, such as alternative transportation investments and alternative land development patterns. For example, some literature (e.g., Litman, 2009) suggests that aggregate societal costs (e.g., health impacts, transportation costs, environmental impacts, and so forth) may range from $0.27 to $0.55 per VMT.

- Passenger demand is not the only determinant of VMT. For example, some literature suggests that the decrease in freight explains almost one-half (43%) of the national decline in

VMT since 2007 (Polzin and Chu, 2014) and that freight in 2040 may account for about one-third of BTUs consumed in the United States (U.S. EIA, 2014).

FINAL REPORT

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INTRODUCTION

Virginia is growing. The population of 91% of Virginia's 133 jurisdictions is forecast to grow by 2040. However, the extent to which Virginia will change—in terms of both overall age and where people will live—is not projected to be uniform throughout Virginia. These changes—in terms of where growth occurs and the age of people living there—have potential implications for long-term multimodal planning.

As an example, one planning-related implication for how population grows is that there is a relationship between density and type of transportation desired: higher density locations may see more transit use and less driving than lower density locations. This relationship varies by location, because factors other than density—land use mix, urban design, and quality of transport services—influence mode share. A synthesis of previous studies (Litman and Steele, 2013) suggested that a doubling of density may yield a reduction in vehicle miles traveled (VMT) of 4% to 12%, as the strength of the relationship between density and VMT varies. For example, the Transportation Research Board (TRB) (2009) reported that doubling density may reduce VMT by 5% to 12% but noted that a reduction of as high as 25% may be achieved if other measures, such as better public transportation and a mix of land uses, are implemented. Changes in VMT, in turn, influence outcomes such as crash risk, congestion, air quality, and water quality; Litman (2009) suggested that such societal costs may approach 27 cents/mile in rural areas and double that number in urban areas.

This report examines how the location and age of Virginia's population may change between 2014 (with the most recent population data being year 2012) and 2040. The analysis first examines changes in the proportion of people age 19 and under (described as "youth"); age 20-64 (described as "adult"); and age 65 and over (65+) (described as "senior") in Virginia's 133 jurisdictions at both the statewide and regional level, including highlights from some of the jurisdictions that are expected to see larger changes. The report examines the extent to which, in various jurisdictions, the number of people who were age 20-34 in 2012 (i.e., born between 1978 and 1992 inclusive and often described as the "millennial" generation, or millennials) is forecast to change by year 2040, when they will be roughly age 45-59. (As discussed later in the report, the forecast data are available in 5-year increments, which is the reason "roughly" is used.) The report also considers the role of migration from other states, immigration from abroad, and uncertainty, which includes these forecasts. The report then identifies factors related to population growth that influence travel demand; examples are trends in vehicle ownership and licensing, divergent forecasts of vehicle ownership in 2040, and the potential role of carsharing. The appendices address six related topics: alternative population forecasts (Appendix A); employment and income forecasts (Appendix B); data details for defining population (Appendix C); potential stakeholder input exercises (Appendix D); alternative fuels forecasts (Appendix E); and a presentation of select forecasts to stakeholders (Appendix F).

PURPOSE AND SCOPE

The purpose of this report is to answer three questions:

1. What population and employment growth is forecast for 2040?

2. What other changes in terms of factors that relate to population and that also influence travel demand are expected by 2040?

3. How can changes in population growth, or related factors, be linked to travel demand and a societal outcome?

The scope of these three questions was established by stakeholders who participated in the development of VTrans2040, Virginia's 2040 statewide multimodal transportation plan, during the first 8 months of 2014. These stakeholders included (1) staff from the Office of Intermodal Planning and Investment, who requested this work; (2) participants who attended meetings where this material was presented to staff in 2014 on March 13, March 14, June 9, and July 23; and (3) attendees who participated in briefings to the Office of Intermodal Planning and Investment's Multimodal Working Group in 2014 where this work was presented. The scope of this report was also influenced by comments provided to the authors of this report through other means, such as questions raised when this material was presented at the annual meeting of the Virginia Chapter of the American Planning Association on July 21 and comments transmitted by stakeholders to the Office of Intermodal Planning and Investment or directly to the authors.

Except for information relating to public transportation, the scope is limited to data and information that were available at the time the draft report was developed, which was September 2014. (Information related to public transportation was gathered from September 2014 to March 2015.) As a result of an executive review held on December 9, 2015, some clarification was added regarding the composition of the Office of Intermodal Planning and Investment's Multimodal Working Group and how this material had been presented to Virginia stakeholders.

METHODS

Four steps were carried out to answer the questions in the "Purpose and Scope" section:

1. Obtain original data sets.
2. Review transportation literature.
3. Combine data and literature findings as appropriate.
4. Provide context as requested by stakeholders.

Obtain Original Data Sets

Over the course of the report's development, stakeholders asked questions such as the following: How has commuting mode share changed in Northern Virginia over the past two decades? What income levels are forecast for Virginia PDCs in 2040? What kind of confidence can we have in population or employment forecasts? What proportion of seniors constitutes "youthful seniors" (i.e., age 65-74) as opposed to "mature seniors" (i.e., age 85 and over [85+])? These types of questions were answered through analysis of original data sets, such as commuting data (e.g., American Association of State Highway and Transportation Officials [AASHTO], 2003); income data from proprietary sources (one such source being Woods & Poole Economics, Inc. [hereinafter Woods & Poole], 2014); publicly available population data (e.g., Weldon Cooper Center for Public Service [hereinafter Weldon Cooper], 2012a); and geographical data (e.g., U.S. Census Bureau, 2013f). Hence, the analysis of these data sets was the responsibility of the authors of this report.

(Unlike the data in AASHTO [2003] and Weldon Cooper [2012a], which are directly accessible from the web, the data from Woods & Poole [2014] come in the form of a CD with various files on the CD; the title given in the reference list is the title used for a file on the CD, which, in the judgment of the authors and this report, is the master file and is appropriate for providing a citation. Individuals who wish to obtain these data can purchase them from Woods & Poole.)

Review Transportation Literature

Stakeholders also posed questions that could be addressed with the findings of specific literature in different transportation topics. For example, one question concerned characteristics that distinguish commuters using a single-occupant vehicle (SOV) from commuters who tend to use other modes; another question concerned the extent to which mode choice for the commute mode was differentiated from mode choice for other trip purposes. The former question is covered at a national level by the report *Commuting in America* (AASHTO, 2013), and the latter question is examined for the Northern Virginia area by Humeida et al. (2012), who identified differences between mode shares for different types of trips. Multiple sources of literature were reviewed; examples of transportation topics included forecasts of potential fuel prices (e.g., U.S. Energy Information Administration [EIA], 2014; Booz Allen Hamilton, 2014; Erdogan et al., 2013) and factors that might explain how VMT has changed in the past or may change in the future (e.g., Dutzik and Baxandall, 2013; Polzin and Chu, 2014).

Combine Data and Literature Findings As Appropriate

In several cases, data from both sets of sources were combined. For example, one comment from staff of the Office of Intermodal Planning and Investment was that projected changes in population should be verified to the extent possible, with one suggestion being to examine recent changes, such as the growth of urban locations. Transportation-related literature that addressed growth in urban areas at the national level was examined (Cox, 2012, 2014). Then, to identify how Virginia's 11 metropolitan areas had grown over the past decade, more detailed Census location data (which show growth in 1-mile increments relative to the central business district [CBD]) were obtained (U.S. Census Bureau, 2013f; Wilson et al., 2012).

Provide Context As Requested by Stakeholders

In some cases, stakeholders asked that additional details relating to the three questions posed be examined. For example, although stakeholders were interested in how population density might increase, they also wanted to know how accurate previous population forecasts had been so that they had some estimate of the uncertainty, or error, that could be expected with a given population forecast. Accordingly, additional details were obtained using the methods in the aforementioned Steps 1, 2, and 3 to provide this context. Specific topics provided by stakeholders within the context of the answer to each of the three questions are as follows:

- *For Question 1,* stakeholders wanted to know the location and age of Virginia's population growth, how migration (from other states) and immigration (from abroad) might affect that growth, employment growth, and the extent to which this growth might occur in areas where public transportation is generally feasible; and the uncertainty associated with population and employment forecasts.

- *For Question 2,* topics identified by stakeholders included historical trends in vehicle ownership and driver's licensure rates; forecasts of vehicle ownership; forecasts of VMT; changes in carsharing, factors that differentiate users of SOVs from those who select other modes; income forecasts; and forecasts of fuel usage and prices.

- *For Question 3,* stakeholders wanted an example that showed (1) how a change in population or a related factor could influence travel demand, and (2) how this computed change in travel could be related to some other more general outcome in addition to travel, such as societal costs of increased VMT based on air quality, crashes, and other externalities.

Thus, the impact of Task 4 of the methods was that although an initial scope was established at the outset of the study, this scope was modified as the study progressed. For example, after seeing a presentation showing projected population growth to 2040 for people age 65+, one stakeholder asked how growth rates vary within this age group, which thus expanded the scope of Question 1. As another example, stakeholders asked that the population forecasts be compared with recent trends. (An example of such a trend was later identified: growth near urban locations such as city hall versus growth near less urban locations farther from city hall.) As a final example, after seeing that densities in some locations could increase by 2040, stakeholders asked the extent to which the increase could make public transportation more feasible, which expanded the scope of Question 3. Following dissemination of a draft report to the Office of Intermodal Planning and Investment's Multimodal Working Group in September 2014, information on public transportation was added to the report.

RESULTS

Five sets of results are presented:

1. the uncertainty of forecasts
2. population growth by location type and age group
3. millennials' location choices and potential impacts on VMT
4. role of immigration
5. vehicle ownership and related factors.

The Uncertainty of Forecasts

As is the case with any projection, there is some uncertainty with forecasts. In general, one may have greater confidence in projections that are for a larger geographical region. For example, in 1980, forecasts of the year 2000 population were generated for a region in central Virginia. At the regional level, the forecast 2000 population and actual 2000 population differed by only 10%. For individual transportation analysis zones (about the size of a census tract), however, the average percent error for each was 39% (McCray et al., 2008). McCray et al. (2008) noted a similar relationship for other variables; for example, whereas the total employment was off by only 12% for the entire region, the average employment error was 136% for individual zones (comparable to census tracts).

In general, one may have more confidence in statewide population projections and less confidence in individual jurisdiction population projections. For example, two forecasts of Virginia's population for year 2030, even though they were made 8 years apart, differed by only 2%: the U.S. Census Bureau (2005) forecast a Virginia 2030 population of 9.83 million, whereas Weldon Cooper (2012a) forecast a Virginia 2030 population of 9.65 million. By contrast, for two forecasts for the jurisdiction of Arlington for year 2040, one forecast a drop of almost 24,000 (a 10.8% decrease) whereas the other forecast an increase of 22% (Sullivan, 2013). In fact, Weldon Cooper (2012b) reported an average error of 36% when comparing projected and actual county populations over a 30-year period (their model is believed to have an average error of 24% for that period, as discussed in Appendix C).

In explaining why forecasts generated by a locality and a state may differ, Cai (2014) explained that whereas Weldon Cooper's 2040 projections for Virginia's jurisdictions were based on past decennial population trends, individual localities may consider a variety of other factors: employment, housing, zoning, and water or sewer availability. In recognition that the local forecast may be just as valid as the statewide forecast (Cai, 2014), Appendix A shows both the statewide forecast and the local forecast where both were available, as well as forecasts from Woods & Poole (2014). For example, Figure 1 shows two forecasts for select jurisdictions in the Northern Virginia Regional Commission (hereinafter Northern Virginia PDC); the local forecasts were obtained from the Metropolitan Washington Council of Governments (MWCOG) (2013). Similar comparisons based on data from other PDCs (e.g., Richmond Regional Planning District Commission, 2012), which were extended to 2040 by the authors of this report, are shown in Appendix A.

The passage of time also influences forecasts. For example, Woods & Poole (2014) and Weldon Cooper (2012d) reported the expected accuracy of county-level forecasts over time; the former reported the accuracy of 1-, 5-, and 10-year forecasts, and the latter reported the accuracy of 20- and 30-year forecasts. These results are shown in Figure 2 and show that at the county level, a forecast for year 2040 might have an error of approximately 24%.

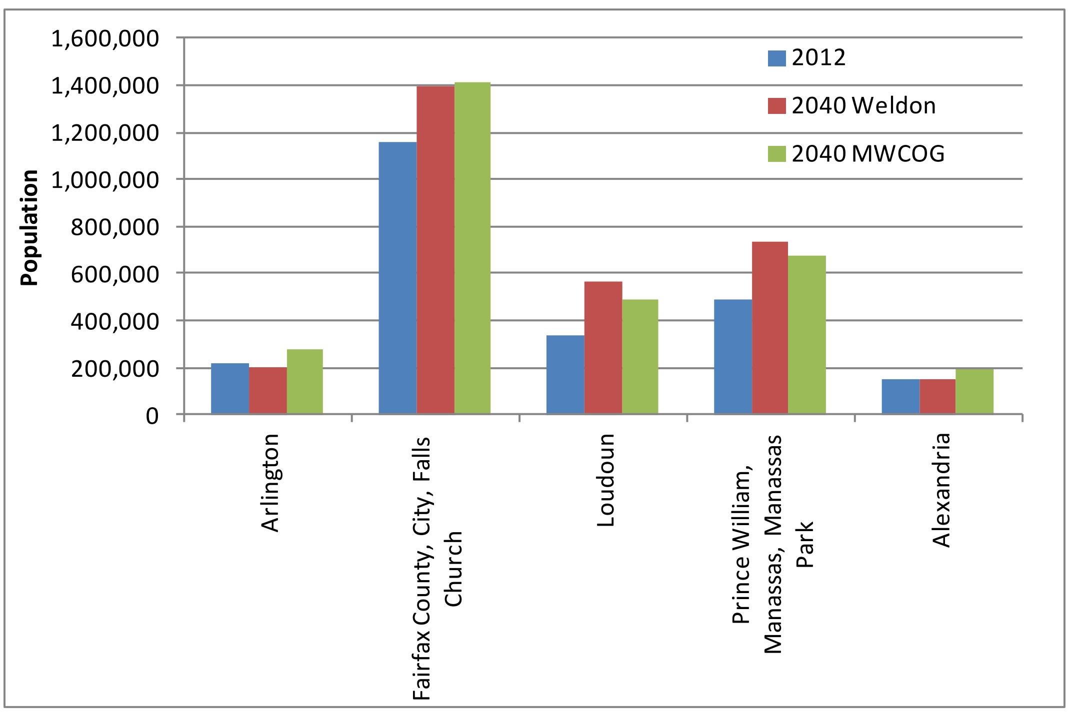

Figure 1. Forecasts of Population Growth: 2012-2040. 2012 = Weldon Cooper (2012c); 2040 Weldon = Weldon Cooper (2012a); 2040 MWCOG = MWCOG (2013); City = Fairfax City.

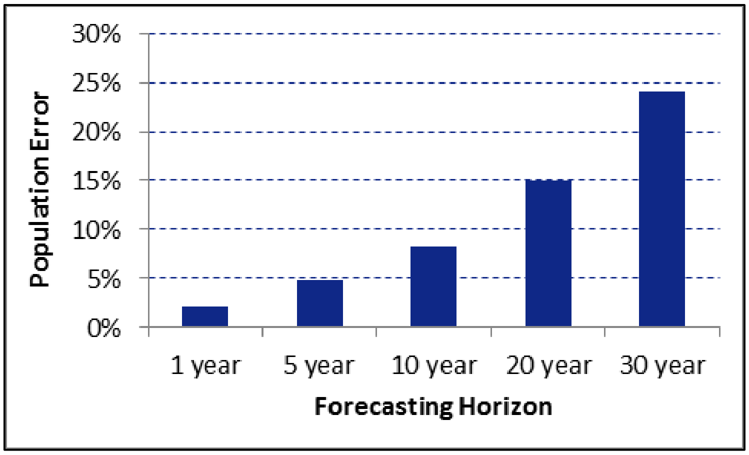

Figure 2. Expected County-Level Population Forecast Error for Virginia. Data for 1-, 5-, and 10-year are from Woods & Poole (2014) and should be applicable to all counties, including those located in Virginia. Data for 20- and 30-year are from Weldon Cooper (2012d) and are specific to Virginia.

Forecast uncertainty is not unique to Virginia. In a study of retrospective forecast accuracy by the National Capital Region Transportation Planning Board (2013), a 20-year population forecast for the region had an error of about 8% (i.e., a forecast total of 4.6 million versus the realized total of 5 million). Manual calculations by the authors of this report based on a graphic provided in the 2013 report suggest that total regional employment had an error of about 12% over the 20-year period whereas individual jurisdictions had an average absolute employment error of about 25%. For example, total regional employment was forecast to be 3.46 million but was actually 3.095 million—an error of about 12%. By contrast, employment for a given jurisdiction—Loudoun County—was forecast to be 95,000 but was actually 144,000, for an error of about 34%.

Forecast uncertainty is not restricted to demographic forecasts—it also applies to behaviors. For example, historical data (Federal Highway Administration [FHWA], 2012; U.S. Census Bureau, 2000, 2011a) indicated that the percentage of Virginians age 15-24 with a driver's license decreased from 72% to 58% over a 20-year period (1990-2010) whereas the percentage of females age 65+ with a driver's license increased (58% to 76%). However, forecasting future shifts is more difficult: Dutzik and Baxandall (2013) found that millennials drove less in 2009 than in 2001 but noted that it was not clear if this represented a long-term preferential trend or was attributable to economic changes. In short, there may or may not be a relationship between generations and modal preferences. In an article in *Forbes*, Muller (2013) pointed out that even as new technologies, such as advanced heads up displays in vehicles, become available it can be difficult to forecast the extent to which prospective consumers will purchase them, especially before costs are known.

Population Growth by Location Type and Age Group

Of the socioeconomic factors discussed herein, arguably the most critical is population change, as population ultimately influences travel demand. This section discusses seven population-related topics:

1. overview of how Virginia's population may change
2. definition of geographic location types
3. growth in Hampton Roads, Northern Virginia, and Richmond CBSAs
4. growth in senior population: age 65+
5. potential implications of population aging for multimodal transportation planning
6. growth in youth population: age 19 and under
7. growth in transit-compatible areas,

Overview of How Virginia's Population May Change

This report discusses Virginia jurisdictions and PDCs. When *jurisdictions* are discussed, the "city" or "county" designation is dropped except for the eight jurisdictions in which a county and a city have the same name: Roanoke City, Roanoke County, Fairfax City, Fairfax County, Franklin City, Franklin County, Richmond City, and Richmond County. Because there is a U.S. Census region that is also named Richmond, the term "Richmond Region" is used when this Census location is discussed in order to avoid confusion with Richmond City, Richmond County, and Richmond Regional PDC.

The boundaries of the PDCs in Figure 3 were modified slightly by the authors of this report such that each jurisdiction was in exactly one PDC. (There was judgment required in setting the modified PDC boundaries shown in Figure 3. For example, Franklin County, which is a member of both the Roanoke Valley-Alleghany Regional Commission and the West Piedmont PDC, was placed in the former PDC because of Census boundaries, as discussed in Figure C3 in Appendix C.)

Projections from Weldon Cooper (2012a) suggested that Virginia's population will grow by more than one fourth from 2012-2040. (U.S. Census Bureau data, which were current at the time this work was conducted, were available from Weldon Cooper [2012c].)

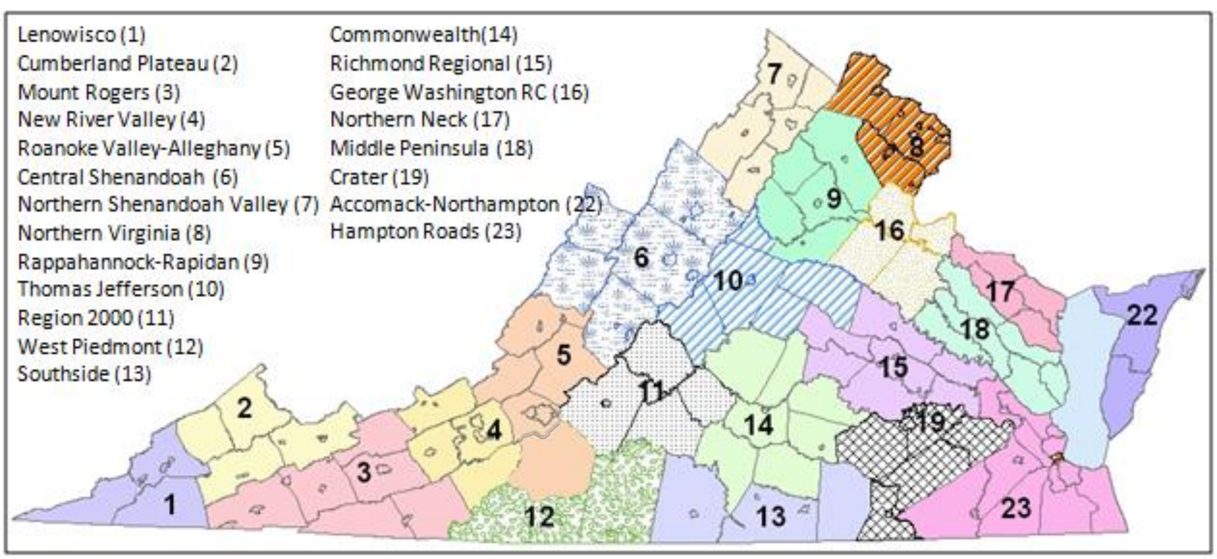

Figure 3. Virginia's PDCs. The identifying number of each PDC is in parentheses. The boundaries were slightly modified by the authors of this report such that each jurisdiction was in exactly one PDC.

In 2012, Virginia's population was 8.2 million, and in 2040 it is projected to be 10.5 million—an increase of 2.3 million or 28%. However, the increase of 2.3 million will likely not be evenly spread throughout Virginia. Rather, approximately 77% of the growth is expected to occur in four of Virginia's larger PDCs: Northern Virginia, Richmond Regional, George Washington, and Hampton Roads (see Figure 4). This percentage climbs to 85% if the Northern Shenandoah Valley Regional Commission and the Thomas Jefferson PDC are added to the list such that, as shown in Figure 4, these six PDCs account for 2 million of the 2.3 million. Figure 4 also shows the relative growth of each PDC. For example, from 2012-2040, George Washington is expected to double (115%) and Northern Shenandoah is forecast to grow by more than one third (42%). Figure 4 also shows that based on forecasts by Weldon Cooper (2012a), Virginia is projected to grow by 2.34 million. Three PDCs (Northern Virginia PDC, Richmond Regional, and George Washington) account for most (about 1.55 million) of the growth. Over the same period, the Northern Virginia PDC is expected to grow by about 29%, and Richmond Regional is expected to grow by about 46%.

Growth should also vary by age group. Whereas in year 2012, people age 65+ accounted for approximately 13% of the state's population, by year 2040 they may account for approximately 18%—an increase of more than 840,000. Although the number of youth is forecast to grow from 2012-2040, they are expected to represent a relatively constant share of Virginia's population: in 2012 they accounted for 25.50% of the population and in 2040 they are forecast to account for 25.24%. The remaining group of people—those age 20-64—is projected to represent 56.7% of the 2040 population, down from 61.5% in 2012. In short, Table 1 indicates that age 65+ may be the fastest growing age group.

Table 1. Projected Virginia Population Growth: 2012-2040

Age Group	2012 Population	2040 Population	Percent Change
Youth (Age 19 and under)	2,087,076	2,657,635	27.34 %
Adult (Age 20-64)	5,036,286	5,968,324	18.51%
Senior (Age 65+)	1,062,505	1,904,270	79.22%
Statewide	8,185,867	10,530,228	28.64%

Data source = Weldon Cooper (2012a, c).

Definition of Geographic Location Types

One question of interest is whether the population growth will tend to be in more "suburban" locations or more "urban" locations. A challenge for characterizing a given jurisdiction as urban, suburban, exurban, or rural is that such labels are relative terms. For example, although Fairfax County may be considered suburban relative to Washington, D.C., it contains more people than many Virginia cities. Appendix C describes three possible taxonomies for labeling Virginia jurisdictions; these are based on *VTrans2035* (Office of Intermodal Planning and Investment, 2010), Virginia's *Multimodal System Design Guidelines* (Virginia Department of Rail and Public Transportation, 2013), and the U.S. Census Bureau (2013d).

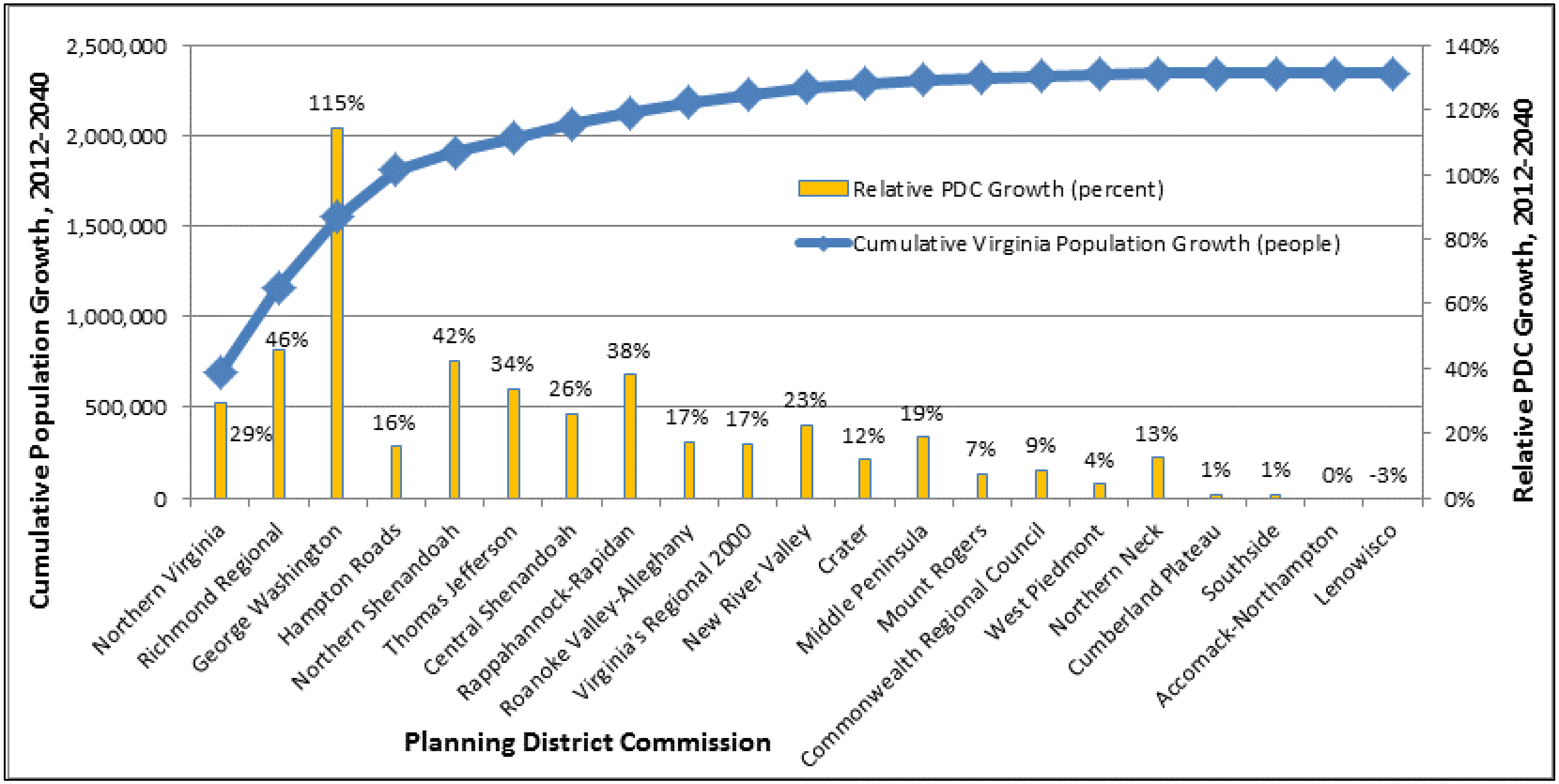

Figure 4. Forecast Cumulative and Relative Growth in Virginia PDCs: 2012-2040. Data based on Weldon Cooper (2012a, 2012c).

Comments provided in response to an initial approach (R. Case, personal communication, 2014; N. Donohue, personal communication, 2014) suggested that any land-based taxonomy (1) should avoid labels such as "suburban" that might be viewed negatively and (2) should use definitions that can be replicated by others. Three other criteria for a taxonomy are that (1) it should be based, in part, on population and/or jobs density (given the role that density plays in Virginia's *Multimodal System Design Guidelines*); (2) it should reflect geography (given the role that geography plays in all three classification systems); and (3) it should be applicable at the jurisdiction level.

As described in Appendix C, the way of categorizing Virginia jurisdictions as urban, rural, and so forth was based on that of the U.S. Census Bureau and then modified by the authors of this report to reflect Virginia conditions. The U.S. Census Bureau first classifies locations as either being part of a metropolitan or micropolitan CBSA or not being in a CBSA. Then, for a location that is within a CBSA, the location can further be classified as central or outlying. These criteria, which are more detailed than what is presented here, are given in the *Federal Register* (2010) and are based on population, population density, adjacency, and economic integration (see U.S. Census Bureau, 2013d, 2013e). For example, to be a CBSA, one criterion relating to total population is that the area must have at least 50,000 people or an urban cluster of at least 10,000 people; another criterion, relating to adjacency, is that a CBSA is based on one or more contiguous jurisdictions. For locations within a CBSA, a criterion relating to economic integration is that an outlying jurisdiction is one where at least one-fourth of its residents work in the central area of the CBSA. For a metropolitan CBSA, a jurisdiction can be classified as central if at least one-half of the jurisdiction's population is in an urban area with at least 10,000 people. An adjacent jurisdiction within the CBSA if it does not meet this centrality requirement can be classified as outlying if at least one-fourth of its residents work in the central area of the CBSA. Ultimately, criteria such as these are used to by the U.S. Census Bureau to designate each jurisdiction as either not in a CBSA or in a CBSA and if in a CBSA, as being in either a central or outlying area.

Figure 5 shows the central and outlying areas for two CBSAs: Richmond and Lynchburg. Appendix C shows a rough alignment between density and VTrans categories in which non-urban locations tend to have lower densities and more urban locations tend to have higher densities. However, Virginia's diversity means that density is not the sole descriptor of a location type—rather, as shown in Figures C4 and C5 in Appendix C, location types are best classified when they are viewed within a given CBSA.

Based on the details in Appendix C, Table 2 presents an approach for classifying locations. Although this approach is based in part on the CBSA designation, two additional considerations based on *VTrans203*5, Virginia's 2035 statewide multimodal transportation plan, are to place two Northern Virginia jurisdictions in their own category and to delineate between the larger CBSAs of Hampton Roads, Northern Virginia, and Richmond and the smaller CBSAs such as Roanoke, Charlottesville, and Bristol. Accordingly, to enable a consistent description of Virginia's jurisdictions, each jurisdiction is classified as one of six location types: (1) Alexandria/Arlington; (2) Central Hampton Roads, Northern Virginia, Richmond; (3) Outlying Hampton Roads, Northern Virginia, Richmond; (4) central small urban area; (5) outlying small urban area; and (6) non-core area. These location types are consistent with Census CBSA boundaries and differentiations made in *VTrans2035.*

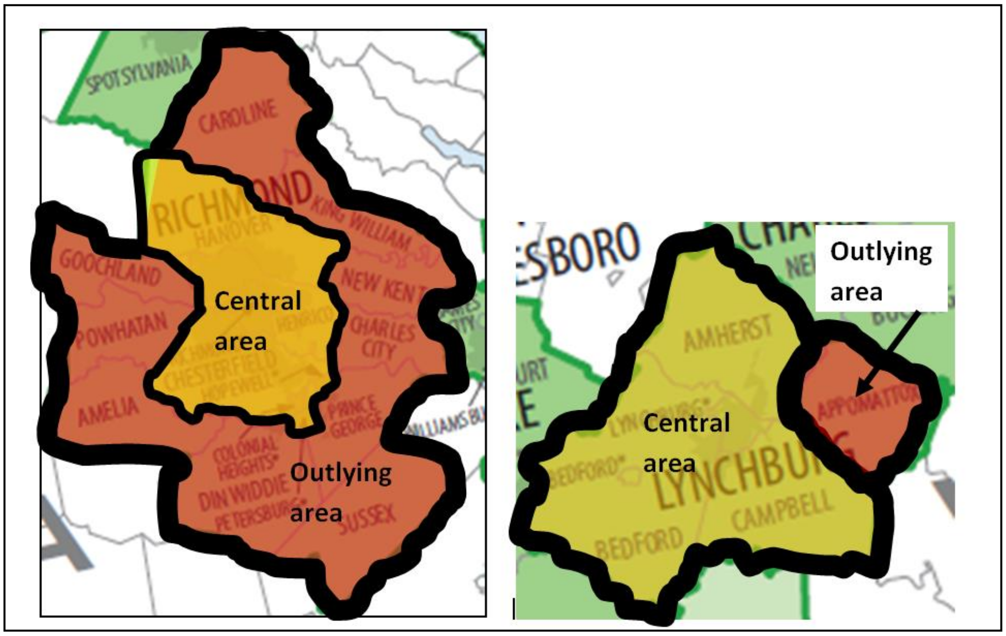

Figure 5. Two Examples of Central and Outlying Areas: Richmond CBSA (*left*) and Lynchburg CBSA (*right*). From the U.S. Census Bureau (2013g) with annotations by the authors of this report.

Table 2. Method for Classifying Jurisdictions for VTrans2040[a]

Location Type[b]	Designation	
	VTrans2040	**VTrans2035**
Alexandria or Arlington	Alexandria/Arlington	Urban core
A central area in one of three CBSAs: Washington CBSA, Virginia Beach CBSA, or Richmond CBSA. (Example: Henrico.)	Central Hampton Roads, Northern Virginia, Richmond Region	Suburban
An outlying area in one of three CBSAs: Washington CBSA, Virginia Beach CBSA, or Richmond CBSA. (Example: Caroline.)	Outlying Hampton Roads, Northern Virginia, Richmond Region	
A central area in any of the remaining CBSAs.[c] (Example: Winchester.)	Central small urban area	Small urban area
An outlying area in any of the remaining CBSAs.[c] (Example: Appomattox.)	Outlying small urban area	
Not in a CBSA. (Example: Alleghany.)	Non-core	Non-core

CBSA = Core-Based Statistical Area.
[a] This taxonomy is based on a review of *VTrans2035* (Office of Intermodal Planning and Investment, 2010), Virginia's *Multimodal System Design Guidelines* (Virginia Department of Rail and Public Transportation, 2013), and the U.S. Census Bureau (2013d).
[b] CBSA boundaries, including the boundaries for outlying and central areas, are defined by the U.S. Census Bureau and are based on population size, population density, adjacency of jurisdictions, and commuting patterns.
[c] These CBSAs are Charlottesville, Blacksburg-Christiansburg-Radford, Roanoke, Lynchburg, Big Stone Gap, Kingsport-Bristol, Danville, Harrisonburg, Martinsville, Staunton-Waynesboro, Winchester, and Bluefield.

Growth in Hampton Roads, Northern Virginia, and Richmond CBSAs

The population forecasts suggest that a nominally greater percentage of Virginians may reside in the location type of Central Hampton Roads, Northern Virginia, Richmond and the location type of Outlying Hampton Roads, Northern Virginia, Richmond than was the case as of 2012. That said, none of the six location types listed in Table 3 is expected to have a population change of more than 2 percentage points. Table 3 shows the percentage of the Virginia population that currently resides in each of the six location types and the percentage projected for 2040. For example, jurisdictions that are in Outlying Hampton Roads, Northern Virginia, Richmond, such as Amelia, Caroline, Warren, and Sussex counties, are expected to have 8.25% of Virginia's population in 2040 compared to 6.53% in 2012.

Just as growth is not distributed evenly by PDC, not all Virginia jurisdictions are expected to grow in the same manner. Spotsylvania and Stafford counties, for example, which are members of the fastest growing PDC (George Washington), are forecast to have population growth in excess of 100%. Throughout Virginia, nine additional jurisdictions are expected to have population growth of more than 50%. Table 4 shows the 10 jurisdictions with the highest absolute forecast population increases, which represent more than two-thirds (71.1%) of the state's projected population growth from 2012-2040.

Table 3. Forecast Changes in Statewide Population Distribution Among the Six Location Types

Location Type	Percentage Total Population 2012	Percentage Total Population 2040	Rate of Change (%)[a]
Alexandria/Arlington	4.49	3.29	-26.7
Central Hampton Roads, Northern Virginia, Richmond	58.66	60.66	3.4
Outlying Hampton Roads, Northern Virginia, Richmond	6.53	8.25	26.2
Central small urban area	16.65	15.98	-4.0
Outlying small urban area	4.05	3.62	-10.7
Non-core area	9.62	8.20	-14.8

[a] As an example, because the population of the location type defined as "Alexandria/Arlington" decreased from 4.49% to 3.29% of the statewide population, the rate of change was (4.49 − 3.29)/4.49 = 26.72%.

Table 4. Ten Jurisdictions With the Greatest Forecast Total Population Increases From 2012-2040

Jurisdiction	Location Type	Increase	Rate of Increase[a]
Chesterfield	Central Hampton Roads, Northern Virginia, Richmond	248,837	76.8%
Fairfax County	Central Hampton Roads, Northern Virginia, Richmond	231,643	20.7%
Loudoun	Central Hampton Roads, Northern Virginia, Richmond	230,297	68.4%
Prince William	Central Hampton Roads, Northern Virginia, Richmond	229,012	53.2%
Stafford	Central Hampton Roads, Northern Virginia, Richmond	199,302	148.3%
Spotsylvania	Outlying Hampton Roads, Northern Virginia, Richmond	173,948	138.4%
Henrico	Central Hampton Roads, Northern Virginia, Richmond	135,698	43.1%
Chesapeake	Central Hampton Roads, Northern Virginia, Richmond	90,071	39.4%
James City	Outlying Hampton Roads, Northern Virginia, Richmond	67,769	98.3%
Frederick	Central Small Urban Area	65,621	81.7%
Total		1,327,259	

[a] For example, Stafford County's 2012 population was 134,352 and its 2040 population is forecast to be 333,654. Thus, its rate of increase is (333,654 − 134,352)/134,352 = 199,302/134,352 = 148.3%.

Growth in Senior Population: Age 65+

The proportion of Virginia's senior population (age 65+) is projected to increase from 12.98% in 2012 to 18.08% by 2040 (Weldon Cooper, 2012a). The senior population is expected to increase in all jurisdictions. In two of the larger jurisdictions the increase is projected as 38,388 (Virginia Beach) and 55,322 (Prince William County). The 10 jurisdictions with the greatest absolute increase are located in two location types: Central Hampton Roads, Northern Virginia, Richmond and Outlying Hampton Roads, Northern Virginia, Richmond, as shown in Figure 6—areas that may also see increases in the population as a whole.

Of the 10 jurisdictions with the smallest absolute increase, 5 are located in non-core areas: Bath, Buena Vista, Emporia, Highland, and Lexington. Two are in central small urban areas (Norton and Radford); 1 is in Outlying Hampton Roads, Northern Virginia, Richmond (Williamsburg), 1 is in Central Hampton Roads, Northern Virginia, Richmond (Falls Church), and 1 is in Arlington/Alexandria (Arlington). Arlington had the lowest increase in the senior population: 221 people.

It is also informative to examine which counties should have the highest proportion of seniors in 2040. (In this context, the "proportion" is the number of seniors in a given locality divided by the number of seniors in Virginia as a whole.) For example, it is projected (Weldon Cooper, 2012a) that in 2040, 195,447 seniors will live in Fairfax County and 1,904,270 seniors will live in Virginia overall. Dividing Fairfax County's senior population by the state's senior population yields a proportion of 0.103, as shown in Figure 7. Thus, approximately one-tenth of all seniors in Virginia are projected to reside in Fairfax County in 2040. Eight of the 10 jurisdictions in which seniors are expected to comprise the highest proportion are located in Central Hampton Roads, Northern Virginia, Richmond. The jurisdictions shown in Figure 7 account for 798,239 seniors, which is 42% of the total Virginia senior population.

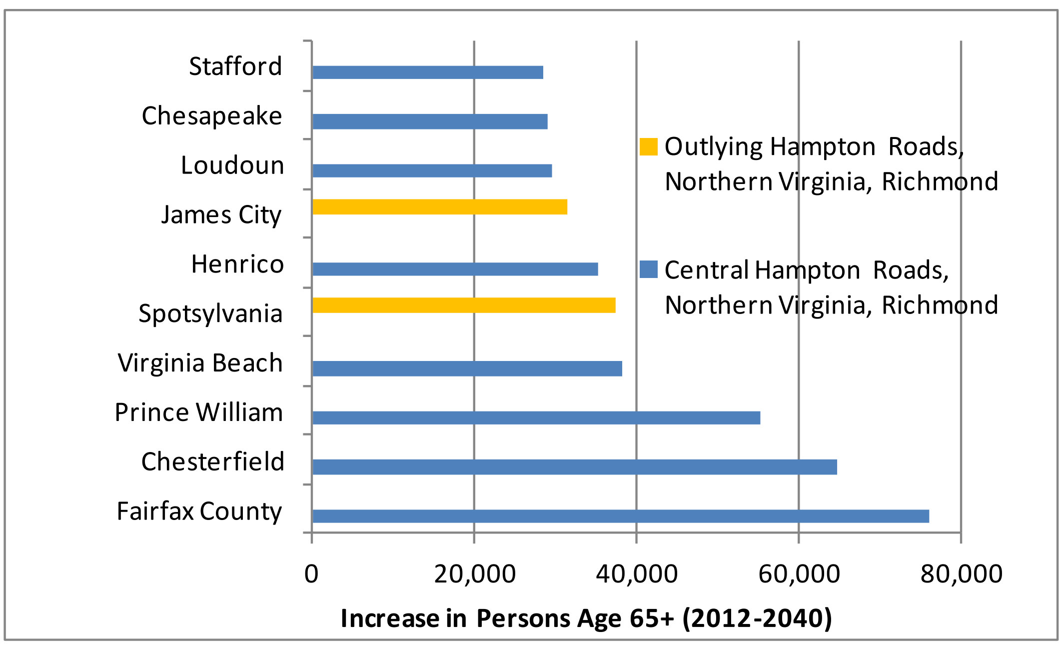

Figure 6. Ten Virginia Jurisdictions With the Largest Forecast Increase in People Age 65+: 2012-2040. Data from Weldon Cooper (2012a, c).

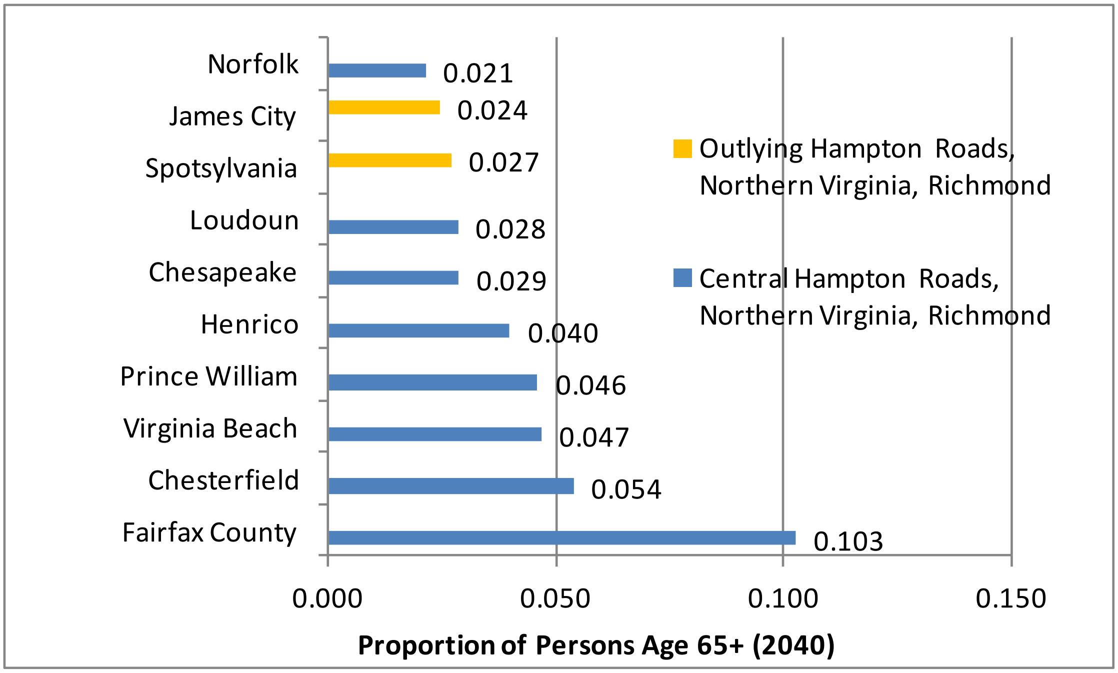

Figure 7. Ten Virginia Jurisdictions With the Largest Forecast Proportion of Seniors (age 65+) in 2040. Data from Weldon Cooper (2012a, c).

The change in the overall distribution of Virginia's senior population among location types is projected to be consistent with that of the statewide population as a whole. As with the total population, a larger proportion of the senior population is projected to live in either Central Hampton Roads, Northern Virginia, Richmond or Outlying Hampton Roads, Northern Virginia, Richmond in 2040 (62.3%) than in 2012 (56.4%). Table 5 is also consistent with Table 3 in that there is a drop in the proportion of the senior population residing in non-core areas.

Another way to consider the aging of Virginia is to examine two age groups: youth, i.e., 19 and under, and seniors, i.e., 65+. Statewide, in 2040, the ratio of people age 65+ to people age 19 and under is expected to be about 0.7, up from about 0.5 in 2012. Further, in 2040, the top one-third of jurisdictions with the highest such ratio—that is, almost double the statewide average—are located in many rural areas, as shown in Figure 8.

Table 5. Changes in Population Distribution of Seniors (Age 65+) Among Location Types: 2012-2040

Location Type[a]	**Percentage Age 65+ 2012**	**Percentage Age 65+ 2040**	**Rate of Change**
Alexandria/Arlington	3.17%	2.05%	-35.4%
Central Hampton Roads, Northern Virginia, Richmond	48.93%	52.37%	7.0%
Outlying Hampton Roads, Northern Virginia, Richmond	7.49%	9.95%	32.9%
Central small urban area	20.17%	18.46%	-8.5%
Outlying small urban area	5.81%	5.19%	-10.6%
Non-core	14.43%	11.97%	-17.0%

[a] Location types are defined in Table 2.

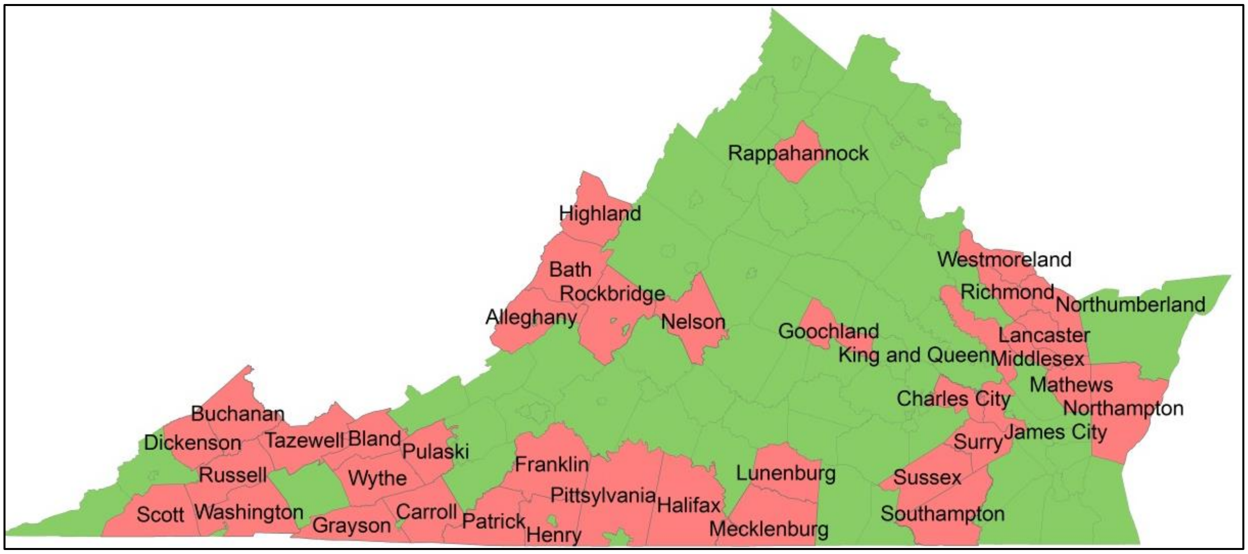

Figure 8. Virginia Counties Projected to Have the Highest Ratios of Seniors (Age 65+) to Youth (Age 19 and Under) in 2040. These counties appear in coral. Data from Weldon Cooper (2012 a).

Potential Implications of Population Aging on Multimodal Transportation Planning

The increase in seniors as a proportion of Virginia's population is relevant to future transportation because of the characteristics and needs unique to this age group. As Dutzik and Baxandall (2013) pointed out, seniors drive fewer miles than the rest of the adult population because retirement diminishes daily driving needs. Further, seniors reported a higher overall incidence of disability than the rest of the population (U.S. Census Bureau, 2012a, 2012c): approximately 10.9% of Virginians had a disability in 2008 compared with approximately 34.9% of the senior population.

In addition, the Administration on Aging (2012) reported that the rate of reported limitations in daily activities continues to increase with age after age 65. For example, in 2010, whereas 8% of "noninstitutionalized" seniors age 65-74 reported difficulty getting in and out of bed or chairs, 21% of "noninstitutionalized" seniors age 85 and over reported this limitation. The Administration on Aging indicated that these numbers were based on "surveys of the noninstitutionalized elderly" and that some, but not necessarily all, disabilities may cause individuals to need "assistance to meet important personal needs." Although the Administration on Aging did not give details on what such needs could be, it is possible that one such need could be transportation. The jurisdictions in Virginia with the greatest increases in the number and proportion of seniors show substantial overlap, with those with the greatest increases in the subpopulation age 85 and over.

It is acknowledged that mobility needs for people age 65+ are not necessarily homogenous but rather vary within this age group. For example, DeGood (2011) reported that whereas 88% of people age 65+ drive, the percentage drops to 69% when the sample is restricted to people age 75+. DeGood further reported that the percentage of respondents to a survey conducted by AARP who indicated they traveled primarily by sharing rides doubled, from 20% to 40%, as respondents moved from age 75-79 to age 85+. Thakuriah et al. (2011) reported that people age 85+ found it more difficult to use transit than seniors age 65-84 (although they found that licensure rates did *not* vary among older age groups). The Brookings Institution (2010) reported a distinction between "mature" and "youthful" elderly with the former being age 75+ and having a greater demand for social services [such as transportation]. Although Virginia's proportion of seniors is forecast to increase overall (from 13% to 18.1% of the population by 2040) and although youthful seniors (age 65-74) are expected to remain the largest component of the senior population, the projections also suggest higher rates of increase for older seniors. For example, the proportion of youthful seniors is projected to increase from 7.5% in 2012 to 8.6% in 2040. More dramatic increases are expected in the older age groups: people age 75-84 may increase from 3.8% to 6.8%, and people age 85+ may increase from 1.6% to 2.7% (see Figure 9).

Virginia's role as a "half-back" state may further influence this growth in the population age 65+. The term "halfback" or "half-back" has been used in the literature (List and Foyle, 2011), including the news media (Strauss, 2012), to describe people, usually retirees, who initially moved from the northeastern United States to southern locations (e.g., Florida) and then moved in a northern direction, but not as far north as the northeastern United States, to the mid-Atlantic states (i.e., the "Carolinas, Tennessee, Virginia and Georgia") (Strauss, 2012). Cited reasons for these middle states having appeal include moderate weather, availability of health care, and a more rural feel than other locations (List and Foyle, 2011; Strauss, 2012). The Brookings Institution (2010) reported that from 2000-2008, Virginia saw one of the largest increases in the senior population (in excess of 18%) as did other mid-Atlantic locations (e.g., Raleigh-Durham, North Carolina, saw an increase of almost 39%). The report also drew a distinction between areas that already had high concentrations of seniors (e.g., West Virginia, Pennsylvania, and Florida) and those that had seen a rapid increase in seniors (e.g., Virginia, Texas, and South Carolina), noting that the former tended to have older seniors who might require higher expenditures for social services or medical care relative to the latter, which tended to have more youthful seniors. As shown in Figure 10, retirees might move from New York (in the north) to Florida (in the South) and then then part way back to the mid-Atlantic states of Virginia, North Carolina, and South Carolina.

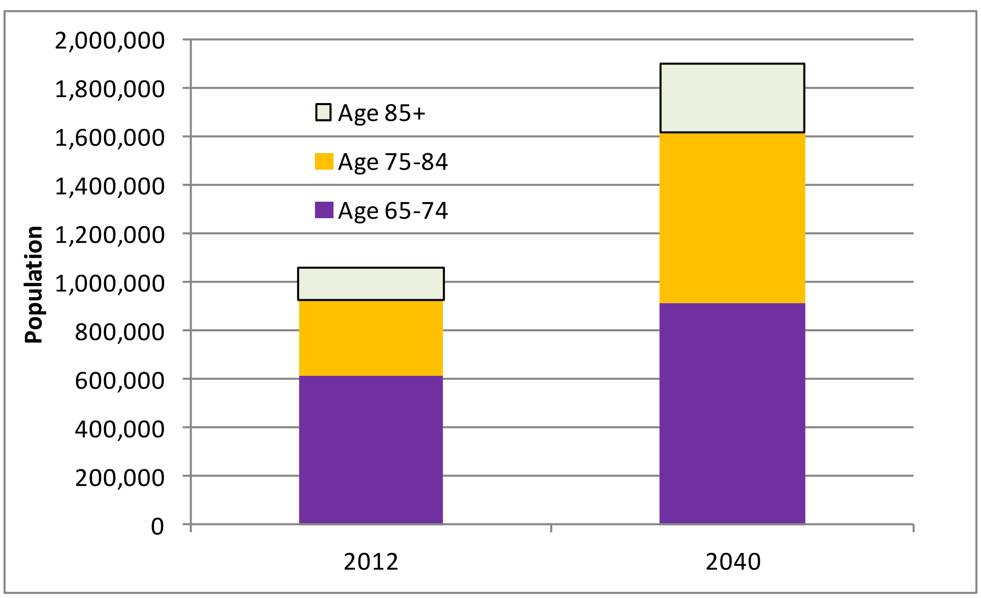

Figure 9. Projected Change in Virginia Population Age 65+ by Age Group: 2012-2040. Data from Weldon Cooper (2012a, c).

Figure 10. Map of Eastern United States (With Select Half-Back States Shaded)

It is possible, therefore, that some of this growth explains the fact that more than one-half of Virginia's growth from 2000-2010 resulted from net migration into Virginia (Virginia Department of Health, 2011). Later data from the 2012 American Community Survey (ACS) (U.S. Census Bureau, Undated b), which reflect movements only for the past year, suggest that approximately 4% of Virginia's total population (about 313,000) migrated to Virginia from other locations. Most moved from other states, but approximately 62,000 (roughly 0.8% of Virginia's population) came from other countries. As shown in Figure 11, most of the migration to Virginia from within the United States came from Virginia's border states (Kentucky, Maryland, North Carolina, Tennessee, and West Virginia, including the District of Columbia); the Northeast; and the southern states of Florida, Georgia, and South Carolina.

Growth in Youth Population: Age 19 and Under

Although the youth population (age 19 and under) is projected to represent a relatively constant percentage of Virginia's total population (see Table 1), its distribution in Virginia will likely change. From 2012-2040, the population age 19 and under is expected to increase in 93 of Virginia's 133 jurisdictions, for a total increase of 570,559. More than one-third of the increase (35%) is forecast to occur in Loudoun, Chesterfield, and Prince William counties, and 78% of the increase is expected to occur in 10 jurisdictions, as shown in Figure 12. Stafford and Spotsylvania counties are projected to more than double their youth population, commensurate with their relatively high growth rates overall. Except for the central small urban area of Frederick, the remaining 9 jurisdictions are located in Central Hampton Roads, Northern Virginia, Richmond or Outlying Hampton Roads, Northern Virginia, Richmond.

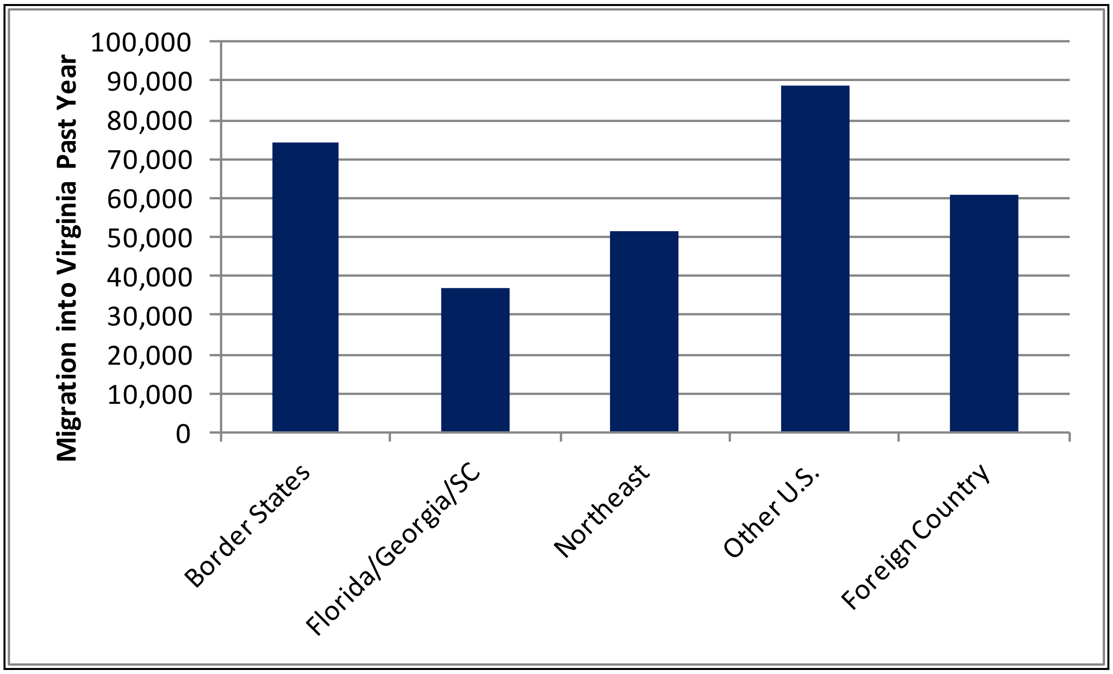

Figure 11. Migration Into Virginia Over a 1-Year Period Ending in 2012. As reported by the 2012 American Community Survey (U.S. Census Bureau, Undated b). "Border States" include the District of Columbia. (The U.S. Census Bureau [2015] explained that respondents are asked where they lived "one year ago" [in 2012]. If that location was not Virginia, then that location is shown Figure 11.)

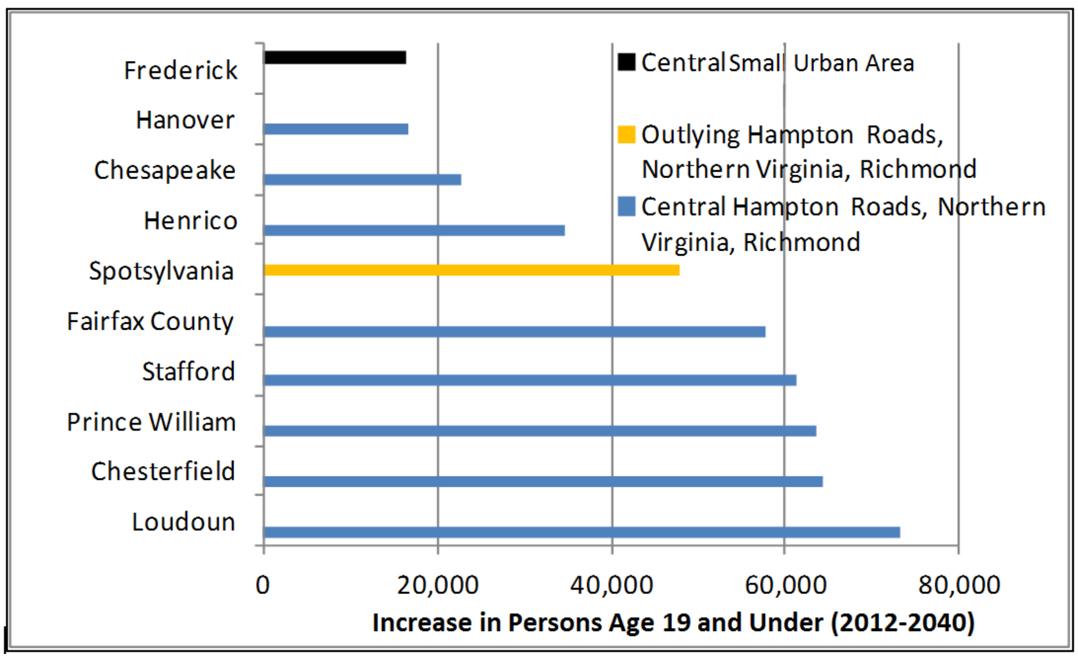

Figure 12. Ten Virginia Jurisdictions With the Largest Forecast Increase in the Youth Population: 2012-2040. Data from Weldon Cooper (2012a, c).

Overall, in 2040, more than one-half (53.9%) of the statewide youth population may be in the 10 jurisdictions shown in Figure 13, all of which are in Central Hampton Roads, Northern Virginia, Richmond or Outlying Hampton Roads, Northern Virginia, Richmond. For example, Chesterfield and Loudoun are projected to have 5.9% and 6.8%, respectively, of the statewide youth population. Even though it is forecast to lose more than 15,000 people age 19 and under, Virginia Beach is expected to have almost 4% of the statewide population of this age in 2040.

Some jurisdictions are expected to see a decrease in the youth population—for a total of more than 26,000. The 10 jurisdictions with the largest decreases are shown in Figure 14. Four of these jurisdictions are in non-core areas, although the 2 jurisdictions with the largest absolute decrease are Arlington and Virginia Beach, both of which may be considered urban locations.

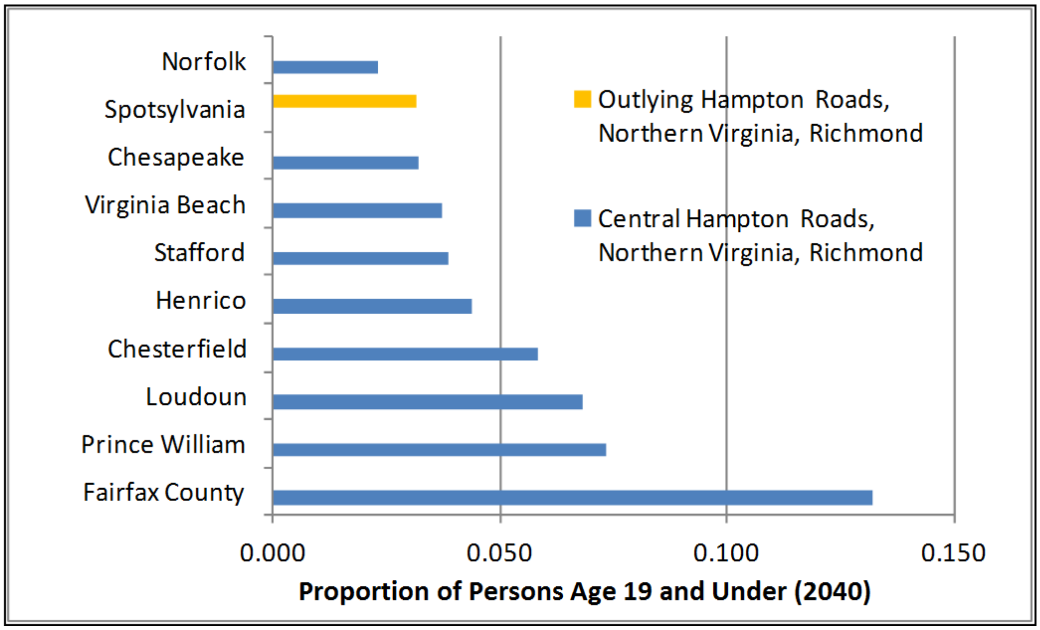

Figure 13. Ten Virginia Jurisdictions With the Largest Forecast Proportion of the Youth Population in 2040. Data from Weldon Cooper (2012a, c).

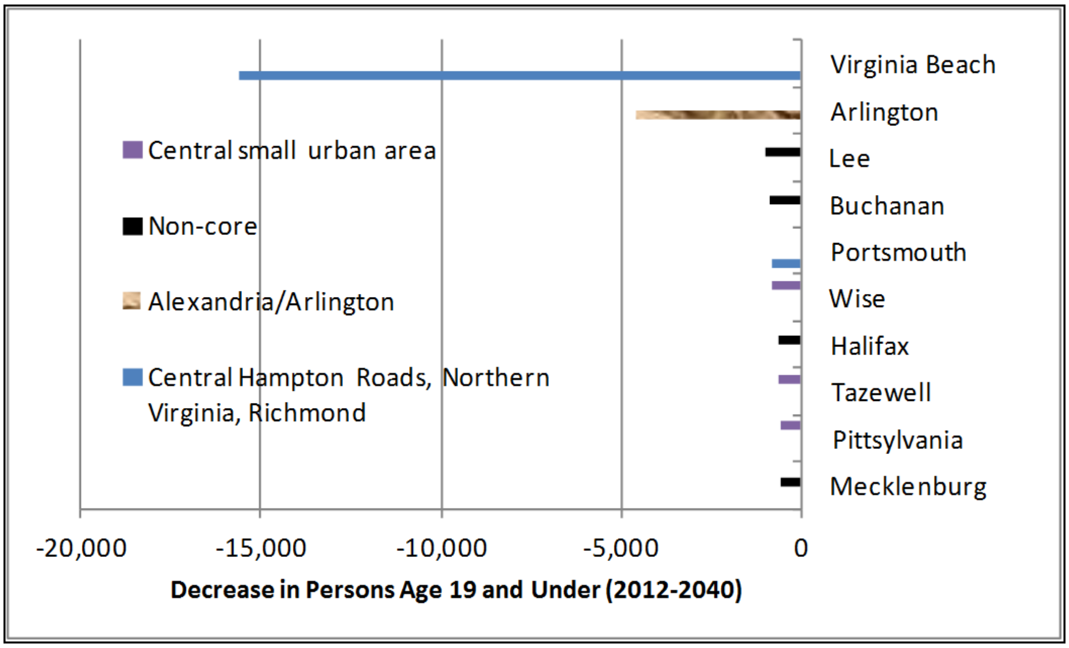

Figure 14. Ten Virginia Jurisdictions With the Largest Forecast Decrease in the Youth Population: 2012-2040. Data from Weldon Cooper (2012a, c).

Overall, the change in the overall distribution of Virginia's youth population among location types is projected to be consistent with that of the statewide population as a whole. Table 6 compares the percentage of the youth population currently living in each location type with the projected percentage of youths in each location type in 2040.

As with the total population, a larger proportion of the youth population is projected to live in either Central Hampton Roads, Northern Virginia, Richmond or Outlying Hampton Roads, Northern Virginia, Richmond in 2040 (72.7%) than in 2012 (68.9%). As with Table 3, except for the Alexandria/Arlington location type, jurisdictions in non-core areas have the largest decrease (which in the case of Table 6 is the percentage of the youth population).

Table 6. Forecast Changes in Youth Population Distribution Among Location Types: 2012-2040

Location Type [a]	Percent Age 19 and Under (2012)	Percent Age 19 and Under (2040)	Rate of Change
Alexandria/Arlington	3.20%	2.32%	-27.47%
Central Hampton Roads, Northern Virginia, Richmond	62.37%	64.71%	3.74%
Outlying Hampton Roads, Northern Virginia, Richmond	6.54%	8.01%	22.60%
Central small urban area	15.83%	15.09%	-4.71%
Outlying small urban area	3.58%	3.03%	-15.29%
Non-core	8.48%	6.84%	-19.34%

[a] Location types are defined in Table 2.

Growth in Transit-Compatible Areas

To some extent, higher population density is associated with an area being more able to provide a regular fixed-route public transportation service. If one defines this service as one being offered all day with a headway of 1 hour or less, an examination of the population densities of Virginia jurisdictions (Weldon Cooper, 2012a), along with the determination of which jurisdictions offer public transportation service, suggests that a jurisdiction population density of 1,200/square mile indicates a location where public transportation is feasible.

To be clear, the feasibility of public transportation in a given location is affected by a variety of factors other than population density: employment density; mix of land uses; zoning policies; whether the street network follows more of a grid pattern as opposed to a dendritic pattern of cul de sacs; fuel prices; parking policies; and the relative subsidies for public transportation as compared to other modes. (It should also be noted that the 1,200 number refers to the entire jurisdiction; if smaller geographical units, such as census tracts, are used, the areas served by transit will require a higher density. In the *Transit Capacity and Quality of Service Manual,* Kittelson & Associates, Inc., et al. (2013) suggested a threshold of almost 5,000/square mile depending on assumptions regarding gross acreage and household size. Further, in Virginia, exceptions can be found for the 1,200/square mile threshold. For instance, Colonial Heights (2,324/square mile) does not have transit service yet Danville (1,001/square mile) does have service. There are also jurisdictions that offer some type of transit service but do not meet the criterion of service every hour and all day. Examples include Loudoun County (653/square mile), which offers a commuter bus service during peak periods; Martinsville (1,253/square mile), which operates a fixed service every 3 hours; and numerous smaller jurisdictions that offer some form of demand-responsive transit service.

That said, the jurisdiction density of 1,200/square mile appears to be a reasonable way of determining a jurisdiction population density that helps make a regular fixed route transit service feasible. For example, such service is found in Prince William County (1,279/square mile), Lynchburg (1,570/square mile), Bristol (1,357/ square mile), Petersburg (1,394/square mile), and Staunton (1,198/square mile). By contrast, lower density jurisdictions, such as Buena Vista (1,000/square mile) and Franklin City (1,039/square mile), do not offer regular service, defined as transit being available on at least an hourly basis throughout the day. A rough check on this 1,200/square mile is as follows: queries of the National Transit Database (based on 2012 data) suggested that about 4.8 million Virginians live in a transit-compatible area. When one tabulates the 133 Virginia jurisdictions and sums the population living in jurisdictions with a density of at least 1,200/square mile, one obtains 4.2 million Virginians—not the exact same answer but within 15%.

Based on the 2040 population projections from Weldon Cooper (2012a), about one-half of the 2.34 million population growth in Virginia from 2012-2040 is projected to be in transit-compatible jurisdictions. These 1.13 million Virginians, as shown in Figure 15, reflect two distinct groups: (1) about 0.68 million in jurisdictions where a transit-compatible density already exists (such as Fairfax County), and (2) about 0.46 million in jurisdictions where the transit-compatible density of 1,200/square mile was not met as of 2012 but is expected to be met in 2040 (such as Chesterfield County). Most (92%) of the growth in the areas defined as "transit compatible" (i.e., 1,200/square mile) is explained by growth in five jurisdictions: Chesterfield, Stafford, Fairfax County, Prince William, and Henrico. Figure 15 also shows that an additional growth of 1.21 million Virginians is expected in jurisdictions that are not expected to have the transit-compatible density of 1,200/square mile in 2040.

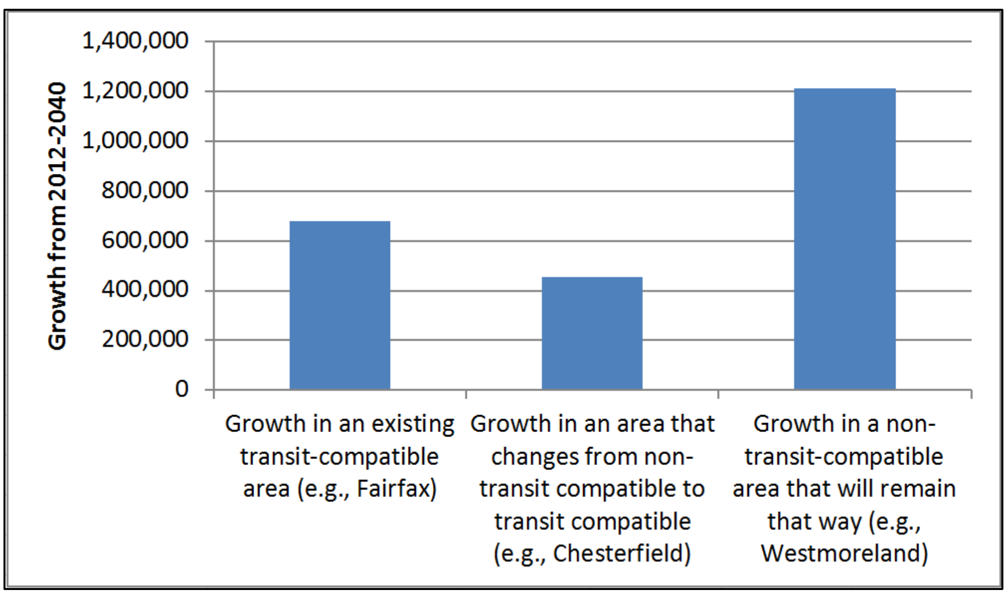

Figure 15. Distribution of Forecast Population Growth in Virginia? Based on Transit Compatibility: 2012-2040. Data from Weldon Cooper (2012a, c).

Another way of examining the growth in transit populations is to consider the entire population of areas that become transit compatible. For example, relative to the current population, an additional 1.6 million Virginians are projected to live in transit-compatible areas in 2040. These Virginians include two distinct groups: (1) the population growth (2012-2040) in jurisdictions where a transit-compatible density already exists (such as Fairfax County), and (2) the entire 2040 population (not just the growth) in jurisdictions where the transit-compatible density of 1,200/square mile was not met as of 2012 but may be met in 2040 (such as Chesterfield County). The representation of these 1.6 million Virginians is shown in Figure 16 (*left*). When population projections from Woods & Poole (2014) were used instead, the results were as shown in Figure 16 (*right*). Although the left and right portions of Figure 16 differ, much of this difference is attributable to differences in growth forecast for Fairfax, Loudoun, and Prince William (as discussed previously, in Woods & Poole [2014], these areas included the interior cities). As is the case with Figures 15 and 16 (*left*), most of the change in transit-compatible areas in the Woods & Poole (2014) data set used to create Figure 16 (*right*) is explained by a few areas. In Figure 16 (*right*), the aforementioned areas of Fairfax, Loudoun, and Prince William, along with Chesterfield, Henrico, and Virginia Beach, account for almost all of the population growth in transit-compatible areas.

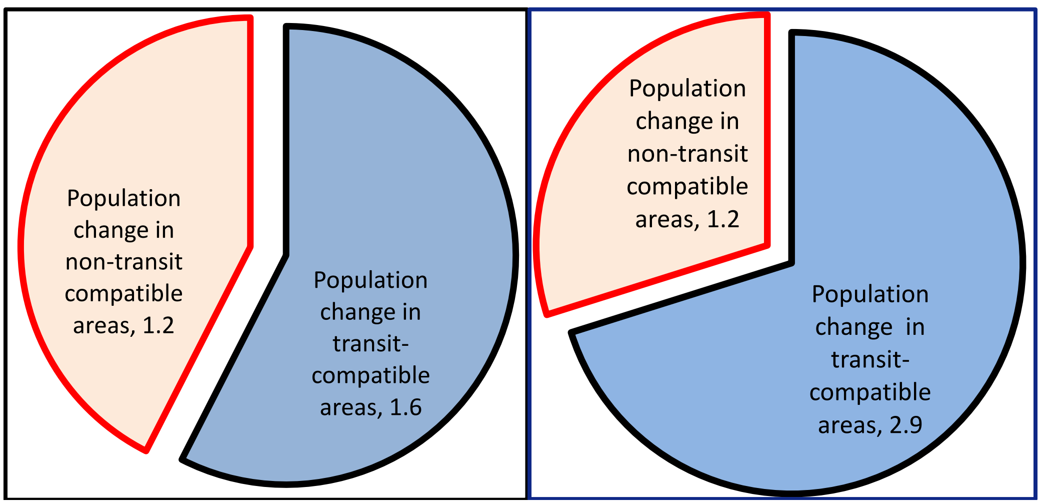

Figure 16. Forecast Population Change (in Millions) of Virginia by Areas of Transit Compatibility: 2012-2040. *Left:* Data from (*left*) Weldon Cooper (2012a); *right,* data from Woods & Poole (2014).

Millennials' Location Choices and Potential Impacts on VMT

A specific interest of VTrans stakeholders is the extent to which the number of millennials (age 20-34 in 2012 and hence born between 1978 and 1992 inclusive) will change in various Virginia locations by 2040. This question is of interest because millennials may have different driving habits than their predecessors. Dutzik and Baxandall (2013) reported that millennials drove less in 2009 than people of the same age in 2001, and current annual VMT are less than those officially projected by the U.S. Department of Transportation and the U.S. EIA. Dutzik and Baxandall (2013) suggested evidence that millennials' housing and transport preferences differ from those of earlier generations (i.e., they cited a survey indicating that 44% of people age 18-34 actively sought to replace driving with another mode of transportation, compared to 33% of people age "35 to 44" and 26% of people age 55+).

The preferences of millennials may be considered in the context of two related factors: forecast changes in VMT for the United States as a whole and patterns of growth over the past decade in Virginia's metropolitan areas. Accordingly, this section considers three topics that affect how millennials' location choices are examined:

1. possible changes in future VMT
2. growth within Virginia metropolitan areas over the past decade
3. locations of millennials.

Possible Changes in Future VMT

There are multiple possible causes of changes in VMT, and these are not all known. For example, Polzin and Chu (2014) asked why national VMT has dropped by 3% since 2007. Generally, they dismissed the role of passenger mode shifts for explaining this decrease. For instance, non-motorized modes (bicycle and pedestrian) do not appear "consequential," with such modes occupying a total of 0.99% of person-miles of travel, and there would not seem to be shifts to air on the basis of a 0.1% decline in air travel. Polzin and Chu (2014) also did not suggest that transit explained the drop in VMT, as they noted no more than a 5.6% shift in urban non–heavy vehicle VMT (thus a lower percentage shift would be observed if total VMT were considered). They also noted a slight increase in "auto" occupancies (2%) and an increase in people working at home (3.26% to 4.33% over more than a decade). Polzin and Chu (2014) did observe that the decrease in freight explained part, but not all, of the drop in VMT: for the period 2007-2011, what Polzin and Chu (2014) referred to as "heavy-vehicle VMT" (e.g., VMT attributed to tractor-trailers and other heavy duty trucks used for moving freight on roadways) decreased by 12%, which explained almost one-half (43%) of the national decrease in VMT. The authors noted three possible causes for the decrease in freight VMT: the role of the economy (e.g., that freight traffic is "correlated with economic activity levels"); improvements in logistics; and shifts in freight travel modes (such as truck to rail). In terms of passenger travel, the authors noted a decrease in the length of the trip and the trip frequency, with greater decreases in rural VMT (2.9%) than in urban VMT (1.3%) for 2007-2011. One cause was the decrease in travel of people age 20-40 (with decreases in VMT of 15% to 20% for the period 2001-2009); factors that might explain this cause could be changes in the economy, demographics, or societal values.

Polzin and Chu's emphasis on freight as a contributor to VMT was echoed by Sorenson et al. (2014), who suggested that freight will play an increasingly important role in VMT (and in energy use), indicating that VMT attributed to "freight trucking" will grow faster than passenger VMT but that both will grow at a slower rate than in the past. For the 2040-2060 timeframe, the authors envisioned three possible scenarios, as shown in Table 7. What is of interest is that for the three scenarios, the growth in VMT attributed to "freight trucking" (which based on a review of Sorenson et al. [2014] appears to include tractor-trailers as well as medium duty vehicles weighing at least 10,000 pounds with cargo and is referred to in Table 7 as "freight truck VMT") was envisioned to be higher than the growth in passenger VMT. The horizon year for these forecasts was not precisely 2040 but rather the 2040-2060 period, which may explain some of the large percentages for Alternatives 2 and 3.

Table 7. Possible Growth in Passenger and Freight Truck VMT From an Estimated Base Year of 2011 to the 2040-2060 Time Period[a]

Alternative	Vehicle Passenger VMT	Freight Truck VMT
1	Decrease by 10%	No change from 2011
2	Increase by 60%	Increase 125%
3	Increase by 80%	Increase by 200%

Source: Sorenson et al. (2014).
VMT = vehicle miles traveled.
[a] A base year was not specified; however, Sorenson et al. (2014) noted that an annual growth rate of 2.1% would yield a 125% increase by 2050. If this increase is per year (i.e., compounded), this would support a base year of 2011.

Erdogan et al. (2013) suggested that VMT may be influenced by the price of fuel and the fuel efficiency of vehicles. In an analysis of the Washington, D.C.–Baltimore area for 2030, they considered four future scenarios based on a low and high fuel price ($3.88 and $15.52 per gallon) and a low and high average fuel efficiency (27 and 52 mpg). At one extreme, that would encourage VMT, i.e., a low fuel price and a high fuel efficiency. The authors found mode shares for driving alone, carpooling, and bus + rail to be 76%, 18%, and 6%, respectively; at the other extreme that would discourage VMT, i.e., a high fuel price and low fuel efficiency, these respective mode shares were 61%, 29%, and 10%, respectively. In addition, the VMT for the latter scenario was about 17% lower than for the first scenario; the difference resulted not just from a mode shift but also from less travel, which in turn was partly attributed to changes in land development patterns. (The authors reported that a limitation of their work was that biking and walking were not considered outside their models; in practice, they noted that at higher density locations, shifts from an auto mode to a transit mode in their model might have manifested as a shift from an auto mode to a biking or walking mode in reality.)

Dutzik and Baxandall (2013) noted that the recent economic downturn complicates analysis of driving behavior. (For example, because a key segment of drivers is the working population, it is not clear whether millennials have opted to drive less than their predecessors out of preference or because of difficulty finding employment.) The authors outlined three possible scenarios for growth in VMT by 2040. The first scenario is that VMT will continue to rise, where the drop from 2004 to roughly 2012 was temporary. For example, millennials might prefer to live and raise families in more suburban locations than they currently prefer. Since suburban locations generally require the use of a private vehicle more than urban locations because of less available public transportation and amenities within walking distance, millennials' driving preferences could also vary based on their preferences for certain location types. The second scenario is that VMT may continue to *drop*, possibly owing to concerns about the environment and fuel prices, where the 2007-2012 drop in VMT represents a fundamental shift in travel demand. This scenario reflects a change in attitudes: for example, in an examination of opportunities to increase public transportation ridership, Sakaria and Stehfest (2013) reported that millennials "appreciate the opportunity to keep working instead of waiting around while traveling." The third scenario is that VMT will increase slightly but VMT growth is restrained by millennials' preferences but enhanced by the fact that more millennials approach "peak driving age." The projected differences in VMT for the first two (most extreme) scenarios are, relative to the 2007 peak VMT, an increase of 24% versus a decrease of 19% by 2040. In short, Dutzik and Baxandall (2013) alluded to both possibilities: There is a chance that the differences in transportation and lifestyle habits currently demonstrated by millennials may fade as they age. But it is also possible that cultural changes and advances in mobile technology will continue or even accelerate millennials' transition away from driving—with massive implications for transportation policy.

Despite the variation in VMT, the variation in the three scenarios is informative in that it suggests an expected range for how Virginia VMT might change in the future. If, for example, the scenarios provided by Dutzik and Baxandall (2013) are applied to Virginia VMT, a forecast range (based on applying these national numbers to Virginia's 2007 value) is from 182 million to 279 million VMT. A more detailed VMT forecast would be based on Virginia-specific factors (such as population and employment growth), but Figure 17 provides a rough guide if relatively recent trends were to continue.

At least two viewpoints can be identified in the literature discussing millennials' location choices: (1) millennials' preference for urban, walkable living is a fundamental shift, and (2) it is not known if this trend will continue. In an example of the former, Benfield (2014) stated: "[t]he demand for large-lot suburbia, by contrast, is diminishing," citing research by others that by 2040, three-fourths of housing demand will be for either attached housing or homes on smaller lots and that two-thirds of millennials wish to live in "walkable" places. Benfield (2014) further suggested that even if growth occurs outside central cities, there will be a demand to make travel within such locations less vehicle dependent. Mallach (2014) stated the latter point—that although people age 25-34 are moving to central cities, three factors that prevent one from presuming this is a long-term shift: (1) additional time is needed to determine if the generation's preferences will continue as they age; (2) other age groups are not returning to the cities in large numbers; and (3) except for cities with strong economies (Boston, San Francisco, and Washington, DC), most parts of cities outside the downtown area are not changing substantially. A common theme of Benfield (2014) and Mallach (2014) was not necessarily to ask the question of whether millennials' preferences will continue—both suggested thinking about how to make urban living affordable for people from all ages and income groups.

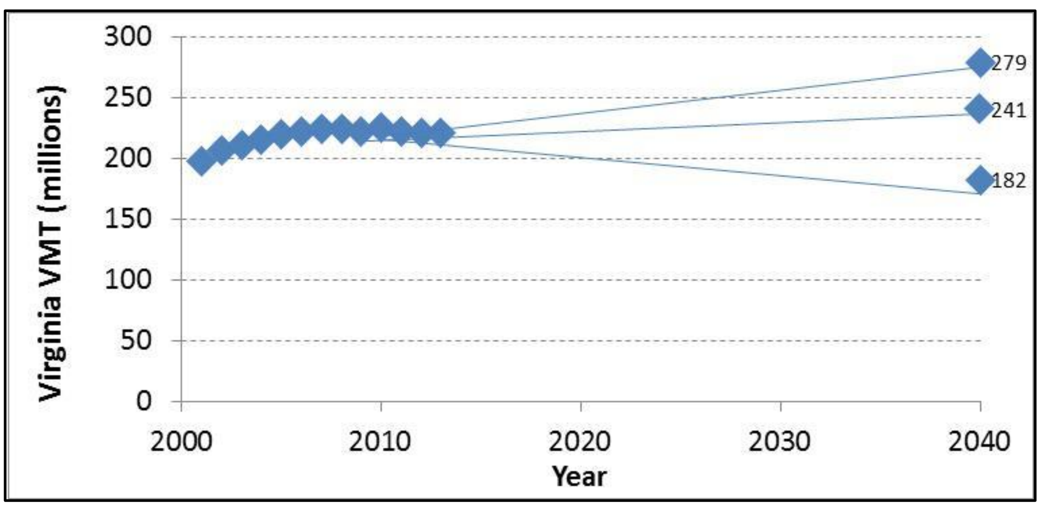

Figure 17. Virginia VMT Historical Values. Data from Virginia Department of Transportation (2014) and Dutzik and Baxandall (2013). VMT = vehicle miles traveled.

In sum, any changes in VMT will be driven by several factors: freight demand, fuel prices, the economic outlook, and of course the location preferences of Virginians. Although location preferences cannot be forecast with certainty, it is productive to examine population growth patterns over the past decade in Virginia.

Growth Within Virginia Metropolitan Areas Over the Past Decade

Cox (2014) classified 9,000 zip codes from 52 metropolitan areas in the United States (each with over 1 million in population) into four categories: "urban core," "earlier suburban," "later suburban," and "exurban." Definitions for these categories are abbreviated here as (1) urban core (density of at least 7,500/square mile and 20% of commuters biking, walking, or using transit); (2) earlier suburban (with the median year of home construction occurring during the period 1946-1979); (3) later suburban (with the median year of home construction occurring after 1979); and (4) exurban (population under 250/square mile [Wendell Cox Consultancy, 2015]). From 2000-2010, the percentage of people age 20-29 living in the urban core areas and the earlier suburban areas decreased (by 0.9 and 4.1 percentage points, respectively) and increased in the later suburban and exurban areas by 3.8 and 1.1 percentage points, respectively.

A review of Cox (2012) and Wilson et al. (2012) suggests that one measure of interest may be the extent to which areas close to the central city are responsible for growth relative to outlying areas. For 11 Virginia-based metropolitan areas, the U.S. Census Bureau (2013f) tabulated the distance that residents lived in 2000 and 2010 from either "city hall" or an equivalent municipal building in 1-mile increments. For example, people living 0-0.999 miles of city hall are coded as 0; people living 1.0-1.999 miles of city hall are coded as 1, and so forth (P. Mackun, personal communication, 2014). For example, from this data set one can tabulate that there were 108,177 people in the Roanoke metropolitan area in year 2000 who lived within 4 miles, i.e., 0-3.9999 miles, of what the U.S. Census Bureau (2013f) had geocoded to be city hall, which was located at Church Avenue between 2nd and 3rd Streets SW; by year 2010, this number had increased by 2.4% to 110,797; by comparison, the population of the entire Roanoke area grew 7.1% over the same period.

Figures 18 and 19 show these 11 Virginia-based metropolitan areas in order of descending total growth from 2000-2012. The Washington [D.C.]–Arlington–Alexandria metropolitan area (Figure 18) grew the most (by 785,731), and the Kingsport-Bristol metropolitan area (Figure 18) grew the least (by 10,989). Figures 18 and 19 also show the percentage of growth attributed to each distance category shown. For example, in the Washington–Arlington–Alexandria metropolitan area, approximately 2.5% of the growth of 785,731 occurred within 2 miles of city hall, whereas 11.9% of the growth occurred within a distance of 10-14 miles of city hall. Overall, the region grew at a rate of 16.4% for the decade. Figures 18 and 19 do not indicate the overall attractiveness of locations within each distance category (i.e., do not indicate whether the population in each category grew or shrank). Further, they do not control for differences in area size (e.g., the area in the 5-9 mile band is greater than the area in the 2-4 mile band) and do not address factors such as availability of developable land—they simply quantify which areas have been responsible for growth.

That said, Figure 18 suggests several observations in terms of growth from 2000-2010. For the three large metropolitan areas (i.e., growth of more than 50,000), the patterns were similar in that almost all distance categories contributed to the overall growth of the region. However, for the Washington-Arlington-Alexandria metropolitan area and the Virginia Beach–Norfolk–Newport News metropolitan area, the category of 30 miles had 30% of the region's growth, whereas in the Richmond metropolitan area, the category of 15-19 miles had 30% of the region's growth. Growth also occurred in the downtown areas; however, if one defines a downtown area as being less than 5 miles from the city center or city hall as defined by the U.S. Census Bureau (2013f), the downtown areas had for 6% to 10% of the region's growth overall. A key difference between the metropolitan areas is that unlike the other two, the Richmond metropolitan area saw a large proportion of its growth (70%) in the area located 5-19 miles from city hall.

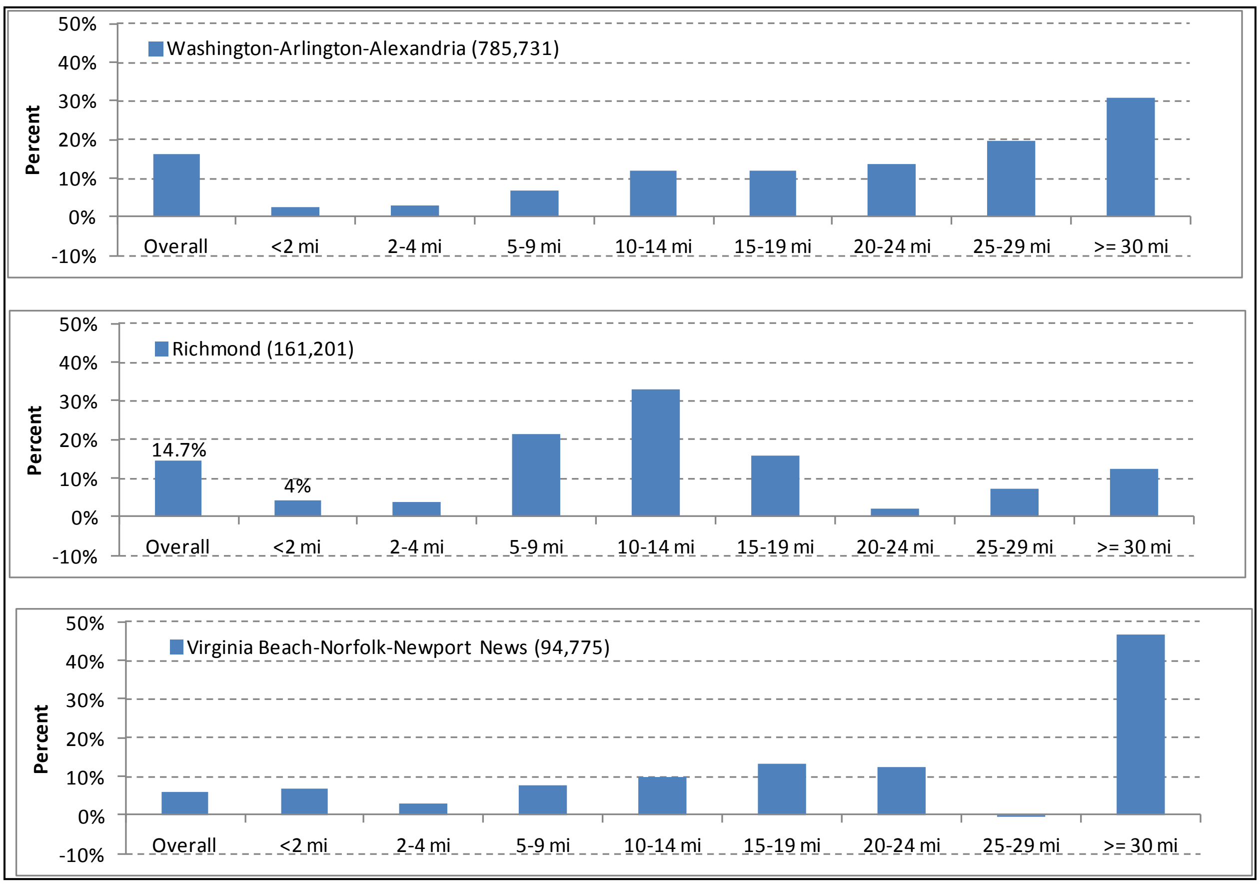

Figure 18. Virginia Metropolitan Areas That Grew by More Than 50,000: 2000-2010. Data from U.S. Census Bureau (2013f). Numbers shown in the horizontal axis reflect the lower integer distance; for example, a person living 4.8 miles from city hall is included in the "2-4 mi" category. The "Washington-Arlington-Alexandria" area includes locations outside Virginia.

Figure 19 suggests that the metropolitan areas with a growth of less than 50,000 had a greater portion of that growth accounted for by areas closer to city hall. In part this is not surprising to the extent that these are smaller areas in terms of geography; for example, for the Harrisonburg metropolitan area, no data are available for people living 17 or more miles from city hall.

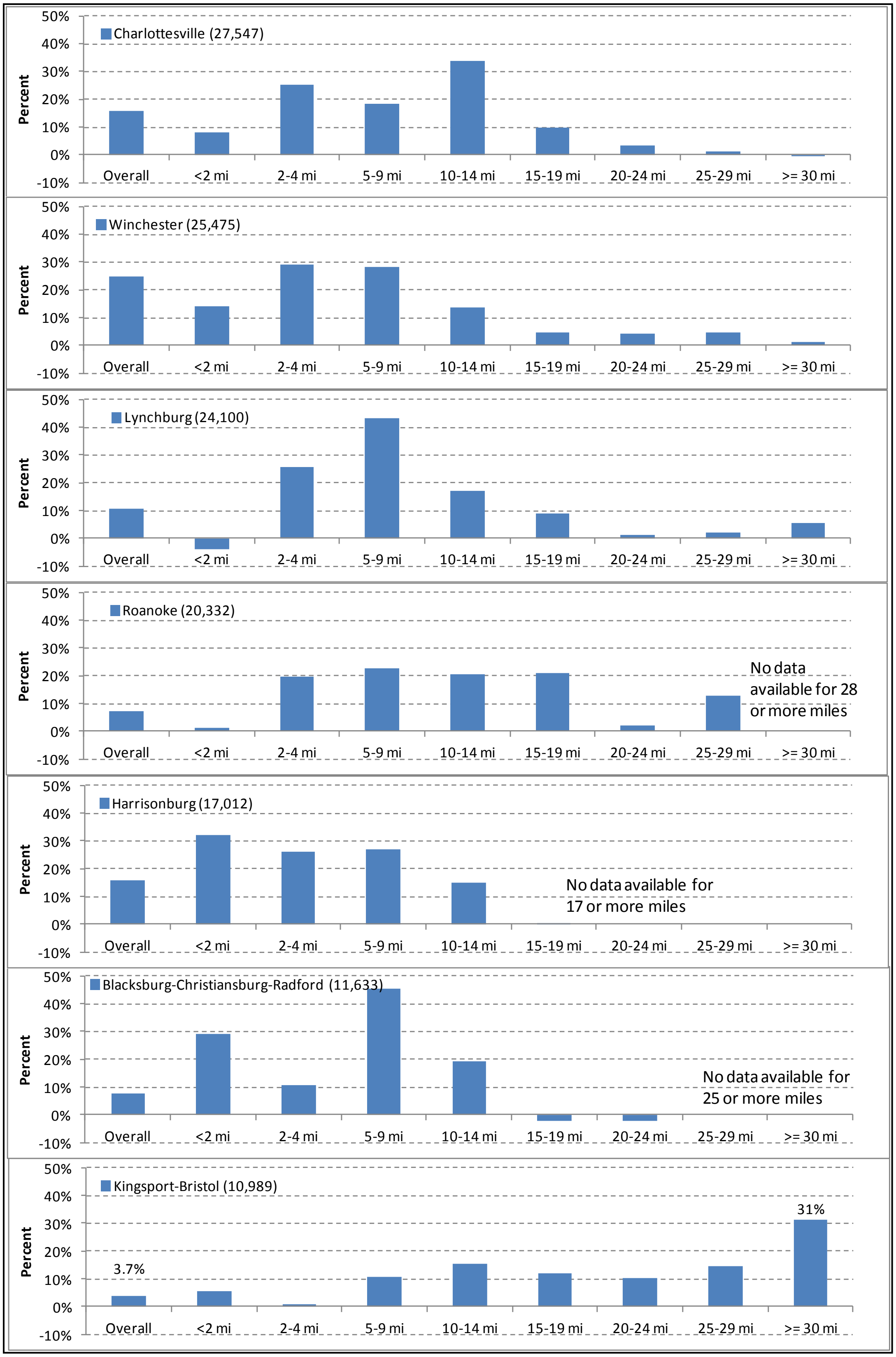

Figure 19. Virginia Metropolitan Areas That Grew by Less Than 50,000: 2000-2010. Data from U.S. Census Bureau (2013f). Numbers shown in the horizontal axis reflect the lower integer distance; for example, a person living 4.8 miles from city hall is included in the "2-4 mi" category. The "Kingsport-Bristol" area includes locations outside Virginia.

That said, the areas within 5 miles of downtown had more than one-fifth of the region's growth from 2000-2010 for six metropolitan areas: Blacksburg-Christiansburg-Radford (40%), Charlottesville (33%), Harrisonburg (58%), Lynchburg (22%), Roanoke (21%), and Winchester (43%). Within that 5-mile radius of city hall, more of the growth was in the range of 2 to 4 miles rather than less than 2 miles for four of the six areas. The exception was the Kingsport-Bristol metropolitan area, which although growing by less than 11,000, saw more of its growth occurring in outlying areas with more than 30% of the growth at a distance of 30 or more miles from the central area.

One metropolitan area, Danville, is not shown in Figure 19. Unlike the other metropolitan areas, the population of Danville decreased from 2000-2010. The total decrease was 3,542 and mostly occurred from the area within 5 miles of downtown—in fact, those areas lost more than 5,000, which was partly offset by a gain of 1,800 in the range of 5 to 19 miles from city hall.

By themselves, Figures 18 and 19 do not indicate the desirability of living near or far from the CBD: the distance categories do not address land availability (e.g., a body of water, other natural barriers, or zoning may make some locations infeasible), and the graphics do not show the percentage increase in population for each distance category. Instead, Figures 18 and 19 show where growth has been occurring relative to what the Census defined as city hall, and there can be a variety of reasons for this growth. For example, as shown in Figure 18, the Richmond metropolitan area grew by 14.7% overall, resulting in the growth of 161,201. Approximately 4% of the growth occurred less than 2 miles (i.e., 0-1.999 miles) from city hall, as coded by the U.S. Census Bureau (2013f). As shown in Figure 19, Kingsport-Bristol grew by 3.7% (10,989), and about 31% of this growth occurred 30 miles or more from city hall (as coded by the U.S. Census Bureau, 2013f).

Locations of Millennials

A question of interest is where millennials will reside in 2040 based on current population forecasts. A variety of definitions exist for *millennials*, and the definition used here is people age 20-34 in 2012 (The Pew Charitable Trusts, 2014)—that is, people born between 1978 and 1992 inclusive. In year 2040, those people will be age 48-62. Because the forecast population data are in 5-year increments (e.g., age 0-4, 5-9, 10-14, etc.), it is not possible to have an exact group of people age 48-62 for year 2040. As an approximation, *millennials* were defined as people age 20-34 in 2012 (i.e., born between 1978 and 1992 inclusive) and age 45-59 in 2040—that is, born between 1981 and 1995 inclusive. (This 45-59 age group approximates the ideal definition of age 48-62 but is not exact. Another possibility would be to define a 2040 millennial as age 50-64 [i.e., born between 1976 and 1990 inclusive], because the 50-64 age group also approximates the 48-62 age group but again is not exact.)

The 2012 data indicate there are 1.74 million Virginians in the millennial category (i.e., age 20-34 or born 1978-1992), and the forecast for 2040 is 1.94 million Virginians in this millennial category (i.e., age 45-59 or born 1981-1995). Thus, the number of millennials is forecast to grow by approximately 200,000—an increase of 12% from 2012-2040. This net change is not uniform: of Virginia's 133 jurisdictions, 28 are forecast to lose a total of 255,951 millennials and 105 are forecast to gain a total of 458,845 millennials.

Figure 20 presents the five jurisdictions with the highest absolute increases in millennials. These jurisdictions are forecast to have a total of 192,531 millennials in 2040, representing approximately 42% of the change in the millennial population in those jurisdictions where the number of millennials is expected to increase. However, these five jurisdictions along with the jurisdictions that have the next five highest projected increases in millennials (Prince William, Hanover, Chesapeake City, Henrico, and Frederick) show a total increase of 274,717 millennials, which is 60% of the statewide growth in millennials in jurisdictions that will see an increase in millennials.

Statewide, the growth noted in Figure 20 is offset by a projected decrease in millennials in other locations, as shown in Figure 21. Of the five counties with the largest decreases in millennial population, Arlington, Norfolk, and Virginia Beach account for a decrease of 118,822. This represents 46% of the change in the millennial population in those jurisdictions where the millennial population is forecast to decrease. A total of 161,162 millennials may be lost from the five localities with the greatest decreases, representing 63% of the statewide change in the millennial population in those jurisdictions where the millennial population is decreasing. The total decrease in the millennial population for the 10 counties with the largest decreases is 222,526, or 87% of the total statewide change in the millennial population in those jurisdictions where the millennial population is decreasing. Thus, the overall distribution of millennials in Virginia is projected to shift somewhat over the next 25 years.

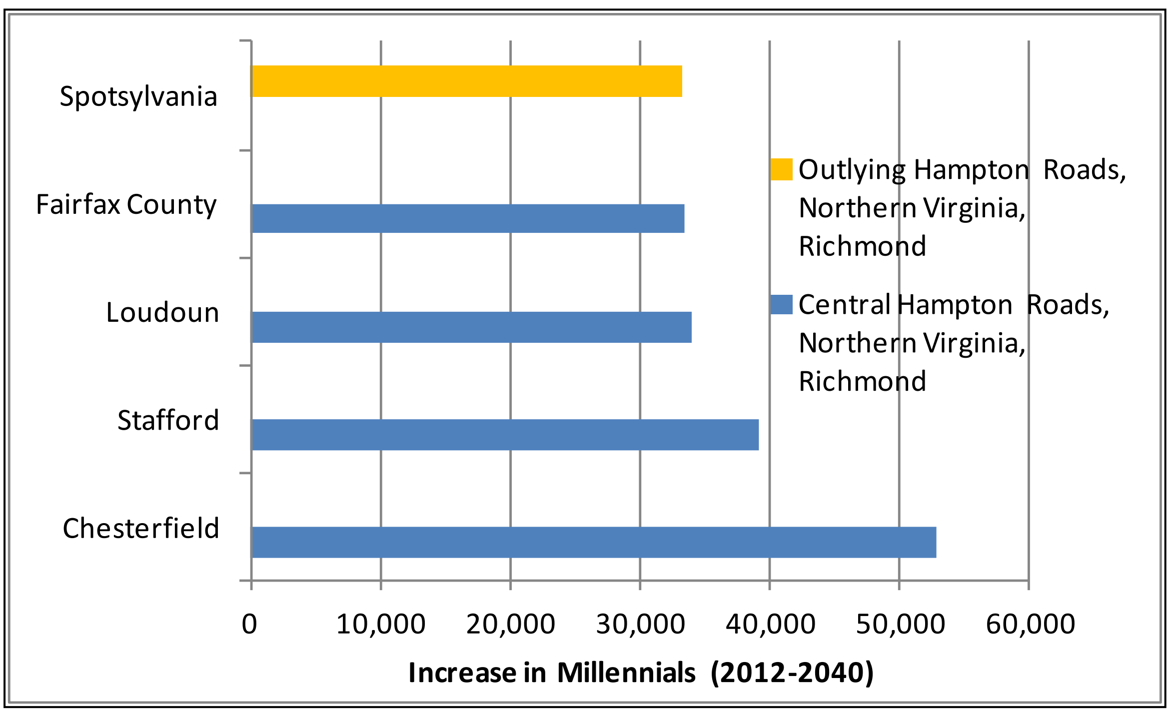

Figure 20. The Five Virginia Counties With the Largest Forecast Increases in Millennials: 2012-2040. Data from Weldon Cooper (2012a, c).

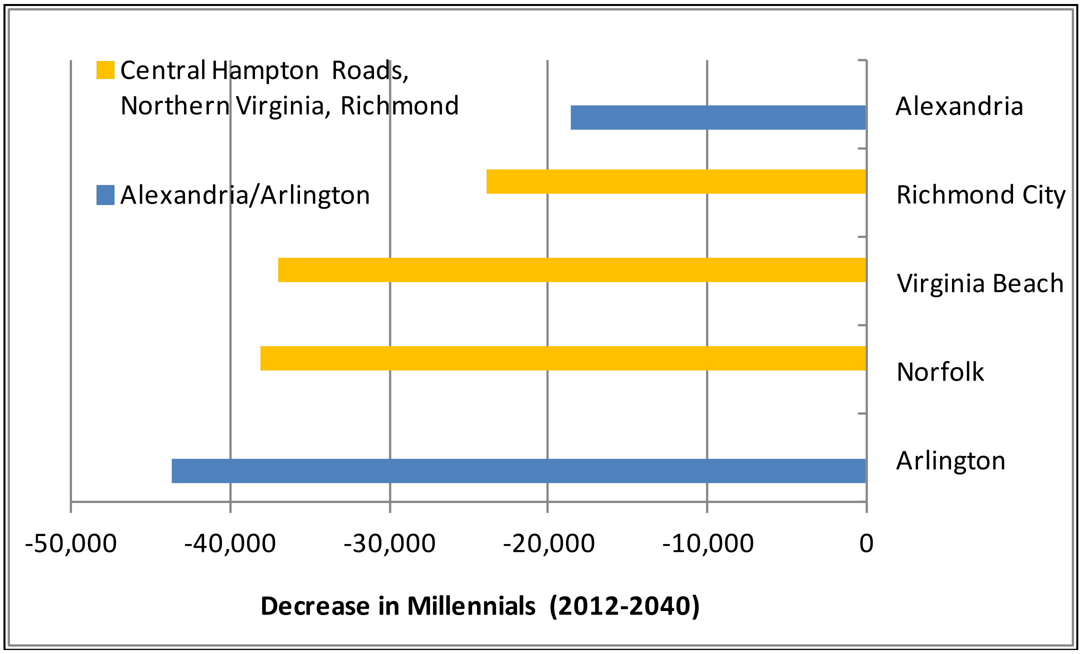

Figure 21. The Five Virginia Jurisdictions With the Largest Forecast Decreases in Millennials: 2012-2040. Data from Weldon Cooper (2012a, c).

There is a high degree of overlap between the jurisdictions projected to see the greatest gain in the millennial population and those where the greatest proportion of all millennials statewide is projected to reside. Figure 22 shows the 10 counties that are forecast together to have 955,704 of the 1,939,019 millennials in Virginia, or nearly 50%, in 2040, all of which are in Central Hampton Roads, Northern Virginia, Richmond except for Spotsylvania, which is in Outlying Hampton Roads, Northern Virginia, Richmond.

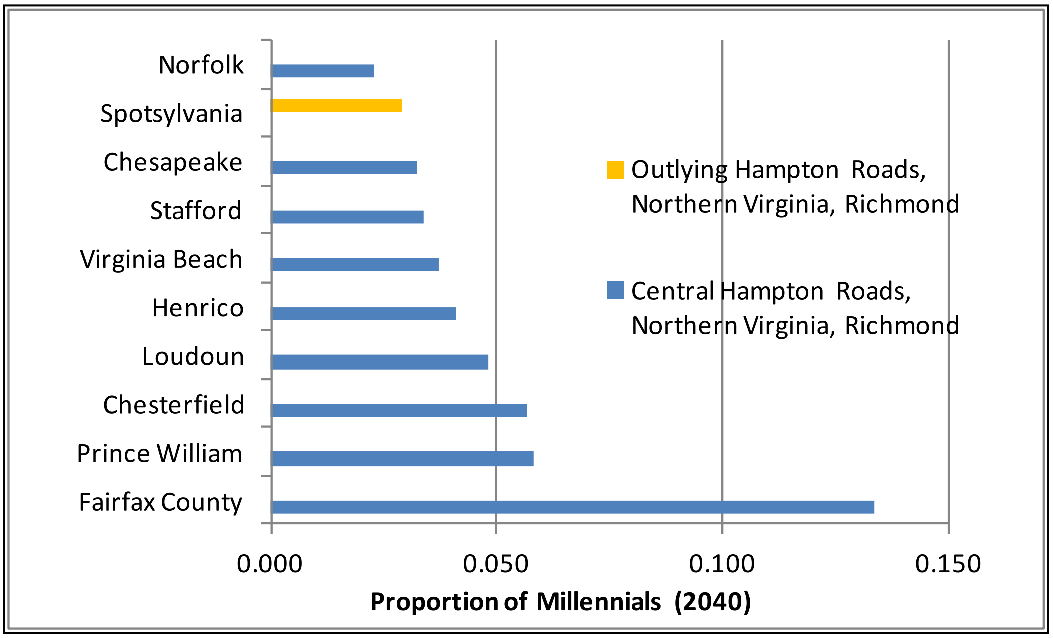

Figure 22. The Ten Virginia Counties With the Largest Forecast Proportion of Millennials in 2040. Data from Weldon Cooper (2012a, c).

At a glance, the change in the overall distribution of Virginia's millennial population among location types has both nominal similarities and nominal differences with the change in the overall statewide adult population (age 20-64). As with the total population, a larger proportion of the millennial population is projected to live in either Central Hampton Roads, Northern Virginia, Richmond or Outlying Hampton Roads, Northern Virginia, Richmond in 2040 (68.96%) than in 2012 (65.45%). The nominal difference is an increase in the number of millennials living in outlying small urban areas (3.14% in 2012 versus 3.78% in 2040) and an increase in the number living in non-core areas, whereas Table 3 suggests a nominal decrease in outlying small urban areas and non-core areas for the population as a whole.

Table 8 compares the percentage of all millennials currently living in each location type with the projected percentage of millennials in each location type in 2040. It also shows the change in the middle age population, defined here as people age 20-64. The proportion of this population is projected to increase in Central Hampton Roads, Northern Virginia, Richmond and Outlying Hampton Roads, Northern Virginia, Richmond by 2040 and to decrease in all other location types, which is the same pattern as for the state population as a whole, the population age 65+, and the population age 19 and under. By contrast, the millennial population is expected to increase also in outlying small urban areas and non-core areas.

Any population projections, such as those shown in Table 8, contain at least two sources of uncertainty. First, population growth is affected by births, deaths, and net migration (i.e., people coming to Virginia minus people leaving Virginia). Immigration is projected to be a particularly important factor driving population growth for the United States as a whole in the coming decades (Passel and Cohn, 2008), and by extension immigration will affect Virginia's population to some degree. Thus, the localities in which immigrants choose to settle will affect the distribution of millennials in Virginia in 2040, as well as the distribution of the youth population.

Table 8. Forecasts of Changes in Millennial and Middle Age Population Distribution Among Virginia Location Types: 2012-2040

Location Type[a]	Percent Millennials		Rate of Change	Percent Adults Age 20-64		Rate of Change
	2012	2040	2012-2040	2012	2040	2012-2040
Alexandria/Arlington	6.96%	3.03%	-56.52%	5.30%	4.11%	-22.36%
Central Hampton Roads, Northern Virginia, Richmond	59.91%	60.62%	1.19%	59.17%	61.51%	3.95%
Outlying Hampton Roads, Northern Virginia, Richmond	5.54%	8.34%	50.44%	6.33%	7.81%	23.38%
Central Small Urban Area	16.87%	15.57%	-7.73%	16.24%	15.59%	-4.04%
Outlying Small Urban Area	3.14%	3.78%	20.57%	3.88%	3.38%	-12.89%
Non-Core Area	7.58%	8.67%	14.35%	9.08%	7.60%	-16.26%

[a] Location types are defined in Table 2.

For example, for the United States as a whole, Passel and Cohn (2008) noted that immigrants and their descendants will account for "all growth" in the 18-64 age group for the period 2005-2050. (The implication is that although births, deaths, and aging will affect this age group, the reason it will grow from a 2005 value of 186 million to a projected 2050 value of 255 million is because of immigration.)

Second, as Appendix C details, Weldon Cooper (2012b) derived the projections discussed in this analysis from models of past trends. Although trend analysis incorporates the increase in immigration into Virginia over the last 10 years as well as millennials' recent locality preferences, it does not explicitly take into account possible variation in immigrants' locality choices or changes in millennials' preferences.

A viewpoint on location attitudes of "urban millennials" was reported in a survey by Sakaria and Stehfest (2013). The authors conducted a survey of 1,000 millennials (age 18-34) in six urban areas: Boston, Chicago, San Francisco, Seattle, Portland (Oregon), and Washington, D.C. The authors cautioned that the survey was not designed to represent the nation, which appears logical given its urban focus. In the survey, slightly more than one-fourth of respondents (29%) indicated that they "agree strongly" with the statement that "I picture myself residing long-term in an urban setting." A similar percentage (28%) agreed strongly that "I picture myself residing long-term in a suburban setting." For the subset of millennials with children (18 years and under living in the household), both percentages were higher: about one third (34%) indicated "I picture myself" in an urban setting, and a similar percentage (37%) indicated "I picture myself" in a suburban setting.

Role of Immigration

One factor that influences uncertainty regarding population forecasts is immigration. National-level policies and economic conditions will influence the number of immigrants coming to the United States and, by extension, Virginia. The Virginia Department of Health (2011) reported that from 2000-2010, more than one-half of Virginia's population growth resulted from people moving to Virginia; however, this number alone does not indicate which portion originated from other states and which portion originated from outside the United States, so the role of immigration is not specified therein. Accordingly it is appropriate to consider (1) the characteristics of current immigration into Virginia (i.e., people coming from outside the United States), and (2) the projected effects of immigration on Virginia's total population and specific subpopulations such as specific age groups.

Characteristics of Current Immigration Into Virginia

Immigration will drive total population growth and the relative growth of different age groups in Virginia from 2012 (or within a few years of 2012) to 2040. The American Immigration Council (AIC) (2013) reported that the U.S. Census Bureau estimated in 2011 that 11.1% of Virginia's population was born outside the United States (900,243 people). Approximately one half (47%) were naturalized U.S. citizens, and approximately 27% were under age 35 as of 2012 (Acosta et al., 2014). A majority of immigrants in Virginia entered the

United States legally; it is estimated that 210,000 people, or 2.7% of the total state population, are unauthorized immigrants. As of 2012, 42% of immigrants to Virginia were from Asia, 35% were from Latin America, 10% were from Europe, and 10% were from Africa (Sen, 2014).

Virginia is not one of the 10 states receiving the highest number of immigrants, nor is it projected to become one in the coming decades. However, Virginia's demographics have been affected by immigration, as 47%—almost one half—of Virginia's Hispanic population is composed of immigrants (Brown and Lopez, 2013). Weldon Cooper estimated that 40% of Asians in Virginia were naturalized citizens and 32% were non-citizens, suggesting that approximately 72% of Virginia's Asian population was born outside the United States (Weldon Cooper, 2011). The population was highly concentrated, as 9 of 20 Asians in Virginia lived in Northern Virginia (71%), Hampton Roads (13%), or Richmond (9%). Brown and Lopez (2013) reported that the 47% of Virginia's Hispanic population born outside the United States is the sixth-highest percentage nationally; the highest is the District of Columbia, where 54% of the Hispanic population was born outside the United States. Frederick County, Virginia was one of the 10 U.S. counties with the greatest percent increase in Hispanic immigrants from 2000-2011 (Brown and Lopez, 2013).

Relevance of Future Immigration to Population Growth

Impacts on Total Population

Approximately one in nine Virginians was an immigrant (i.e., born outside the United States) as of 2011, which is comparable to the national proportion of one in eight people (AIC, 2013; Passel and Cohn, 2008). It is projected that by 2050, one in three people in the United States will be either foreign-born or have at least one foreign-born parent (Woodrow Wilson School of Public and International Affairs at Princeton University and The Brookings Institution, 2011). Although national projections cannot be taken as a complete proxy for anticipated changes within a state, it is reasonable to expect that Virginia will be influenced to some extent by the projected increase in immigration to the United States as a whole. Reporting for the Pew Research Center's Hispanic Trends Project in 2008, Passel and Cohn (2008) projected that 82% of the total growth in the U.S. population from 2005-2050 will be attributable either to immigrants or to the children and grandchildren immigrants will have in the United States.

It is also notable that Virginia's neighboring states have had growth in their Hispanic populations from immigration in the past decade. The Pew Hispanic Center reported that 7 of the 10 states with the highest percentage of growth in the Hispanic population were in the southeastern region of the United States, which included North Carolina, South Carolina, Alabama, Georgia, and Maryland (Brown and Lopez, 2013). These states still have small Hispanic populations relative to the total Hispanic population in the United States, as 55% of immigrant and U.S.-born Hispanic people in the United States reside in California, Texas, and Florida. However, the growth in the Hispanic populations of Virginia's neighboring states could impact Virginia's demographics in the future if Hispanic immigrants or their children choose to relocate to Virginia in the coming decades.

Impacts on Age Groups

Immigration will also affect the relative growth of particular age groups. Immigrants most frequently arrive as young adults, age 20-35, and both immigrants and their children generally have higher birth rates than the native-born population (Passel and Cohn, 2008). Thus, most of the population growth in the coming decades driven by immigration will not be the result of new entrants per se, but rather of the birth rates they are projected to have relative to the native-born adult population. Further, although immigrants themselves will ostensibly age between the time this report was developed in 2014 and 2040, their relatively higher birth rates imply that the net effect of immigration will be an increase in the youth and working age population during that time (AIC, 2012).

Uncertainty in Immigration Projections

Because of the potential contribution of immigration to total state population growth, uncertainty regarding future immigration rates for Virginia contributes to the uncertainty of overall population projections. The number of immigrants allowed to enter the United States annually is affected directly by congressional action. For example, the Immigration and Nationality Act of 1965 abolished a quota system based on national origins and is widely agreed to have been the catalyst for the increase in the number and diversity of immigrants to the United States in the past several decades (Woodrow Wilson School of Public and International Affairs at Princeton University and The Brookings Institution, 2011). The future of immigration and the status of unauthorized immigrants currently residing in the United States comprise a politically controversial issue, and predictions of future immigration policy made by the authors of this report would be speculative. In fact, the Congressional Budget Office (2006) noted that forecasts of U.S. immigration levels (for the United States as a whole) have a "high degree of uncertainty," with the Congressional Budget Office (2011) indicating that this factor (the net change in people coming to the United States) is the largest contributor to uncertainty in national population forecasts.

Extension of Driver's Licenses to Unauthorized Immigrants

Whether or not to extend driver's licenses to unauthorized immigrants has generated controversy in states with large populations of unauthorized immigrants, such as Texas and California. Although Virginia currently has a small population of unauthorized immigrants, awareness of this debate and the potential implications for transportation may be of use in anticipating possible changes in the coming decades. Those in favor of permitting unauthorized immigrants to receive a driver's license noted that doing so would improve immigrants' access to jobs and thus decrease their potential dependence on social services and also ensure that all drivers were subject to some education on safe practices (National Immigration Law Center [NILC], 2013). Those in opposition stated that unauthorized immigrants contribute to U.S. unemployment by holding jobs that unemployed citizens could otherwise take and viewed permission to receive a driver's license as a form of rewarding people who had broken a law (Briggs, 2012). Virginia has a relatively small population of unauthorized immigrants and has not considered legislation with regard to either side of the debate. However, as of 2013, 11 states had passed laws extending driver's licenses to all residents, and as immigration into Virginia continues, it is possible that the issue will become more prominent in Virginia in the coming decades (NILC, 2013).

Vehicle Ownership and Related Factors

The authors of this report have sought to use the word "vehicle" rather than "auto" for consistency as much as possible. However, the literature regarding vehicle travel may refer to either (or both); for example, the word "vehicles" is used by BP (2014), and the word "auto" is used by Chatman and Klein (2013) and Polzin and Chu (2014). In some cases, the literature appears to use the word "vehicles" and "automobiles" synonymously (e.g., Chatman, 2013); *The Economist* (2012) used the terms "vehicle" and "car" synonymously. It is possible, however, for the meanings of these two words to differ. In the case of Litman (2014), the word "automobile" is a general term that denotes any vehicles for personal use such as light trucks, motorcycles, and cars. In the case of the U.S. Census Bureau (2013a, b), the words "vehicle" and "automobile" do not have the same meaning: "vehicle" is the general term that includes subsets such as light duty trucks and automobiles. Thus, when these latter two sources are contrasted (i.e., U.S. Census Bureau [2013a, b] and Litman [2014]), the term "auto" can have different meanings.

Traditionally, interest in vehicle ownership has been driven by a desire to determine the need for various types of transportation services. For example, a survey of riders in Phoenix, Arizona, showed that almost one-half (48%) of local bus passengers had no vehicle available, compared to just 5% of express bus passengers (Dayal, 2012). Recently, however, the question of interest has become whether vehicle ownership will continue to increase, as it has in the past, or whether per capita levels will remain unchanged—or possibly decrease. This question of vehicle ownership can be examined across five dimensions of Virginia-specific data: registered vehicles, vehicles available per person, attainment of driver's licenses, the role of carsharing, and the influence of vehicle availability on mode share. Then, the societal impacts of VMT may be considered. Each dimension uses different data sets and, as shown, can yield different results.

Registered Vehicles

In 2012, a total of 7.12 million private and commercially owned vehicles (autos, buses, trucks, and motorcycles) were registered for Virginia's 8.19 million residents, roughly 0.85 commercial and private vehicles per person, whereas in 1990, there were 0.80 such vehicles per person. Commercial vehicles cannot be fully separated from these numbers; however, if one considers only autos, motorcycles, and either "light trucks" (the term used in 1990) or "pickups, vans, sport utilities, or other light" (the terms used in 2012 all of which refer to "trucks"), there were 0.79 such vehicles per person in 1990, which increased to 0.84 per person in 2012. (The number of private and commercial "automobiles" per person dropped over this period because such a number does not include sport utility vehicles and light trucks.) To be clear, these vehicles represent commercial and private use. If *all* vehicles are considered—regardless of ownership (commercial, private, and public) and regardless of type (tractor-trailer, bus, auto, and so forth)—the number of vehicles per person increased from 0.81 in 1990 to 0.87 in 2012. Regardless of how vehicles are measured, the number of vehicles per person grew from 1990-

2012. However, a consensus view from the literature is that per capita vehicle ownership will not continue to increase but rather will either remain constant or decrease. Generally, this literature refers to vehicles for personal use, which have been characterized as automobiles or passenger cars, although some studies appear to use vehicles that include, but are not limited to, automobiles.

Factors That Suggest Vehicle Ownership per Capita Will Not Increase

One viewpoint is that vehicle ownership levels per capita have stabilized in the United States. At the national level, British Petroleum [BP] (2014) forecast that vehicle ownership per capita will be roughly flat at approximately 0.80 vehicles per person through 2035 (meaning that an increase in population would increase the number of vehicles, recognizing that these vehicles include private and commercial uses). For the Organisation for Economic Co-operation and Development's "OECD America" region, defined as Canada, Chile, Guam, Mexico, Puerto Rico, the U.S. Virgin Islands, and the United States, the Organization of the Petroleum Exporting Countries (2012), in its *World Oil Outlook*, forecast growth in vehicle ownership per capita from 0.55 "passenger cars" per person in 2009 to 0.60 passenger cars per person in 2035; however, noting that the United States had a current level of 0.71 passenger cars per person in 2009, this growth for the region as a whole did not necessarily reflect a change in per capita ownership rates in the United States. Dargay et al. (2007) forecast that by 2030, the U.S. vehicle ownership rate would stabilize around 0.849 vehicles per capita.

Litman (2014) pointed out that vehicle ownership can be poorly predicted by the use of trend-based models, noting that growth in vehicle ownership levels during the 20th century was driven by factors such as increasing affordability of vehicles and fuel, faster travel speeds, and infrastructure that supported this mode. Without those underlying factors increasing, it seems unlikely that per capita growth in vehicle ownership would continue. Shaheen and Cohen (2013) agreed that ownership and energy costs influence ownership and noted two additional factors: "economic uncertainty" (which is interpreted here to refer to uncertainty about one's future employment) and an interest in reducing greenhouse gas emissions. Chatman (2013) singled out parking as a factor that is typically not considered when vehicle ownership policies are evaluated, finding in a study of transit-oriented development that parking was a "powerful" explanatory variable for "auto ownership" (however, the author appears to use "autos" to mean "vehicles," as indicated by respondents to a survey]: dwelling units that had less than one parking space off the street for each adult had, on average, 16% fewer vehicles per adult—and if both on-street and off-street parking was scarce, there were 29% fewer vehicles per adult compared to a situation with ample on-street and off-street parking.

Factors That Could Contribute to Lower per Capita Ownership

Worldwide—not specific to Virginia—*The Economist* (2012) suggested that in the short term, two factors—the recession and the increase in fuel prices—can explain part of the decrease in VMT observed since some point in the 2000s in richer countries such as the United States, Britain, France, Belgium, and Australia. However, *The Economist* (2012) pointed that at least three other fundamental changes may be present, leading to reductions in travel even in the absence of a recession and a fuel price increase, where the saturation of vehicle ownership means it is unreasonable to expect vehicles per person to increase further. These three changes may be the feasibility of substituting some Internet use for some trips (in terms of the use of social media to replace in-person meetings and the use of deliveries in place of in-person shopping); delayed receiving of a driver's license; and more people choosing to live in urban rather than in rural areas. For example, *The Economist* (2012) suggested that 6% of people in rural areas in the United States live without a vehicle compared to 13% of people in cities of more than 3 million in population.

Although their study focused on New Jersey rather than Virginia, Chatman and Klein (2013) reported findings that may be relevant to Virginia given the expected influence of immigration on population growth from 2012-2040. Chatman and Klein (2013) conducted focus groups of people born abroad who, by the time the interviews were conducted, had moved to live in the United States; their question of interest was why it is sometimes observed that immigrants have lower levels of vehicle use than American-born residents, even after time spent in the United States and socioeconomic variables are accounted for. The authors suggested that in the long term, "different residential location priorities," along with growth of private transit services and transit riders who do not speak English, may explain why vehicle use and ownership remain lower for immigrant groups.

Vehicles Available per Person

The U.S. Census Bureau reports vehicle availability by household. These data are not as timely as data on vehicle registrations because as of 2015 they are collected every year only for jurisdictions with a population of 65,000 and over. Otherwise, the data are collected every 3 years (for jurisdictions of 20,000 to 65,000) or every 5 years (for jurisdictions under 20,000). Because such data used to be collected as part of the decennial census for all jurisdictions, it is possible to compare how vehicle availability by household, or by person, has changed from 1990-2000 and 2012 for the 30 jurisdictions in Virginia that had a population of at least 65,000 in 2012. Further, one can make this comparison for all jurisdictions with the understanding that the "2012" data will reflect data for the period 2008-2012.

Table 9 provides these comparisons statewide from 1990 and 2000 data based on the Census Transportation Planning Package (CTPP) (AASHTO, 2003) and 2012 data from the 5-year ACS (U.S. Census Bureau, 2013a). Table 9 also provides the data for only the 30 largest Virginia jurisdictions based on the same sources except that the ACS 1-year estimates (U.S. Census Bureau, 2013b) are used for the 2012 data set. These data suggest that vehicle availability per person increased slightly from about 0.67 in 1990 to approximately 0.71 in 2012. (Had vehicles available per household, which excludes people in group quarters such as college dormitories, prisons, and nursing homes, been examined, the ratios for 1990, 2000, and 2012 would have been 1.80, 1.83, and 1.90, respectively.)

Table 9. Vehicles Available per Person in Virginia: 1990, 2000, and 2012

Location	1990	2000	2012
Statewide	0.668	0.698	0.709[a]
Jurisdictions with Population of 65,000 or more in 2012	0.661	0.682	0.692

[a] For 2012, the actual statewide ratio of vehicles available per person is probably slightly higher than 0.709 because vehicles available is based on data collected for the period 2008-2012 whereas the population is based on the 2012 population. Had this approach been used for the 30 jurisdictions with a population of 65,000 or more in 2012, the ratio would have been 0.685 rather than the higher value of 0.692 shown.

Changes in Vehicles Available per Person From 1990-2012

For the 30 largest Virginia jurisdictions, the data show two trends for the period 1990-2012 (see Figure 23). For the period 1990-2000, vehicle availability increased in 26 of the 30 jurisdictions; by contrast, for the period 2000-2012, vehicle availability increased in 20 of the 30 jurisdictions. In the latter period, there were relatively large increases in some of the more rural jurisdictions and the small urban areas (e.g., Augusta, Suffolk, and Roanoke County) and relatively large decreases in some of the urban and small urban areas (e.g., Arlington, Alexandria, and Lynchburg). Whether these data indicate (1) a drop in vehicle availability as a matter of choice in response to the use of other modes; (2) a drop in vehicle availability because of changed economic conditions; or (3) randomness with no direct planning implications cannot be determined from examination of the data alone. Given the length of the periods involved, however, the data do suggest that it is plausible that vehicle availability may not continue to increase.

There does not appear to be a strong correlation between the change in vehicles available shown in Figure 23 and the change in population of these jurisdictions. For 1990-2000, the correlation coefficient was 0.27 between the change in vehicles available per person and the percentage growth of the jurisdiction, and the correlation coefficient for these two variables for the 2000-2010 period was -0.25. Given that a value of 0 indicates no correlation and a value of ±1.0 indicates perfect correlation, the correlation appears weak. The correlation was -0.40 between change in vehicle availability and 2012 densities, suggesting the potential for some degree of correlation between higher density areas and decreasing vehicle availability, although it is difficult to draw definitive conclusions.

However, there was a stronger correlation (-0.67) between the 2012 vehicles available and the actual 2012 densities. To be clear, there was scatter; for example, Virginia has four jurisdictions in the density range of 1,000-2,000/square mile (in order of increasing density these are Prince William, Henrico, Lynchburg, and Virginia Beach) with a per capita vehicle availability of 0.67, 0.71, 0.55, and 0.71, respectively, for an average of 0.66. That said, Figure 24, along with all 30 jurisdictions with a population of 65,000 or more, does show that increasing density is associated with reduced vehicle availability.

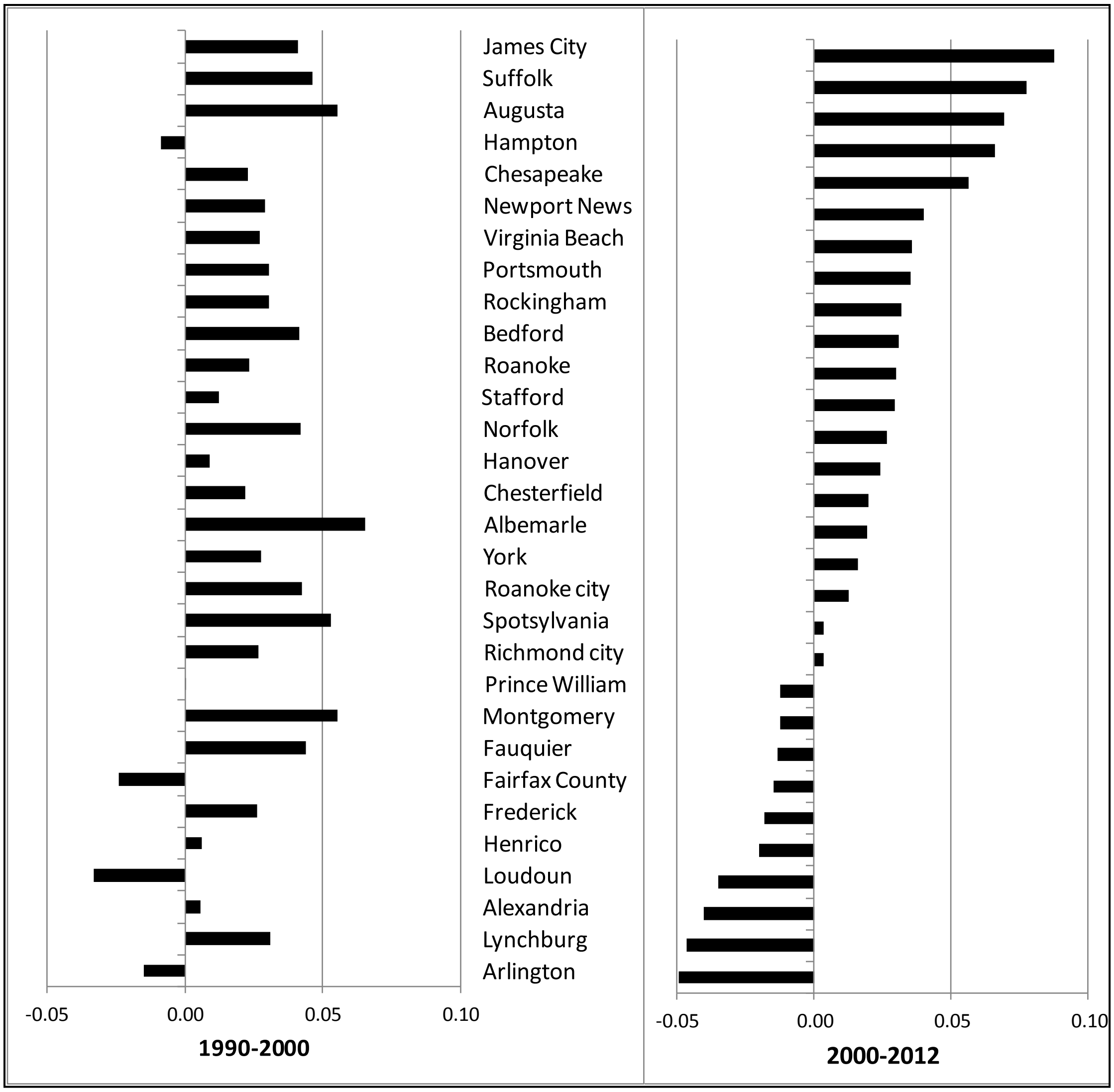

Figure 23. Change in Vehicles Available per Person in Select Virginia Jurisdictions: 1990-2012. Data extracted from AASHTO (2003) and U.S. Census Bureau (2013b). The year category "1990-2000" indicates the change from data collected for 1990 to data collected for 2000. The year category "2000-2012" indicates the change from data collected for 2000 to data collected for 2012.

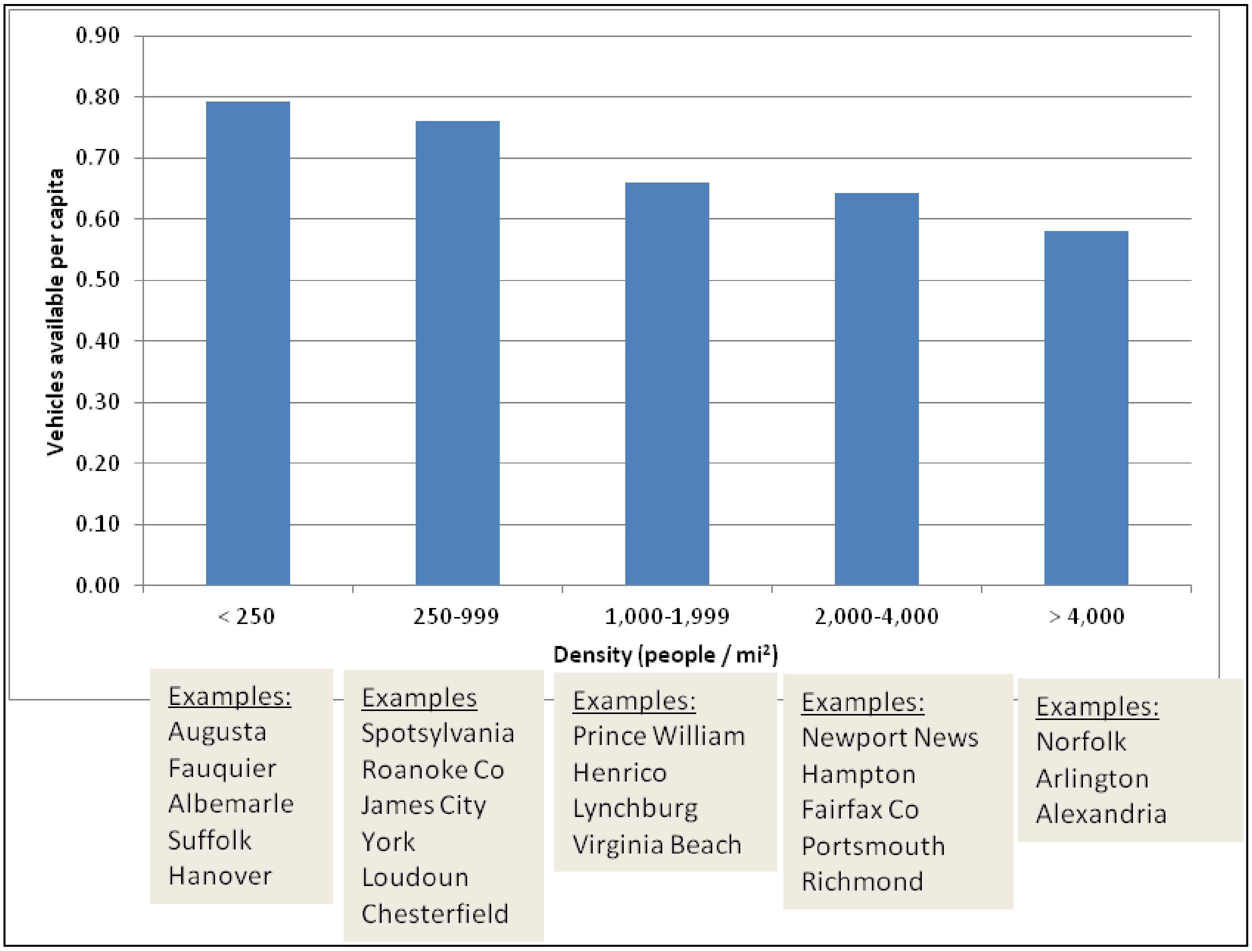

Figure 24. Vehicles Available per Capita and Density for the 30 Virginia Jurisdictions With a Population of at Least 65,000 in 2012. Data from U.S. Census Bureau (Undated a; 2013b) and Weldon Cooper (2012c).

Changes in Vehicles per Person by Location

The data also show substantial variability in vehicles available by jurisdiction. For the 30 jurisdictions for which 2012 data are available, the number of vehicles available per person was smallest in Norfolk, Lynchburg, Richmond, Arlington, and Portsmouth (with ratios of 0.55 to 0.60) and largest in Augusta, Bedford, James City, Roanoke (County), and Rockingham (with ratios of 0.81 to 0.90), as reflected in Figure 25. Differences in vehicles available per person can reflect factors other than demand for vehicle transportation such as income (e.g., Dargay et al., 2007) and a large proportion of the population residing in group quarters (e.g., people who reside in correctional facilities, dormitories, or nursing homes.)

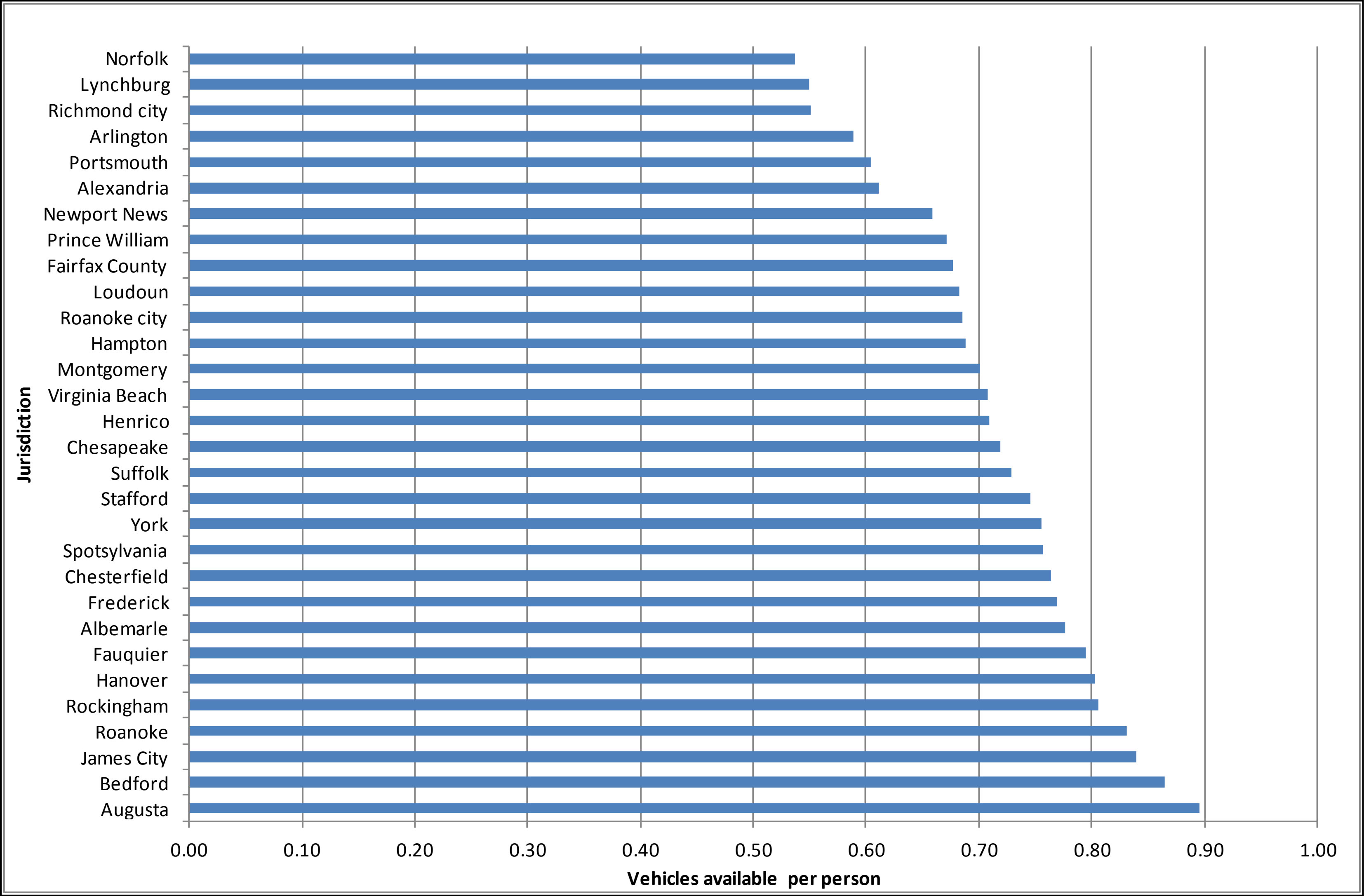

Figure 25. Vehicles Available per Person in Virginia Jurisdictions With a Population of at Least 65,000 in 2012 (U.S. Census Bureau, 2013b)

Changes in Zero Vehicle Households by Time and Location

Virginia data suggest that a greater proportion of households in urban areas may have no vehicle available than is the case in rural areas; however, the data are more nuanced. Statewide, 6.3% of Virginia *households* have no vehicle available (U.S. Census Bureau, 2013c), and examples can be found of urban areas with higher percentages (e.g., Charlottesville at 10.6% or Richmond at 17.9%) as well as rural areas with lower percentages (e.g., New Kent and Clarke counties at 1.7% and 1.8%, respectively). However, some of the areas with the highest proportion of zero-vehicle-available households are locations that would be characterized as small urban areas: examples are Danville (16.6%), Martinsville (16.8%), Petersburg (17.1%), Franklin City (18.9%), and Emporia (20.8%). Further, the data suggest that the proportion of households with no vehicle slightly decreased over the past two decades, from 8.8% (1990) to 7.6% (2000) to 6.3% (2012).

At the time this report was developed, slightly less than 190,000 households in Virginia did not have access to a vehicle, representing 3.9% to 4.4% of all people in Virginia. The uncertainty arises for two reasons: (1) the 2012 data represent a 5-year period; hence, the precise population is not known; and (2) the size that should be used for the category of households of "4 or more people" is not known. Thus, the range of 3.9% to 4.4% results from different values for these assumptions.

Attainment of Driver's Licenses

In work performed for *VTrans2035*, Miller (2012) reported that the percentage of Virginians age 15-24 with a driver's license decreased from 1990 (72%) through 2010 (58%); as of 2014, the percentage was 59% (for the most recent data available, i.e., through year 2012). Although these percentages may reflect generational preferences, it is possible they are influenced by graduated licensing requirements. Changes in licensing age requirements could explain differences for younger drivers (e.g., in 2015 the age was 16 years 3 months and in the past had been 16).

Figure 26 shows the percentage of Virginians in each age group with a driver's license for 1990 and 2012; generally, the percentages were nominally lower in 2012 than in 1990 for people under 55 and higher in 2012 than in 1990 for people age 60 and over. For instance, whereas 92% of people age 20-29 had a license in 1990, this percentage was 79% in 2012. Overall, whereas 89.2% of Virginians age 15 and over (15+) had a driver's license in 1990, this percentage was 83.4% in 2012.

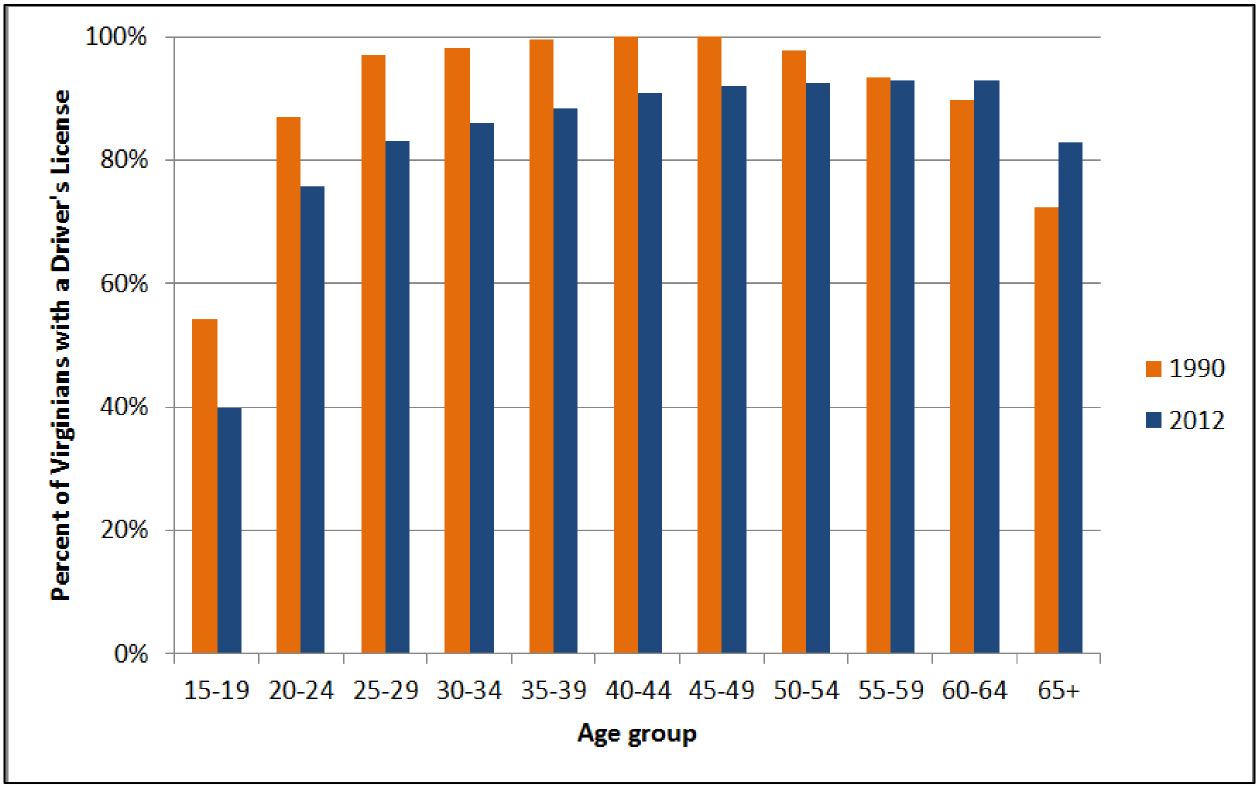

Figure 26. Percentage of Virginians With a Driver's License by Age in 1990 and 2012. Data calculated from FHWA (1990, 2012) and U.S. Census Bureau (2000, 2012b).

Role of Carsharing

Carsharing has been defined as "short-term car rental" (Walker, 2012) and generally denotes borrowing a vehicle for private or commercial use where one pays per hour or per mile (Tal, 2009). Business models for carsharing include (1) an entity that directly rents vehicles to people (e.g., Zipcar); (2) an entity that coordinates rentals between people who own vehicles and those who want to rent them (also known as "peer-to-peer carsharing" or "personal vehicle sharing"); and (3) "corporate carsharing" where employees of a business that has joined a carsharing organization use vehicles for personal or commercial purposes (Clark et al., 2014). Shaheen et al. (2009) reported that carsharing will generally reduce VMT; studies that were published from 2000-2006 reported VMT reductions of 8% to 80%. In the foregoing study, Shaheen et al. (2009) noted that the manner in which the survey of users was conducted might explain some of this variation but also suggested that location-specific factors (e.g., the provision of on-street parking to operators) and differences in users might explain this variation. A review of Klincevicius et al. (2014) suggests that such differences may include income, population density, distance to destinations (such as the CBD), and availability of other modes of transportation (e.g., distance to a heavy rail station).

In large cities where parking is at a premium, surveys of carsharing users have shown a reduction in vehicle ownership. For example, Martin et al. (2010) wrote that the urban space used for street or alley parking is "a costly component of infrastructure to the public and private sector."

Table 10 summarizes the expected costs of parking based on a review of literature (Coffel et al., 2012; TRB, 2010) available in 2014. Generally, it does not appear that data on the number of parking spaces in various jurisdictions are available. Although coverage data in large city CBDs have been reported (e.g., Manville and Shoup, 2005), data on aggregate parking in Virginia jurisdictions have not been obtained (L. McFadden, personal communication, 2014).

A distribution of 30,000 surveys to carsharing members in seven large cities (Boston, New York, Portland, Seattle, Toronto, Vancouver, and Washington, D.C.) suggested that participation in carsharing organizations reduced vehicle ownership (Martin et al., 2010). To be clear, much of this reduction occurred in situations where one-vehicle households eliminated their vehicle and the vehicles removed had VMT lower than the national average (i.e., three-fourths of the vehicles removed had less than 10,000 miles annually compared to a U.S. average of 12,300 miles annually). The authors also noted that on average the shared vehicles had a fuel efficiency of 10 mpg higher than that of the eliminated vehicles.

Tal (2009) did not state that carsharing will fail to reduce VMT but questioned the magnitude of the expected decrease. Although some initial users will have no vehicle (and hence carsharing will increase their VMT), many others will seek to reduce their travel costs (and hence their VMT will drop). Tal (2009) suggested that previous studies were based on the behavior of such initial joiners. By contrast, people who join carsharing at a later time may be those who have an incentive other than cost reduction (e.g., they may need a different type of vehicle) and thus VMT reductions may not be as large for this group of later joiners. Clark et al. (2014) reported that in one peer-to-peer carsharing organization in Britain, almost one-third of members who chose to rent vehicles reported higher VMT in the period prior to joining the service; the other members reported no change. That said, Clark et al. (2014) noted that members of this carsharing organization tended to drive fewer VMT (usually under 1,000 VMT annually) than the national average in Britain (3,400 VMT annually).

Table 11 summarizes the behavioral impacts of carsharing as reported in the literature, but technology itself may influence the feasibility of carsharing. For example, Fagnant and Kockelman (2013) suggested that autonomous vehicles (defined by the authors as vehicles that require "almost no direct human input" in order to drive successfully along many types of roadways) may also increase carsharing.

Table 10. Annualized Cost per Vehicle Parking Space in the United States Circa 2010

Type of Structure	Total	Total Excluding Land	Construction	Operating and Maintenance
Suburban street	$765	$671	$326	$345
Urban street	$1,341	$888	$543	
Suburban surface lot	$885	$670 $421[a]	$326 $289[a]	$345 $132[a]
Urban surface lot	$2,062	$1,118 $302[a]	$543 $202[a]	$575 $100[a]
4-level garage	$3,835	$2,746 $2,356[a]	$2,171 $806[a]	$575 $1,550[a]
Bicycle parking	n/a	$48[a]	$12[a]	$37[a]

[a] Cost is based on Coffel et al. (2012). The cost of all other items is based on TRB (2010).

Part of this increase could be cultural as people begin to view such vehicles as an on-demand service (perhaps analogous to using a taxi), part could be economical (as people seek to reduce costs by sharing rides), and part could be technological (as people use communications technologies to allow them to access a nearby autonomous vehicle). The authors further noted that such autonomous vehicles could reduce parking requirements through increased vehicle sharing and an ability to "self-park" in less expensive areas (Fagnant and Kockelman, 2013).

Table 11. Impacts of Participation in Carsharing As Reported in the Literature

Study	Key Findings	Implications
Shaheen et al. (2009)	Carsharing programs in North America reported a VMT reduction of 8% to 80% per user.	Wide range is based partly on how the survey was designed but also on (1) differences in users and (2) differences in locations.
Martin et al. (2010)	• Each shared vehicle eliminated from 9 to 13 vehicles that otherwise would have been purchased based on surveys in six large cities and reduced the vehicles per household from 0.47 to 0.24. • Shared vehicles had greater fuel efficiency than eliminated vehicles.	• Carsharing could reduce the need for vehicles in large cities and by extension the need for parking. • Carsharing could increase fuel efficiency for the fleet overall.
Klincevicius et al.(2014)	For households within one-third mile of a carsharing station, carsharing was "negatively correlated" with vehicle ownership. (Quoted phrase used by authors because the model showed that increases in distance to the CBD or metro stations, income, or population sparseness was also correlated with increased vehicle ownership.)	• Carsharing may reduce vehicle ownership. • Other factors may influence carsharing such as income, density, and distance to amenities.
Tal (2009)	VMT reductions for later joiners of a carsharing service might not be as great as those for earlier joiners.	• Carsharing may reduce VMT but not necessarily as much as expected by initial studies.
Clark et al. (2014)	Renters of personal carsharing networks reported that carsharing increased their VMT; however, such individuals tended to drive fewer VMT than the national average.	• Carsharing may increase mobility and VMT for some individuals who previously had low VMT.

VMT = vehicle miles traveled; CBD = central business district.

Vehicle Availability and Mode Share

One reason for being interested in the number of vehicles available is its influence on mode share. AASHTO (2013), for example, reported that the national commuting mode share for driving alone was 81% for households with two vehicles available compared to 72% for households with one vehicle available. Yet the number of vehicles available is not the only factor that influences mode share; further, although the mode share for commuting is often studied because of the availability of data, commuting is just one of several trip types. Accordingly, this section first examines the extent to which the commute trip can suffice as an indicator of the mode share and then considers other factors, in addition to vehicles available, that influence this commute mode. Because people with fewer vehicles available may choose other modes, this section examines changes in the commute mode in Virginia's most urban region since 1990.

The three subsections are:

1. the commute trip as an indicator of mode share
2. demographic factors that influence the commute mode
3. changes in the commute mode in one urban region

The Commute Trip As an Indicator of Mode Share

The commute trip—defined here as the trip from home to work and from work to home—can serve as a rough indicator of a given mode's combined appeal and availability in a given jurisdiction; for example, the percentage of commuters (based on 2012 data) who used public transportation in Arlington (25%) was higher than the percentage of commuters who used public transportation in Loudoun (3%). This difference in percentages strongly suggests that public transportation is either more available, more desirable, or has some combination of desirability and availability that is higher in the former jurisdiction than in the latter. Because the mode of transportation for commuting is routinely collected as part of the ACS (e.g., U.S. Census Bureau, 2011b), the commute trip provides a ready way to assess how mode choices vary by jurisdiction.

However, a weakness of the commute trip is that it accounts for only about one-fifth of all trips. The 2009 National Household Travel Survey (Santos et al., 2011) indicated that on a national level the commute trip accounted for 16% of all trips and 19% of all mileage (when computed on a per capita basis). As a more local example, data reported by MWCOG, based on a 2007/2008 household survey specific to that region, indicated that the commute trip accounted for approximately 18.5% of all person-trips (Humeida et al., 2012). Thus, the commute trip is not fully representative of mode choice for other trip purposes. For example, the same data set (Humeida et al., 2012) suggested that whereas public transportation represents 15.6% of commute trips within the region, it represents 5.3% of all trips within the region. By contrast, whereas biking and walking accounted for 3.2% of commute trips, they represented 8.2% of all trips.

Demographic Factors That Influence the Commute Mode

In addition to location, AASHTO (2013) pointed out several factors—sex, age, race/ethnicity, immigration, income, and vehicles available—that increased the likelihood that an individual would choose a given commuting mode. These factors are ranked here from the least influential to the most influential in terms of their ability to influence driving alone:

- *Sex.* To be clear, sex matters less than the other factors named herein; that said, the female mode share (77.00%) was higher than the male mode share (76.19%) for driving alone (by a difference of 0.81%), and the female mode share (5.29%) was higher than the male mode share (4.63%) for public transportation (for a difference of 0.66%). Males were more likely than females to carpool (0.41% difference), bicycle (0.45% difference), walk (0.17% difference), or use one of the following modes: taxi, motorcycle, or walk (0.58% difference).

- *Age.* People age 55+ had a higher mode share for driving alone (78.3%) than people age 16-34 (73.3%)—a difference of 5%. By contrast, workers age 16-34 were more likely than workers age 55+ to take public transportation (2.1% difference), bicycle (0.5% difference), or walk (1.9% difference). In addition, workers in the older age group were more likely to work at home (6.5%) than workers in the younger age group (2.8%), for a difference of 3.7%.

- *Factors that were "co-mingled" with race and ethnicity.* AASHTO (2013) identified mode choice differences by race and ethnicity; however, their report also cautioned that race and ethnicity might be co-mingled with characteristics such as location, age, type of work, and wealth. That said, the mode share for driving alone was highest for the white population (80.1%) and lowest for the Asian (67.2%) and Hispanic populations (67.8%)—a difference of 12.3%. Carpooling was highest for the Hispanic population (15.8%) and lowest for the white population (8.0%).

- *Immigration.* AASHTO (2013) reported that as commuters spent a longer time in the United States, their behavior approached, but did not replicate, that of commuters born in the United States. Whereas the drive alone mode share for U.S.-born commuters was 79.1%, the drive alone mode share for immigrants was 66.0%—a difference of 13.1%. By contrast, immigrants were more likely to use public transportation (10.0% mode share) than U.S.-born commuters (3.8% mode share), and immigrants were also more likely to carpool (14.5% mode share) than U.S.-born commuters (8.6% mode share).

- *Income.* AASHTO (2013) reported that income did not affect the choice of mode to the extent it had in the past. That said, whereas 80% of workers with a high household income ($60,000 to $120,000 annually) drove alone, the percentage was 65% for workers with a low household income (less than $10,000 annually).

- *Vehicles available.* For workers with no vehicle available, the drive-alone mode share was 21%; such workers might have driven with a vehicle available from their business or with a vehicle they borrowed from a friend (AASHTO, 2013). The drive-alone mode share approached 72% for households with one vehicle and then equaled or exceeded 80% for households with two more vehicles.

AASHTO (2013) also explained that mode use also varied by profession; for example, workers with jobs in the category of "arts, recreation, lodging services" showed a greater tendency toward public transportation than toward driving alone; the reverse was the case for workers with jobs in "construction." However, AASHTO explained that such differences resulted from the location of the job as well as the factors discussed previously. For example, workers with jobs that were located in the CBD generally had a higher transit mode share than workers with jobs that were located in an exurban location.

Figure 27 summarizes how changes in certain factors influenced the drive alone mode share. For example, based on a review of AASHTO (2013), changing from a no-vehicle available household to a 1-vehicle-available household increased the drive alone mode share from 21% to 72%, for a difference of 51%; this difference is shown in Figure 27. For example, in Figure 27, 80% of workers with a high household income ($60,000-$120,000) drove alone compared to 65% of workers with a low household income (under $10,000). The difference (80% − 65% = 15%) is shown in the figure.

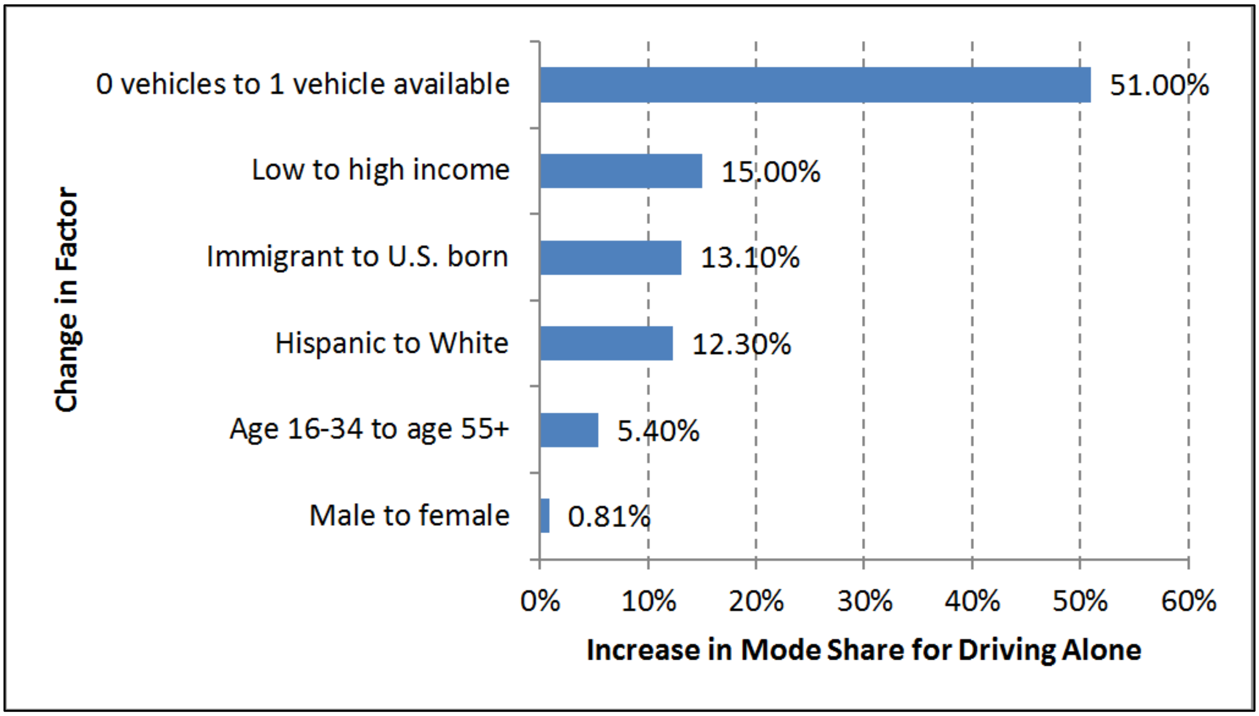

Figure 27. Influence of Factors on Mode Share for Driving Alone. Data from AASHTO (2013). For example, AASHTO (2013) reported that 73.3% of persons "Ages 16-34" drove alone compared to 78.7% of persons "Ages 55+"; accordingly, the difference (5.40%) is reported in Figure 27.

Changes in the Commute Mode in One Urban Region

In the Northern Virginia PDC, public transportation is a substantial contributor to mode share—and one that increased substantially over the past decade—but public transportation is not the largest mode of transportation. For the Northern Virginia PDC, based on *1-year* 2012 ACS data for the five jurisdictions with a population of at least 65,000 (Arlington, Alexandria, Fairfax County, Loudoun, and Prince William, representing 96% of the workers age 16+ in the region), and based on the *5-year* 2008-2012 ACS data for the four jurisdictions under 65,000 in population (Fairfax City, Falls Church, Manassas, and Manassas Park representing 4% of the workers age 16+ in the region), the mode shares for journey to work were drive alone (70.4%), public transportation (10.3%), carpool (10.1%), worked at home (5.5%), walked (2.2%), taxi/motorcycle/other (1.0%), and bicycle (0.5%).

Since 1990, the share of public transportation for the region has increased: according to the 1990 and 2000 Census Transportation Planning Package, mode share attributable to a single category reported as "public transportation (including taxicab)" in the Northern Virginia PDC was 9.4% (in 1990) and 8.6% (in 2000). If it was the case that taxi had a 0% mode share in 2000, public transportation's mode share has increased by 1.7 percentage points, from 8.6% to 10.3%. (The single category of "taxicab, motorcycle, or other means" was 1% of all modes in 2012. The single category of "motorcycle or other means" was 0.7% of all modes in 2000. If it was the case that the true mode share of taxi and the true mode share of motorcycle did not change from 2000-2012, an estimate of taxi mode share in 2000 would have been 0.3%, meaning that public transportation alone would have had an 8.3% mode share in 2000. Therefore, the increase in the public transportation mode share to 2012—from 8.3% to 10.3%—would have been about 2 percentage points.)

Carpooling also dropped over this period, from 16.3% (in 1990) to 13.5% (in 2000) to 10.1% (in 2012). AASHTO (2014) reported that carpooling for the United States as a whole dropped from 13.4% (in 1990) to 12.2% (in 2000) to 9.7% (in 2010). Thus carpooling in the Northern Virginia PDC remained nominally higher than the national average but showed a drop of roughly 6 percentage points (from 1990- to 2012) compared to a drop of roughly 4 percentage points for the same period.

Figure 28 compares the most recent data available for five modal categories (shown as 2012) to the mode shares from the 1990 and 2000 CTPPs (based on where people reside). As may be seen, public transportation and taxi were combined in the 1990 and 2000 CTPPs, and taxi was combined with motorcycle in the 2012 ACS. Therefore, to have equivalent categories, in Figure 28, public transportation, taxi, and motorcycle are aggregated. Biking and walking were combined in the 1990 and 2000 CTPPs and thus are aggregated in Figure 28.

Figure 28 shows that the carpooling percentages dropped and telecommuting percentages rose. It is not clear if these two trends are related. The U.S. Department of Transportation (1993) raised the possibility that an increase in telecommuting might reduce ridesharing, noting the need for additional research in that area (which would support such an inference). Wells et al. (2001) noted that in a sample of Minnesota travelers, telecommuters had higher rates of carpooling than did non-telecommuters. More recently, Mans et al. (2012) noted that telecommuting's impact on travel could be "positive, negative, or neutral" with respect to overall VMT.

A limitation of this presentation of data is that because the ACS has a smaller sample size than the decennial long form on which the CTPP is based (Cambridge Systematics, Inc., et al., 2007), one would expect the margin of error to be larger for the ACS, and to be clear, no tests of statistical significance have been conducted by the authors of this report with these data. Further, a characteristic of Figure 28 is that it presents the data in a specific manner—as a percentage of total mode share. An alternative approach—which does not convey as much information—would have been to show the increase in public transportation use only, without other modes, from the 2000 CTPP through the 2012 ACS, as shown in Figure 29. By the omission of information about the modes with a larger mode share, the change in public transportation appears more dramatic. (A potential problem with Figure 29 is that the sampling methods for the CTPP and ACS are different, but Figure 29 simply shows another way of presenting this information.)

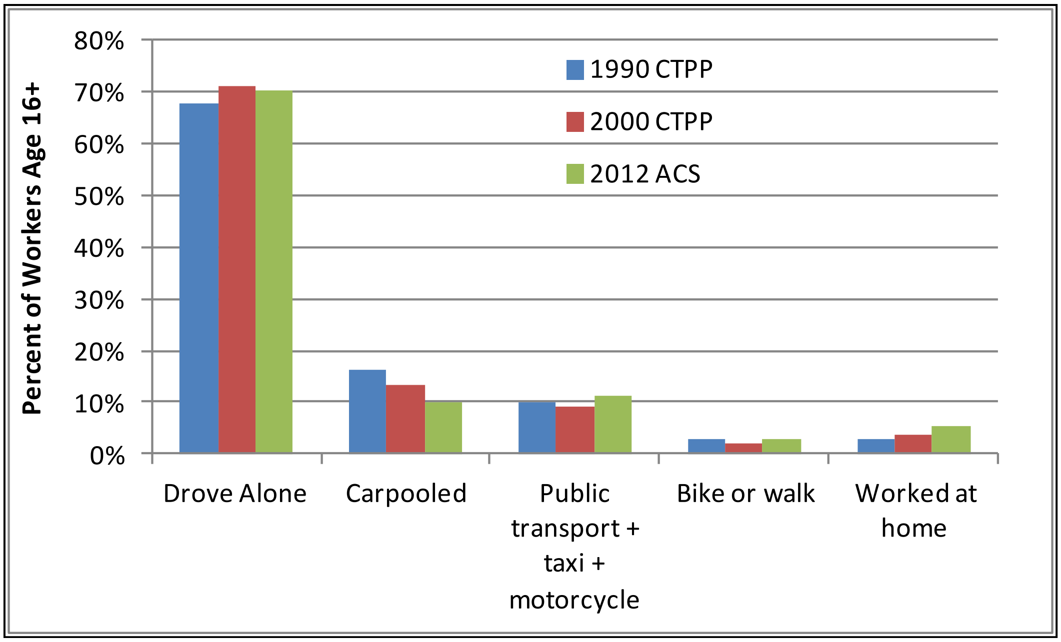

Figure 28. Commuter Mode Use by Commuters Age 16+ for the Northern Virginia PDC. CTPP = Census Transportation Planning Package; ACS = American Community Survey. Data for 1990 CTPP from AASHTO (2003); data for 2000 CTPP from AASHTO (2003); data from 2012 ACS from U.S. Census Bureau (Undated c, d).

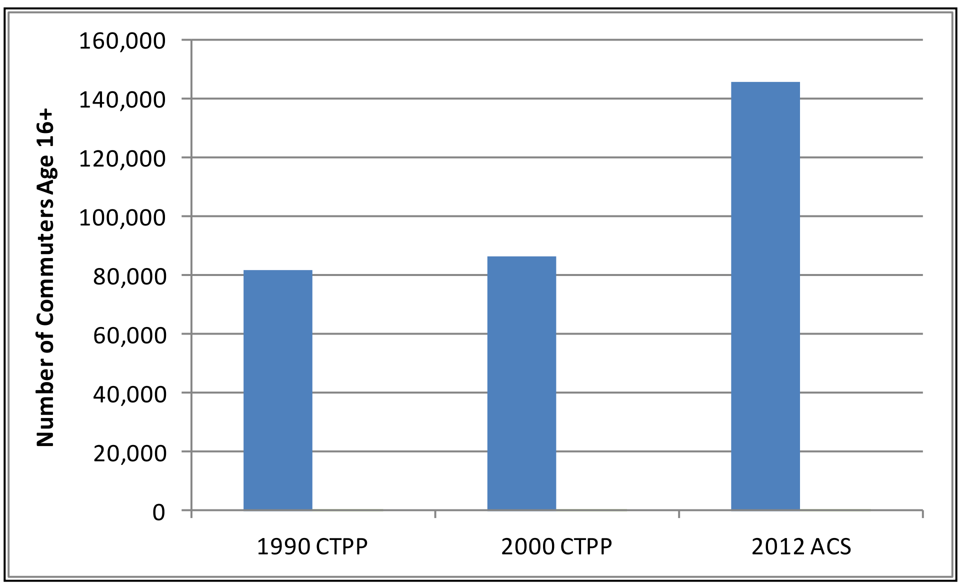

Figure 29. Number of Commuters Age 16+ Using Public Transportation for the Northern Virginia PDC. CTPP = Census Transportation Planning Package; ACS = American Community Survey. Data for 1990 CTPP from AASHTO (2003); data for 2000 CTPP from AASHTO (2003); data for 2012 ACS from U.S. Census Bureau (Undated c, d).

Societal Impacts of VMT

Changes in VMT can have both positive and negative impacts for society. To the extent that VMT is an indicator of ease of travel, increased VMT can signify increased access to activities such as employment, recreation, and trade. For example, it is generally accepted that international trade has increased over the past 50 years. Dicken (2011) reported that two major transportation improvements—the widespread use of commercial jets and the advent of containers for shipping—reduced transportation costs from 8% of total import costs in 1970 to just 3% of such costs in 2002.

That said, when considering just vehicle travel, Litman (2009) suggested that each additional mile traveled levied additional societal costs that are not borne by the vehicle owner, and these costs are the focus of this subsection and the first stakeholder input exercise in Appendix D. Although the motorist pays for certain costs such as owning and maintaining the vehicle, fuel, insurance, and travel time that the motorist spends in congestion, there are also external costs to society not paid by the motorist. These include (1) impacts on the environment (e.g., air pollution, greenhouse gases, noise, and water pollution); (2) impacts on other motorists (e.g., congestion and crashes), ancillary transportation services (e.g., retiming of traffic signals); and opportunity costs (e.g., the land that is used for transportation does not generate economic value through other means). A total of 27 disparate such costs were identified in these four categories, and a subset of these is shown in Figure 30.

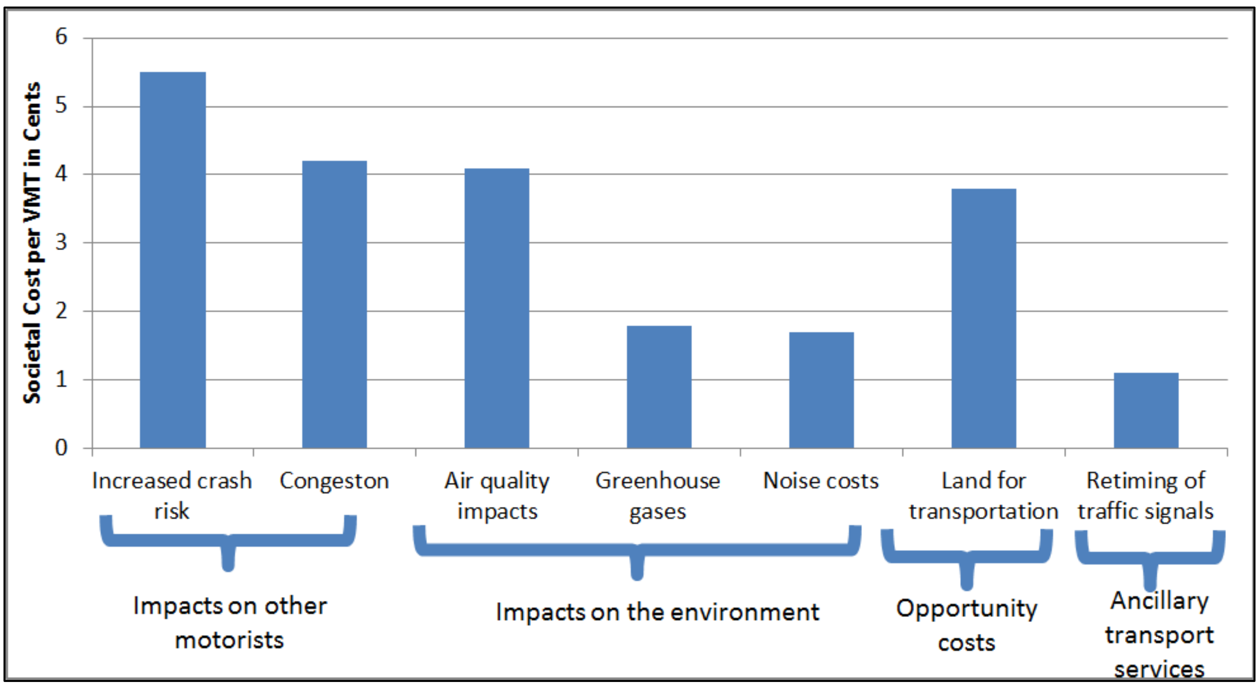

Figure 30. Subset of Societal Costs for Travel by an "Average" Vehicle Identified by Litman (2009). (Litman identified societal costs (e.g., costs to society not borne by the vehicle driver) that are not shown in the figure. Assumptions for this "average" vehicle as noted by Litman included an average fuel efficiency of 21 mpg and an average occupancy of 1.5 persons per vehicle.)

To be clear, the amount of these costs varies by individual circumstance; for example, Litman (2009) suggested that the external cost per VMT could be $0.27 (for a rural area), $0.42 (for travel during an off-peak time in an urban area), or $0.55 (for travel during a peak time in an urban area). Generally, these societal costs represented an additional 40% to 58% increase above the costs paid by the motorist; for example, a motorist in a rural area might pay $0.67 per VMT; this number did not include the societal costs not paid by the motorist, which were estimated as $0.27 per VMT (Litman, 2009).

A weakness of such costs is that they aggregate disparate effects of VMT. For example, two societal impacts of the additional VMT generated by a single motorist who moves to an urban area can be considered: an increase in crash risk and an increase in congestion. These two societal costs are distributed very differently: a crash exerts a tremendous cost on a small number of people (only those involved in the crash with the new motorist), whereas congestion exerts a small cost on a larger number of people (those traveling at the same time as the new motorist).

Accordingly, one can also consider individual societal costs per VMT. For example, Mashayekh et al. (2011) reported that based on an examination of impacts in U.S. urban areas, air quality costs were about 3 cents per VMT; such costs included environmental impacts (e.g., loss of crops), human impacts (e.g., mortality), and impacts of greenhouse gas emissions. The authors also reported previous research that excluded greenhouse gases and considered only the health impacts of pollutants that currently are regulated under the Clean Air Act Amendments, such as nitrogen oxides, volatile organic compounds (both of which react in summer months to produce ground level ozone or smog), ammonia, carbon monoxide, and particulate matter; the societal costs per VMT were reported as 1.3 to 1.4 cents (Mashayekh et al., 2011).

To be clear, quantifying the impact of VMT on these different aspects requires assumptions. For example, writing for the World Bank, Minjares et al. (2014) reported that emissions generally affect asthma, lung function, and cardiovascular health; however, with regard to specific emissions (such as particulate matter smaller than 2.5 microns in diameter), the amount of emissions contributed by motor vehicles relative to other sources ranged from 5% to 50%. Thus, it can be difficult to say precisely that *x* VMT will have *y* health effects.

CONCLUSIONS

Three questions were raised in the "Purpose and Scope" section of this report:

1. What population and employment growth is forecast for 2040?

2. What other changes in terms of factors that relate to population and that also influence travel demand are expected by 2040?

3. How can changes in population growth or related factors be linked to travel demand and a societal outcome?

To answer these questions, 26 findings are noted here. Question 1 is addressed by Findings 1 through 15, which concern population and employment growth forecasts; the uncertainty associated with population and employment forecasts as discussed in Appendices A and B; and how migration and immigration might affect population and employment growth. Question 2 is addressed by Findings 16 through 24, which concern demographic factors related to population, such as vehicle ownership and driver's licensure rates, forecasts of vehicle ownership, carsharing, forecasts of fuel usage and prices (see Appendix E), and VMT. Question 3 is addressed by Findings 25 and 26, which provide one example of how the location of population growth may influence the demand for travel, which is measured as VMT and which in turn may be linked to societal costs.

Population Forecasts

1. *By 2040, Virginia's population is expected to grow by approximately 2.34 million, with more than one-third of this increase (36%) attributable to people age 65+*. Whereas this age group represented 13% of Virginia's population as of 2012, it is forecast to represent 18% of the population in 2040. Although the youngest subset of this demographic (people age 65-74) is forecast to increase from 7.5% (in 2012) to 8.6% (in 2040) of Virginia's population, the forecast increases for older age groups are more dramatic: people age 75-84 may increase from 3.8% (in 2012) to 6.8% (in 2040), and people age 85+ may increase from 1.6% to 2.7% over the same period.

2. *This population growth is not forecast to be distributed evenly by location*. According to Weldon Cooper (2012a), 4 of Virginia's 21 PDCs accounted for 77% of the forecast population growth (Northern Virginia, Richmond Regional, Hampton Roads, and George Washington) and 10 of Virginia's 133 jurisdictions accounted for 71% of the forecast growth. The 10 jurisdictions were Chesterfield County, Fairfax County, Loudoun County, Prince William County, Stafford County, Spotsylvania County, Henrico County, Chesapeake, James City County, and Frederick County.

   However, according to Woods & Poole (2014), the same 4 PDCs accounted for 81% of forecast growth and the top 10 jurisdictions accounted for 76% of the forecast growth. Further, the top 10 jurisdictions were similar but not identical to those forecast by Weldon Cooper (2012a): Fairfax County, Loudoun County, Prince William County, Chesterfield County, Henrico County, Chesapeake, Virginia Beach, Spotsylvania County, Stafford County, and Bedford. (It should be noted that Woods & Poole combined some counties and cities; for instance, the portion of growth attributed to Fairfax County had to be separated by the authors of this report from the portion attributed to Fairfax City and Falls Church.)

3. *For all subpopulations, the proportion of statewide population in locations designated as Central or Outlying Hampton Roads, Northern Virginia, Richmond, defined by the U.S. Census Bureau as CBSAs, is forecast to increase from slightly more than 65% in 2012 to slightly less than 69% in 2040, with decreases in small urban areas and non-CBSA areas*. The forecasts for all three population age groups (under age 20, age 20-64, and age 65+) show a similar trend. Nominally, there is a difference between the forecasts for these groups

and those for the millennials (age 20-34 as of 2012 [i.e., born 1978-1992] and roughly age 45-59 in 2040), for which a slight increase in those that would reside in what are characterized in the report as outlying small urban areas and non-core areas (i.e., areas that are not part of a CBSA) is forecast. (Forecast age data are available only in 5-year increments such that age 45-59 is the approximation of the millennial generation in 2040. That is, this report defines millennials as persons born between 1978 and 1992 inclusive for the "present" case [based on year 2012 population data], but because forecast age data are available in 5-year increments, millennials in 2040 are persons born between 1981 and 1995 inclusive.)

4. *About one-half of the 2.34 million population growth expected by 2040 is expected to be in transit-compatible areas.* In recognition that a variety of factors influence the feasibility of public transportation, a rough indicator of transit compatibility is a jurisdiction that has a population density of at least 1,200/square mile. Almost one-half of Virginia's population growth from 2012-2040 is expected to be in jurisdictions that are projected to have a density of 1,200/square mile in 2040.

Employment Forecasts

5. *Forecast employment growth is not evenly distributed by location.* Woods & Poole (2014) suggested that 81.6% of all employment growth from 2012-2040 will be in 4 PDCs: Northern Virginia (48.2%), Richmond Regional (15.3%), Hampton Roads (14.1%), and George Washington (which hosts the City of Fredericksburg) (4.0%). The same data set suggests that 78.5% of all employment growth from 2012-2040 will be in these 10 areas: Fairfax County–Fairfax City–Falls Church, Loudoun, Henrico, Prince William–Manassas–Manassas Park, Chesapeake, Chesterfield, Virginia Beach, Arlington, Spotsylvania-Fredericksburg, and Alexandria. (In some cases this data set combines cities and adjacent counties.) Statewide, Woods & Poole (2014) data suggested a 60% growth in employment in 2040 relative to 2012. However, when all 21 PDCs were considered, the median increase was 35.7%, as discussed in Appendix B.

6. *For the previous decade (2000-2010), the area less than 5 miles from city hall accounted for less than 10% of the region's growth for the three large metropolitan areas in Virginia but accounted for more than one-fifth of the region's growth for six of the eight smaller metropolitan areas in Virginia.* For the decade 2000-2010, the area less than 5 miles from city hall accounted for 6% to 10% of the region's growth overall for the three U.S. Census–defined metropolitan areas of Virginia Beach–Norfolk–Newport News, Washington-Arlington-Alexandria, and Richmond. For six of Virginia's smaller metropolitan areas, the percentage of growth less than 5 miles from city hall averaged 36% (Blacksburg-Christiansburg-Radford, 40%; Charlottesville, 33%; Harrisonburg, 58%; Lynchburg, 22%; Roanoke, 21%; and Winchester, 43%). For the two other smaller metropolitan areas, the percentage was on the order of 6% (Kingsport-Bristol) or negative (-105%) because of population loss (Danville).

Uncertainty of Virginia Population and Employment Forecasts

7. *There is more uncertainty associated with employment forecasts than with population forecasts. Further, there is more uncertainty associated with county level forecasts than with state and regional forecasts.* Historically, 20-year county population forecasts have had an average error of 24% (see Appendix A) (Weldon Cooper, Undated), whereas the 20-year population forecasts for larger areas such as a set of six metropolitan regions throughout the United States were an average of 7.3% (TRB, 2007). In short, one might have the most confidence in the statewide population forecasts in Table 1, less confidence in the regional forecasts in Figure 4, and the least confidence in the county-specific forecasts in Table 4.

   Employment forecasts may have additional uncertainty because of the behavioral component. For example, a 20-year retrospective analysis by the National Capital Region Transportation Planning Board (2013) suggested that jurisdiction-level employment forecasts might have an average absolute error of 25% compared to a population error of 11%; Woods & Poole (2014) noted that average absolute percentage errors for employment and population for counties are 8.3% and 13.2%, respectively, over a 10-year period. (Generally, behaviors are more difficult to forecast: e.g., it is not known if millennials' current preference for urban regions is a temporary or long-term trend.)

8. *Population forecasts by Weldon Cooper (2012a) are not identical to those by PDCs but seem similar.* For all PDCs for which forecasts by the PDC were available, the Weldon Cooper and PDC population forecasts differed by an average of only 2.5%. For example, Weldon Cooper (2012a) and MWCOG (2013) forecasts differed, on average, by 3% for the region.

9. *State population forecasts by Woods & Poole (2014) and Weldon Cooper (2012a) differ by about 14%.* Woods & Poole's forecast for Virginia's 2040 population was 11.7 million, and Weldon Cooper's was 10.5 million, a 1.1 million difference. For the Northern Virginia PDC, forecasts differed by 22%. For example, Loudoun County was forecast to grow 148% by Woods & Poole and 68% by Weldon Cooper; Stafford County was forecast to grow 70% by Woods & Poole and 148% by Weldon Cooper. It is important to note that Weldon Cooper and Woods & Poole used different methods to make population forecasts; the former focused on historical trends, and the latter used an economic model (noting that "population is a function of employment opportunities").

10. *Population change forecasts by Weldon Cooper (2012a) and Woods & Poole (2014) are similar for most PDCs.* For 2040, the difference for 18 of the 21 PDCs was less than 50,000 and for 20 of the 21 PDCs was less than 150,000. For 19 of the 21 PDCs, the difference was less than 20%. For the 3 PDCs for which a local 2040 forecast was available, the local forecast was between the forecasts of Weldon Cooper and Woods & Poole, suggesting that these two sources can provide a useful range for population forecasts.

11. *An empirical confidence interval suggests that the statewide 2040 employment growth might vary from 31% to 89% of the forecast value.* With the Woods & Poole (2014) forecast of 60% growth in statewide employment as a midpoint, the statewide growth in employment

relative to 2012 might range from 31% to 89% based on the methods developed as described in Appendix B.

12. *Statewide, per capita total income is forecast to increase 59% from 2012-2040 after controlling for inflation (Woods & Poole, 2014).* Such income includes not only wages but also dividends, interest income, rental income, government transfer payments, and other income; in short, it is income from all sources. As discussed in Appendix B, this income growth varies by PDC, and although a specific confidence interval was not calculated, it is acknowledged that uncertainty will affect these estimates, as is the case with population and employment growth forecasts. Woods & Poole reported that over a 10-year period, the average absolute percent error for income forecasts at the metropolitan area level throughout the United States was 9%.

Possible Effects of Migration and Immigration on Population and Employment Growth

13. *The combination of migration (from other U.S. states) and immigration (from abroad) is expected to be a substantive driver of population growth in Virginia.* Currently one in nine people in Virginia is an immigrant. Immigrants and their descendants are forecast to contribute approximately 82% of the national population growth from 2005-2050 (Passel and Cohn, 2008), and this trend is likely to be reflected in Virginia's growth. When both immigration and migration were considered, more than one-half of Virginia's growth from 2000-2010 was from some form of migration. The most recent annual data available—the 2012 ACS—suggested that the number of people who moved to Virginia over a 1-year period accounted for approximately 4% of Virginia's population.

14. *Immigration is expected to contribute primarily to the growth of the youth and working-age subpopulations.* Immigrants are most often in the 20-35 age group and generally have a higher birth rate than the U.S.-born population. New immigrants and their children and grandchildren will therefore contribute the majority of the growth in the youth and working-age populations in the coming decades as the native-born population ages overall (AIC, 2012; Passel and Cohn, 2008).

15. *There is substantive uncertainty in the forecast of immigration rates.* Overall immigration rates and representation from different countries of origin depend on political and economic conditions in the United States and abroad as well as future legislation limiting or extending entry into the United States (see, for example, NILC, 2013; Woodrow Wilson School of Public and International Affairs at Princeton University and The Brookings Institution, 2011).

Vehicle Ownership and Driver's Licensure Rates

16. The propensity to own a vehicle for individual travel can be measured in at least four ways based on the data that are available: registered automobiles and light trucks per capita (which includes commercial vehicles); vehicles available per household; driver's licenses per capita; and the number of households with zero vehicles (see Table 12). Although the *decrease in licensure rates could imply less reliance on vehicle transport, the other three measurements would not necessarily support this inference.*

A slightly different data set (i.e., Department of Motor Vehicles) than that used to determine licensure rates in Table 12 shows variation by location, where the PDC with the highest licensure rate in 2012 (Middle Peninsula PDC with 93.4%) and the PDC with the lowest licensure rate in 2012 (New River Valley PDC with 72.4%) have a difference of more than 20 percentage points.

Table 12. Summary of Vehicle Ownership and Driver's Licensure Rates for Virginia

Metric	Source	1990	2000	2012
Registered vehicles per person[a, b]	FHWA *Highway Statistics*	0.787	0.842	0.845
Vehicles available per person[b]	Census Transportation Planning Package and the American Community Survey	0.668	0.698	0.709[b]
Zero-vehicle households		8.8%	7.6%	6.3%
Virginians age 15+ with a driver's license	FHWA *Highway Statistics*	89.2%	86.0%	83.4%
Virginians age 20+ with a driver's license		92.7%	89.4%	87.3%

[a] Computed as private and commercial automobiles, trucks, and motorcycles minus truck tractors and farm trucks; this metric includes, however, vehicles that are nonetheless commercial.
[b] This figure is for all Virginians—those in households and those in institutions. For year 2012, the ratio is probably underestimated.

Forecasts of Vehicle Ownership and Possible Carsharing Impacts

17. *A consensus view is that vehicle ownership per capita in the United States will not increase*. Some sources suggest that such ownership will remain flat (e.g., BP, 2014), and others identify factors that affect this ownership (e.g., Chatman and Klein, 2013; Litman, 2014). Factors that have led to increased ownership in the last one-half of the 20th century included better roads, more affordable vehicles, and higher travel speeds. Factors that could lead to decreased per capita ownership levels include uncertainty about employment, higher parking costs, concern about emissions, the substitution of electronic communications for some trips, delayed driver's licensing, more people living in urban rather than rural areas, and some groups of immigrants using vehicles to a lesser degree than U.S.-born residents even after socioeconomic differences are accounted for.

18. *Virginia forecasts for vehicle ownership have both similarities and differences with national trends.* Vehicle ownership rates do not appear to be declining, but their rate of growth appears to have slowed or stopped: an estimate of registered vehicles per person in Virginia for year 2012 (0.845) was similar to that for year 2000 (0.842). The number of Virginians with a driver's license has dropped: whereas 89% of Virginians age 15+ had a driver's license in 1990, this percentage was 83% in 2012, with more substantive decreases in the younger age groups. However, the number of number of households with zero vehicles available has also dropped steadily since 1990. A possible explanation is Virginia's geographic diversity: from 1990-2000, the number of vehicles available per person increased in most (26 of 30) of Virginia's largest jurisdictions; then from 2000- 2012, this ratio increased in only about two-thirds (20 of the 30 jurisdictions). Interestingly, *The Economist* (2012) reported that 6% of people in rural areas live without a vehicle compared to 13% of

people in large cities; in Virginia, an estimated 3.9% to 4.4% of people live without a vehicle.

19. *National data indicate that the number of vehicles available influences commute mode share.* AASHTO (2013) reported that for workers with no vehicle available, the drive-alone mode share was 21%; it increased to 72% for households with one vehicle available and exceeded 80% for households with two vehicles available. Other factors that had an impact on commute mode share, listed in decreasing order of influence as measured by their ability to influence the SOV mode, were income, immigration, age, and gender. For example, 80% of people with a high household income drove alone compared to 65% of people with a low household income, for a difference of 15%; people age 55+ had a higher mode share for driving alone (78.3%) than people age 16-34 (73.3%)—a difference of 5%.

    To be clear, there can be scatter in any data set. For example, in the nine jurisdictions defining the Northern Virginia PDC, the commute mode share for driving alone *increased* from 67.9% (in 1990) to 71.1% (in 2000) and then *decreased* to 70.4% (in 2012). Five of these nine jurisdictions, which each had a population over 65,000, accounted for more than 96% of the workers age 16+ residing in the PDC, and in those five jurisdictions, the number of vehicles available was also known. The number of vehicles available per person overall in these five jurisdictions decreased from 0.700 (in 1990) to 0.684 (in 2000) to 0.664 (in 2012). Thus, in this particular example, the link between vehicles available and mode share was not immediately apparent.

20. *Carsharing, defined as the short-term use of a vehicle on a per-mile or per-hour basis, has the potential to reduce VMT and vehicle ownership; however, the reductions are dependent on location and user characteristics*. Benefits of carsharing reported in previous studies included reduced VMT (8% to 80%); reduced fuel consumption because of shared vehicles having greater fuel efficiency than nonshared vehicles; and reduced vehicle ownership (Martin et al., 2010; Shaheen et al., 2009). Realization of such benefits depends on the characteristics of the location where the sharing takes place (e.g., the availability of alternative transportation or access to destinations) and the characteristics of the user (e.g., some participants in a carsharing program may participate in order to use a different type of vehicle [Tal, 2009]). One area of exploration in denser environments may be reduced costs of parking, given that the annualized construction and operating cost for a parking space may range from $765 (for a suburban street) to almost $4,000 (for a four-level parking garage). Another benefit noted in the literature is increased mobility options for people without a vehicle, and although such users will increase VMT, the amount of VMT they drive tends to be small relative to people who have their own vehicle (Clark et al., 2014).

21. *The discussion of carsharing suggests that behavioral uncertainty is exacerbated by new technologies.* The literature suggests that the advent of autonomous vehicles may accelerate carsharing (Fagnant and Kockelman, 2013), partly because of economics (where people seek to attain the benefits of these vehicles without the capital outlay) and partly because of cultural changes (as people become accustomed to sharing vehicles). Yet it is not yet clear whether such trends will occur. A contributing factor may be public policies toward carsharing, such as the provision of parking for such vehicles.

Forecasts of Fuel Usage and Prices

22. *In 2040, fuel prices in the United States are forecast to range from $3.11 to $6.23 per gallon in 2012 dollars, and other ranges are possible.* As described in Appendix E, midpoint forecasts for 2040 fuel prices per gallon, in 2012 dollars, were $3.90 (gasoline) and $4.73 (diesel) (U.S. EIA, 2014). However, based on assumptions about economic growth in the Middle East and China; Canadian production costs for bitumen; and Brazilian production costs for renewable fuels, the U.S. EIA (2014) suggested that 2040 gasoline prices may vary from $2.61 to $5.04 and diesel prices may vary from $3.11 to $6.23 (in 2012 dollars). Other suggested ranges were $5.71 to $9.41 in 2012 dollars (Booz Allen Hamilton, 2014) based in part on older U.S. EIA work and based on a scenario analysis that considered a low price and a high price: $3.88 to $15.52 (Erdogan et al., 2013).

23. *Freight in 2040 may account for about one-third of BTUs consumed in the United States.* When considering just five modes, the U.S. EIA (2014) forecast the percentages of BTUs consumed to be 53% for light duty vehicles, 33% for freight trucks, 12% for air, 2% for freight rail, and less than 1% for passenger rail. By 2040, the U.S. EIA (2014) forecast that compressed natural gas / liquefied natural gas (CNG/LNG) vehicles will grow by a factor of almost 20, such that such fuel will account for 3% of total BTUs consumed by the transportation sector. Most of this consumption of CNG/LNG is by either medium duty or heavy duty vehicles (71%) or freight rail (17%).

24. *According to the U.S.EIA (2014) one-third of all vehicles sold in the United States in 2040 are projected to be "micro hybrid" vehicles* (hereinafter hybrid vehicles) in that they can use gasoline or diesel but not at idle. Other types of electric vehicles, such as plug-in hybrid vehicles, are expected to account for 7% of new light duty vehicle sales, and vehicles that can be fueled by E85 are expected to account for 11% of light duty vehicle sales.

Reasons to Forecast Change in Location Growth and VMT

25. *One reason to forecast location growth is to understand impacts on VMT and, by extension, the demand for other modes of transportation.* Higher density is associated with lower VMT and more transit use, but the strength of this association varies by location. For example, some literature suggests that greater VMT reductions may occur if the density of a higher density location is increased than if the density of a lower density location is increased. As an illustration, Figure 31 overlays 2010 population densities for select Virginia jurisdictions over a graph of the expected impacts on VMT reported by Meyer and Miller (2013). (In Figure 31, Meyer and Miller [2013] reported data suggesting that jurisdictions with population densities of 500-2,000/square mile tended to have 11.6% fewer VMT than jurisdictions with population densities less than 500/square mile. Three Virginia jurisdictions with a 2010 population density in the former category are Emporia, Henrico, and Loudoun. Hypothesized VMT reductions are based solely on those reported by Meyer and Miller (2013), and the densities are based on 2010 populations and land areas [U.S. Census Bureau, Undated a, 2011a].)

Virginia-specific data show a negative correlation of -0.67 between vehicles available per capita and density. For example, the Virginia jurisdictions with a population under 250/square mile in 2012, such as Augusta and Hanover counties, had an average of 0.79 vehicles available per capita, whereas the jurisdictions with a population of 2,000-4,000/square mile, such as Newport News and Richmond, had 0.64 vehicles available per capita.

A limitation of this finding is that passenger demand is not the only determinant of VMT: the decrease in freight explains almost one-half (43%) of the national decline in VMT since 2007 (Polzin and Chu, 2014), and, as noted in Finding 24, freight may account for one-third of energy consumed by the transportation sector in 2040 (U.S. EIA, 2014).

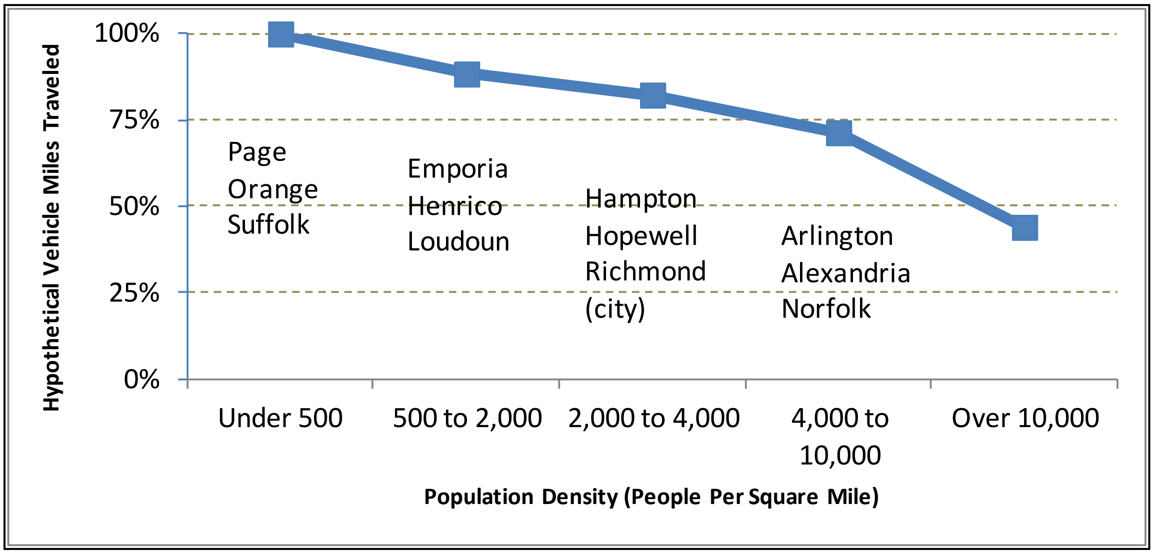

Figure 31. Potential Relationship Between VMT and 2010 Population Density. Data from Meyer and Miller (2013) and U.S. Census Bureau (Undated a, 2011a). Actual Virginia VMT were not collected. (The language used in the categories shown in the horizontal axis is the original language of Meyer and Miller [2013] such that in theory the year categories overlap at certain points such as exactly 2,000 people per square mile; in practice, because density requires division of population by land area, it is always possible to determine whether density is above or below a particular value.)

26. *One reason for quantifying changes in VMT is to evaluate societal costs of alternatives, such as alternative transportation investments and alternative land development patterns.* Societal costs refer to costs not borne by the motorist. Examples include environmental impacts (e.g., air pollution, greenhouse gases, noise, and water pollution); effects on other motorists (e.g., congestion and crashes); ancillary transportation services (e.g., retiming of traffic signals or other traffic control); and opportunity costs (e.g., the land that is used for transportation is land that does not generate economic value through other means). To be clear, such costs are dependent on assumptions: for instance, air quality costs alone have been monetized based on values of 1.3 to 3.0 cents per VMT depending in part on whether only health effects were included (based on pollutants regulated by Clean Air Act Amendments) or whether additional impacts attributable to greenhouse gases (e.g., crop damage) were included (Mashayekh et al., 2011). That said, Litman (2009) suggested such aggregate societal costs may range from $0.27 to $0.55 per VMT.

RECOMMENDATION

1. *The Virginia Department of Transportation's Transportation and Mobility Planning Division and the Virginia Transportation Research Council should share the forecasts generated in this report with Virginia planners*. Such planners include VDOT and PDC staff. The reason for sharing these forecasts is that they may help staff evaluate various alternatives that relate to transportation investments, including investments that affect land development.

BENEFITS AND IMPLEMENTATION

Benefits

In some locations, stakeholders may be able to anticipate a wider range of transportation investments than would be the case if the forecasts were not considered. For example, in locations where density is increasing in order to make public transportation more feasible, the forecasts may enable one to consider both highway and fixed-route transit investments, and possibly one might be more cost-effective than the other. In locations where persons who do not have a driver's license is increasing yet where densities remain low, one might consider paratransit solutions. A potential benefit of implementing this recommendation, therefore, is that in some locations one may be able to consider a wider range of investments which may lead to identification of either more cost-effective investments or investments that address an unmet transportation need.

Implementation

This recommendation has been partially implemented through sharing this information at the Virginia Planning and Programming Annual Meeting (held February 4, 2015) and at a subsequent statewide meeting 1 week later that was attended by PDC staff. These forecasts have also been provided to individual PDC staff that have requested certain data elements. Publication of this report will complete the implementation of this recommendation.

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APPENDIX A

VARIATION IN POPULATION-RELATED CHARACTERISTICS

Overview

Transportation is a derived demand, meaning that to forecast transportation needs for a region, one must forecast the underlying population, which will generate these transportation needs. Accordingly, the body of this report provides population projections for each PDC in Virginia. Yet a population projection—even if presented as a single number—in fact represents different characteristics that also influence transportation demand. This appendix discusses four such population-related characteristics:

1. alternative population forecasts by PDC
2. driver's licensure rates by PDC
3. relationship between age and disability
4. impact of limited English proficiency (LEP).

Four tasks were required to analyze these population-related characteristics.

1. *Obtain alternative 2040 population forecasts.* Data were obtained from two statewide sources: Weldon Cooper (2012a) and Woods & Poole (2014). In addition, representatives of each of Virginia's 21 PDCs were contacted by telephone and asked if they used alternative forecasts, i.e., other than Weldon Cooper or the Virginia Employment Commission (VEC), for their locality. (VEC was mentioned because historically VEC has been responsible for generating population forecasts; at the time of this analysis in 2015, VEC had contracted with Weldon Cooper to produce these forecasts.) If the PDCs used alternative forecasts, the source of the alternative forecast was noted and the data for those respective forecasts were compiled and are presented in Table A1. If the PDCs did not use forecasts other than Weldon Cooper (or the VEC), no PDC data are listed.

2. *Compare alternative 2040 population forecasts.* The term "modified" PDC was used because a few counties are a member of more than one PDC. In order to determine jurisdictions for PDCs that formed a complete partition of Virginia where every county or city was included in only one PDC, the following modifications were made by the authors of this report. For PDC 12 (West Piedmont), Franklin County was not included as it was included in PDC 5 (Roanoke Valley–Alleghany). For PDC 14 (Commonwealth), Nottoway County was added as Nottoway had not previously been included in any PDC. For PDC 19 (Crater), Charles City County and Chesterfield County were not included, as they were included in PDC 15 (Richmond Regional). For PDC 23 (Hampton Roads), Surry County was not included, as it was included in PDC 19 (Crater). Gloucester County was also not included in PDC 23, as it was included in PDC 18 (Middle Peninsula).

For some adjacent localities, the forecasts from Woods & Poole (2014) were combined. For example, Woods & Poole (2014) had a single projection for the area defined by Fairfax County, Fairfax City, and Falls Church City, whereas Weldon Cooper (2012a) had separate projections for each of these three jurisdictions. Thus, one can compare only the combined area of these three jurisdictions.

3. *Compute licensure rates across localities.* The number of licensed drivers by jurisdiction each year is released by the Virginia Department of Motor Vehicles (1999, 2005, 2012). These localities were sorted into jurisdictions of the 21 PDCs. Licensure rates based on people age 15+ were calculated for each PDC. The licensure rate is calculated as follows:

   Licensure rate = Number of licensed drivers / Number of people age 15+

   The reason age 15+ was used in the denominator is that the historical population data obtained from Woods & Poole (2014) were given by 5-year age group (e.g., under age 5, age 5-9, age 10-14, age 15-19, and so forth). By using age 15+ in the denominator of the licensure rate, one has a rough approximation of the number of eligible drivers.

4. *Collect information regarding LEP and disabilities.* Data from the ACS (U.S. Census Bureau, 2012a, b; 2014a, b, c) were used to determine the proportion of Virginians with disabilities (stratified by age group) and the proportion of Virginians with LEP (by locality).

Alternative Population Forecasts by PDC

Overview

The uncertainty of population forecasts results from differences in numbers of people over time and location. By examining two or more forecasts, one can have a rough understanding of how much a forecast might vary depending on various assumptions. For example, three different 2040 population forecasts for the Northern Virginia region are, respectively, 3.035 million, 3.043 million, and 4.086 million. This gives one some confidence that the 2040 forecast will probably be in the range of roughly 3 million to 4 million—and suggests one cannot expect to have a forecast that is more precise than ±1 million in that location. Alternative population forecasts also allow one to consider reasons for uncertainty about the changing population; for example, it may be the case that some of the uncertainty in Northern Virginia is affected by population growth in adjacent suburban Maryland and Washington, D.C.

The majority of this report uses population forecasts from Weldon Cooper (2012a). Alternative forecasts were obtained from Woods & Poole (2014) and were sought from each of the 21 PDCs.

Differences in PDC Forecasts

Virginia's population is expected to grow by 2040 according to Weldon Cooper (2012a) and Woods & Poole (2014). However, there is a 14% difference (1.1 million) between the two forecasts: Weldon Cooper forecast the total population of Virginia in 2040 to be slightly above 10.5 million, whereas Woods & Poole forecast a higher population of 11.7 million. The large majority of Virginia's 21 PDCs is expected to grow. Weldon Cooper forecast that only 2 of the 21 PDCs in Virginia will decline in population, whereas Woods & Poole forecast that all PDCs will grow. Table A1 shows the forecast population of the 21 PDCs in 2040.

Table A2 suggests that the greatest disagreement between the forecasts by Weldon Cooper (2012a) and Woods & Poole (2014) is for the two adjacent PDCs of Northern Virginia and George Washington. The top four disagreements were for Northern Virginia, George Washington, Virginia's Region 2000, and Rappahannock-Rapidan Regional Commission.

Table A1. Projected Population Growth by PDC: 2012-2040

PDC	Weldon Cooper 2012	Weldon Cooper 2040	Woods & Poole 2040	PDC 2040
[1] Lenowisco	93,241	90,328	100,124	-
[2] Cumberland Plateau	112,262	113,558	117,439	-
[3] Mount Rogers	192,501	206,757	219,096	-
[4] New River Valley	178,933	219,420	203,700	-
[5] Roanoke Valley-Alleghany	332,119	382,111	408,049	[a]
[6] Central Shenandoah	290,054	365,539	371,941	-
[7] Northern Shenandoah	226,069	321,879	320,066	-
[8] Northern Virginia	2,346,221	3,035,256	4,086,384	3,043,038
[9] Rappahannock-Rapidan	169,355	233,827	254,411	-
[10] Thomas Jefferson	239,202	319,945	321,314	[a]
[11] Virginia's Region 2000	255,342	305,996	352,409	-
[12] West Piedmont	190,956	198,920	200,352	-
[13] Southside	84,608	85,447	91,429	-
[14] Commonwealth	103,756	112,745	123,377	-
[15] Richmond	1,025,561	1,496,953	1,498,485	1,401,221[b]
[16] George Washington	340,815	731,196	598,140	617,340
[17] Northern Neck	50,165	56,443	60,154	-
[18] Middle Peninsula	90,852	108,028	114,416	-
[19] Crater	173,142	193,659	185,818	-
[22] Accomack-Northampton	45,567	45,557	45,766	-
[23] Hampton Roads	1,645,146	1,906,666	2,010,850	1,988,100
Virginia Total	8,185,867	10,530,230	11,683,620	-

Data from Fredericksburg Metropolitan Area Metropolitan Planning Commission (2013); Hampton Roads Planning District Commission (2013); Miller (2014); MWCOG (2013); Richmond Area Metropolitan Planning Organization (2011); Roanoke Valley–Alleghany Regional Commission (2013); Weldon Cooper (2012a); Woods & Poole (2014).
[a] PDCs used only projections that did not include all localities within their jurisdiction. For example, PDC 10, Thomas Jefferson PDC, included the counties of Albemarle, Fluvanna, Greene, Louisa, and Nelson and the City of Charlottesville. The PDC uses "the RWSA's [Rivanna Water and Sewer Authority] 2011 Regional Water Demand Forecast as the forecast base" (Rhodes, 2014). However, the Regional Water Demand Forecast (RWSA, 2011) included projections only for all of Albemarle County and Charlottesville.
[b] Forecast is calculated only to the year 2035.

Table A2. Differences in Growth Forecast by Weldon Cooper and Woods & Poole by PDC: 2012-2040

PDC	Weldon Cooper 2040 Growth	Woods & Poole 2040 Growth	Difference
[8] Northern Virginia	29.37%	74.17%	44.80%
[16] George Washington	114.54%	75.50%	39.04%
[11] Virginia's Region 2000	19.84%	38.01%	18.18%
Virginia Total	28.64%	42.73%	14.09%
[9] Rappahannock-Rapidan	38.07%	50.22%	12.15%
[1] Lenowisco	-3.12%	7.38%	10.51%
[14] Commonwealth	8.66%	18.91%	10.25%
[4] New River Valley	22.63%	13.84%	8.79%
[5] Roanoke Valley-Alleghany	15.05%	22.86%	7.81%
[17] Northern Neck	12.51%	19.91%	7.40%
[13] Southside	0.99%	8.06%	7.07%
[18] Middle Peninsula	18.91%	25.94%	7.03%
[3] Mount Rogers	7.41%	13.82%	6.41%
[23] Hampton Roads	15.90%	22.23%	6.33%
[19] Crater	11.85%	7.32%	4.53%
[2] Cumberland Plateau	1.15%	4.61%	3.46%
[6] Central Shenandoah	26.02%	28.23%	2.21%
[7] Northern Shenandoah	42.38%	41.58%	0.80%
[12] West Piedmont	4.17%	4.92%	0.75%
[10] Thomas Jefferson	33.76%	34.33%	0.57%
[22] Accomack-Northampton	-0.02%	0.44%	0.46%
[15] Richmond	45.96%	46.11%	0.15%

Data were from Weldon Cooper (2012b) and Woods & Poole (2014). Percentages were calculated as growth in 2040 relative to 2012. For example, Weldon Cooper forecast that the population of the Northern Virginia PDC in 2040 will be 29.37% higher than in 2012.

The difference in forecast population change between Weldon Cooper (2012a) and Woods & Poole (2014) for most PDCs (15 of 21) was below 10%. In the two cases with a large difference—PDC 8 (Northern Virginia) and PDC 16 (George Washington) with respective differences of 45% and 39%—the local projections (see Table A1) were closer to Weldon Cooper than to Woods & Poole. As shown in Table A1, these percentage differences were more than double that of any other PDC. Figure A1 shows the total forecast population for PDCs 8 and 16 from these two sources and those provided by the PDCs. For the 2 PDCs, Weldon Cooper differed by an average of 4% from the PDC'-based projection, whereas Woods & Poole differed by an average of 38% (Fredericksburg Area Metropolitan Planning Organization, 2013; MWCOG, 2013).

Figure A2 illustrates the cumulative population forecasts by PDC from each source. Woods & Poole (2014) forecast the 2040 population of the Northern Virginia PDC to be slightly over 4 million (4,086,384), and Weldon Cooper (2012a) forecast just over 3 million (3,035,256). MWCOG (2013) forecast a 2040 population for the Northern Virginia PDC to be just over 3 million (3,043,038). If Weldon Cooper and Woods & Poole had the same forecast for the Northern Virginia PDC, the difference in Virginia's 2040 forecast statewide population would be about 1%.

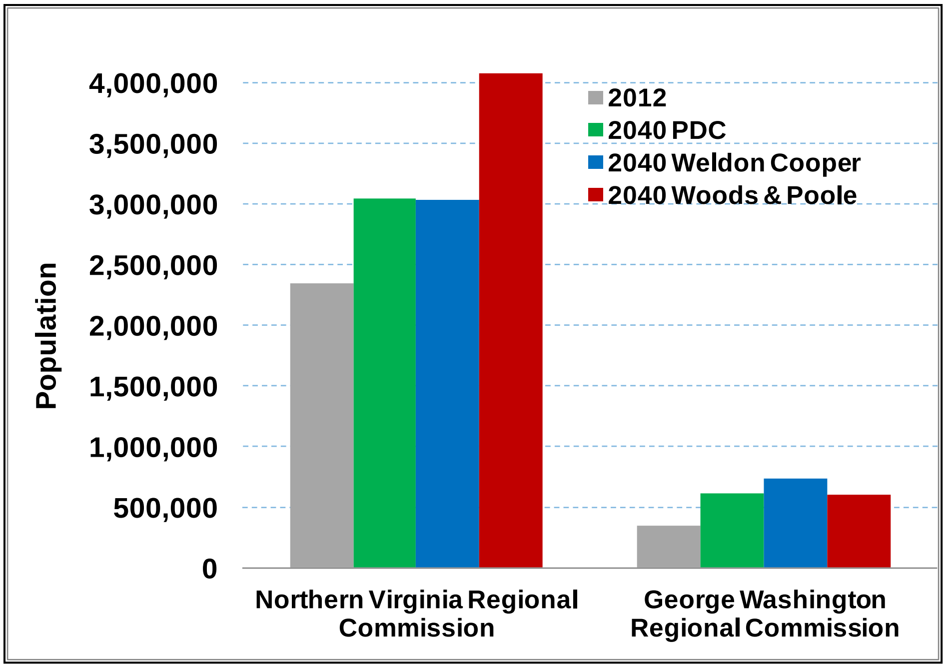

Figure A1. Forecast Populations of PDC 8 (Northern Virginia Regional Commission) and PDC 16 (George Washington Regional Commission): 2012-2040. Data from Fredericksburg Area Metropolitan Planning Organization (2013), MWCOG (2013), Weldon Cooper (2012a), and Woods & Poole (2014).

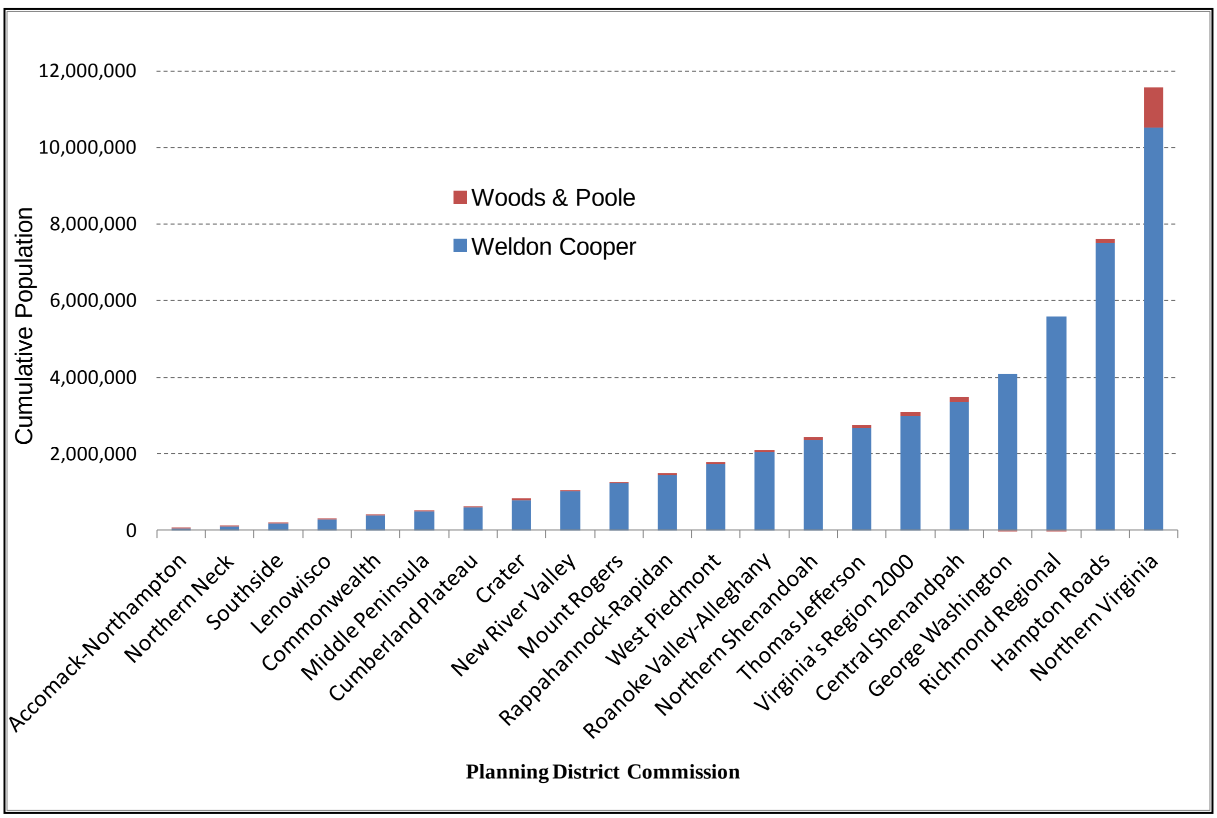

Figure A2. Cumulative Population Forecasts by PDC: 2040. Data from Weldon Cooper (2012a) and Woods & Poole (2014).

The Northern Virginia PDC is composed of nine jurisdictions, although they are collapsed into five areas by Woods and Poole (2014). These five areas are Alexandria City, Arlington City, Loudoun County, Prince William County with Manassas City and Manassas Park City, and Fairfax County with Fairfax City and Falls Church City. Figure A3 presents their projected population from Weldon Cooper (2012a), Woods & Poole (2014), and MWCOG (2013).

Figure A3 illustrates that Woods & Poole (2014) forecast a larger population in 2040 than did Weldon Cooper (2012a). For Loudoun County, Prince William County with Manassas City and Manassas Park City, and Fairfax County with Fairfax City and Falls Church City, the difference is more than 965,000. This may be compared to the overall Virginia projection variation of 1.1 million, and it is clear that these three localities make up the majority of the difference in forecast growth between Weldon Cooper and Woods & Poole for Virginia.

The accuracy of the 2040 forecasts is not known. An observation is that the forecasts by Weldon Cooper (2012a) and Woods & Poole (2014), despite a difference in statewide forecasts (10.5 million versus 11.7 million), are less than 10% apart for most PDCs. In the two PDCs that have the greatest difference, the Weldon Cooper forecast is closer to the PDC forecast than is the case with the Woods & Poole forecast. The difference in Northern Virginia makes up the large majority of the difference in forecasts.

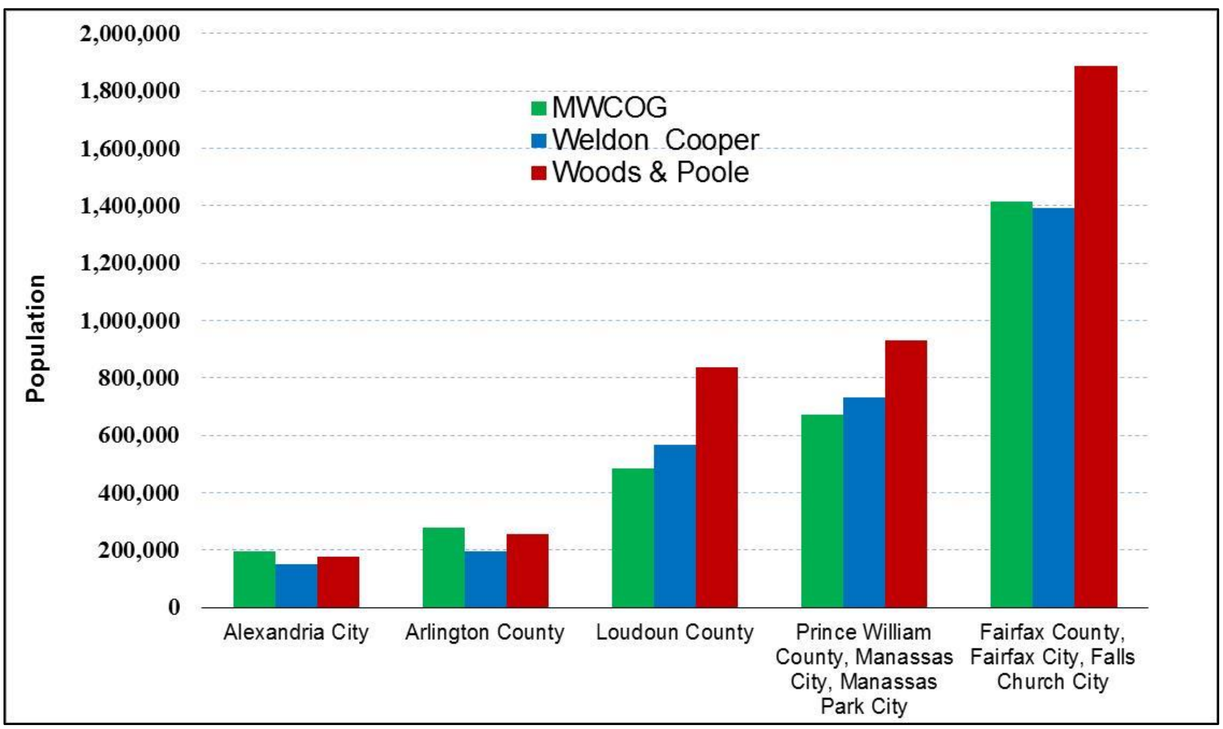

Figure A3. Forecast Population of Localities in the Northern Virginia PDC: 2040. Data from MWCOG (2013), Weldon Cooper (2012a), and Woods & Poole (2014).

Driver's Licensure Rates by PDC

Driver's licensure rates—the percentage of the population age 15+ that has a valid driver's license—can help one understand how transportation demand may change. A lower licensure rate means a growing percentage of the population cannot legally drive and therefore must rely on other modes of transportation. A higher licensure rate may mean the opposite. The licensure rate is important in comprehending changing modes of transportation and therefore changing trends of transportation into the future.

Differences in Licensure Rates Over Time

The licensure rate in Virginia is slowly declining: from 88.1% in 1999 to 85.6% in 2012. However, the decline was only 2.5% over 13 years. This leaves the average rate of change at about -0.2% per year for 1999-2012. Table A3 lists licensure rates for the years 1999, 2005, and 2012 for Virginia and each of Virginia's 21 PDCs.

Except for the Crater PDC and the Accomack-Northampton PDC, Virginia's PDCs had declining licensure rates from 1999-2012. This implies not only that overall licensure is declining but also that the decline is not limited to certain locations.

Table A3. Driver's Licensure Rates by PDC: 1999-2012

Planning District Commission	1999	2005	2012
Virginia	88.1%	87.5%	85.6%
[1] Lenowisco	87.5%	82.6%	80.9%
[2] Cumberland Plateau	90.1%	89.4%	87.3%
[3] Mount Rogers	88.6%	88.4%	86.7%
[4] New River Valley	76.4%	74.3%	72.5%
[5] Roanoke Valley-Alleghany	89.2%	88.7%	86.5%
[6] Central Shenandoah	83.5%	82.7%	80.8%
[7] Northern Shenandoah	92.7%	93.1%	90.3%
[8] Northern Virginia	95.8%	93.9%	90.3%
[9] Rappahannock-Rapidan	94.4%	95.7%	92.9%
[10] Thomas Jefferson	84.7%	84.6%	83.3%
[11] Virginia's Region 2000	86.2%	84.7%	83.0%
[12] West Piedmont	86.4%	85.3%	83.7%
[13] Southside	82.9%	82.2%	80.8%
[14] Commonwealth	79.1%	77.8%	76.0%
[15] Richmond	88.2%	87.7%	85.7%
[16] George Washington	92.1%	91.0%	88.9%
[17] Northern Neck	90.7%	90.2%	88.9%
[18] Middle Peninsula	94.2%	95.4%	93.4%
[19] Crater	78.9%	78.8%	79.9%
[22] Accomack-Northampton	80.5%	82.2%	86.9%
[23] Hampton Roads	81.9%	81.7%	80.7%

Rates were calculated using data from the Virginia Department of Motor Vehicles (1999, 2005, 2012) and Woods & Poole (2014).

The 4 PDCs with the lowest licensure rates in 2012 were New River Valley, Commonwealth, Crater, and Hampton Roads. The 4 PDCs with the highest licensure rates in 2012 were Middle Peninsula, Rappahannock-Rapidan, Northern Shenandoah, and Northern Virginia. The population and licensure rate of these PDCs were uncorrelated. The two greatest drops in licensure rates from 1999-2012 were in PDC 1 (Lenowisco) and PDC 8 (Northern Virginia), with a decrease in licensure rates of 6.53% and 5.53%, respectively.

Complications in Comparing Annual Licensure Rates

Definitions have changed over time: the Virginia Department of Motor Vehicles (DMV) (1999) defined *licensed drivers* as including "only people with Virginia Licenses (whether revoked or suspended)" and made no mention of learner's permits. The DMV (2005) later changed the definition to include people with learner's permits and to exclude "people with stop(s) [sic] and expired Virginia Licenses." In 2012, the DMV made no note of stopped, expired, revoked, or suspended licenses but did include learner's permits. Further, the inclusion of college students as residents (in the area where they attend college) affects licensure rates in certain locations because college students may be listed as living at one location but their licenses may have been issued at a different location (where they resided before enrolling in college).

Relationship Between Age and Disability

It is possible that the proportion of the population with a disability may influence the need for certain transportation services, such as fixed-route transit service and demand-responsive (paratransit) service. (Not all disabilities are the same, so there is not a guarantee that a change in disabilities will change the demand for transportation; however, if a disability hampers driving, other types of transportation may be needed.) Because age and disability are related, it is appropriate to consider how changes in age groups by 2040 might influence the number of Virginians with a disability.

Disability by Age Group

The ACS (U.S. Census Bureau, 2012b) estimated that 12.2% of people in the United States have a disability; for Virginia, the percentage is 10.8% (about 860,000). Older populations have a higher disability rate than younger populations; for example, people age 18-64 have a disability rate of 8.4%, whereas people age 65+ have a disability rate of 33.6% (Erickson et al., 2014). For people age 75+, the disability rate is 49.6%. An inference is that the disability rate increases almost exponentially as the population becomes older. The disability rate of people age 65+ is quadruple that of people age 18-64, and one-half of all people in Virginia age 75+ have a disability. Older populations are expected to have a greater number of people with a disability than younger populations and therefore require alternative modes of transportation.

Increasing Senior Populations

The senior population is expected to increase greatly in the future. The number of Virginians age 65+ is expected to increase by 79% from 2012-2040 (Weldon Cooper, 2012b). This indicates the largest growth in the age groups of age 0-19, 20-64, and 65+. In 2040, the age group 65+ is forecast to be 18% of the population, compared to 13% in 2012.

Alternative population forecasts also yield an increasing senior population. Woods & Poole (2014) generated forecasts for every 5-year age group into 2040 that, as was done with the data from Weldon Cooper (2012b) can be placed into age groups of 0-19, 20-64, and 65+. Because Woods & Poole forecast a much higher growth in the overall population, it would be misleading to compare the change in the senior population forecast by Woods & Poole and by Weldon Cooper. However, the proportion of the population that is age 65+ can be compared for these two data sources, and in this regard, Weldon Cooper and Woods & Poole have similar forecasts. Woods & Poole forecast that the persons age 65+ will make up 19.5% of the total population by 2040, similar to the 18% forecast by Weldon Cooper.

Potential Impacts of Aging on the Number of Virginians With a Disability

As of 2012 and consistent with past years, senior populations have a higher disability rate. The senior population is expected to increase by year 2040 (Weldon Cooper, 2012a; Woods & Poole, 2014). Future disability rates have not been forecast; however, if disability rates remain consistent with historical data, an increase in the population of Virginians with a disability would be expected along with the large increase in the senior population.

Impact of Limited English Proficiency

People with LEP may have additional needs related to transportation. Examples include the need to understand transit station announcements, transit fare or highway toll instructions, fare and toll payment methods, transfers between transit lines or modes, and signing. These difficulties are not unique to people with LEP but may be exacerbated by a lack of English proficiency, especially in unplanned situations, such as emergency evacuations (Liu and Schachter, 2007). Locations that have populations with LEP may need to address these needs.

Across Virginia, 15% of people speak a language in addition to or other than English. More than one-third of this population, about 5.6% of Virginia's population, indicated that they speak English "less than very well" (U.S Census Bureau, 2014a). Older data reported by the Virginia Department of Health (2006) indicated that one-fifth of this population is in "linguistically isolated households" where no member of the household speaks English "very well" (phrases enclosed in quotations marks refer to the question as posed in the ACS).

These 430,000 Virginians who speak English less than very well are not evenly distributed. More than 10% of the populations of Fairfax County, Prince William, Alexandria, and Loudoun are in this category. However, Figure A4 clarifies that they are not restricted to large urban areas, given the substantive portions of this population in small urban areas such as Albemarle (U.S. Census Bureau, 2014b).

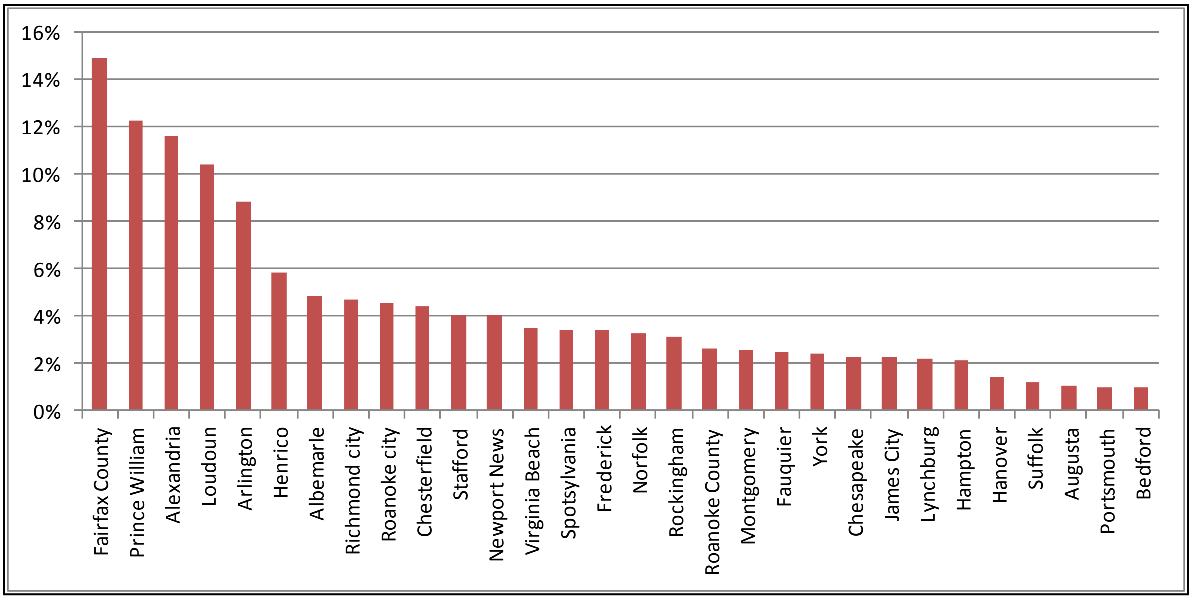

Figure A4. Percent of Virginia Population Who Speak English Less Than "Very Well" in Each Virginia Jurisdiction: 2007-2011. Data from U.S. Census Bureau (2014b).

Statewide, almost one-half of this population (48%) speaks Spanish at home—the next most common languages are Korean (7%); Vietnamese (6%); Hindi, Urdu, and other Indic languages (6%); Chinese (5%); African languages (4%); Arabic (4%); and Tagalog (2%) (U.S. Census Bureau, 2014a). As shown in Figure A5, slightly older data show that clusters of Virginians who indicated they do not speak English "very well" in the 2007-2011 ACS are in

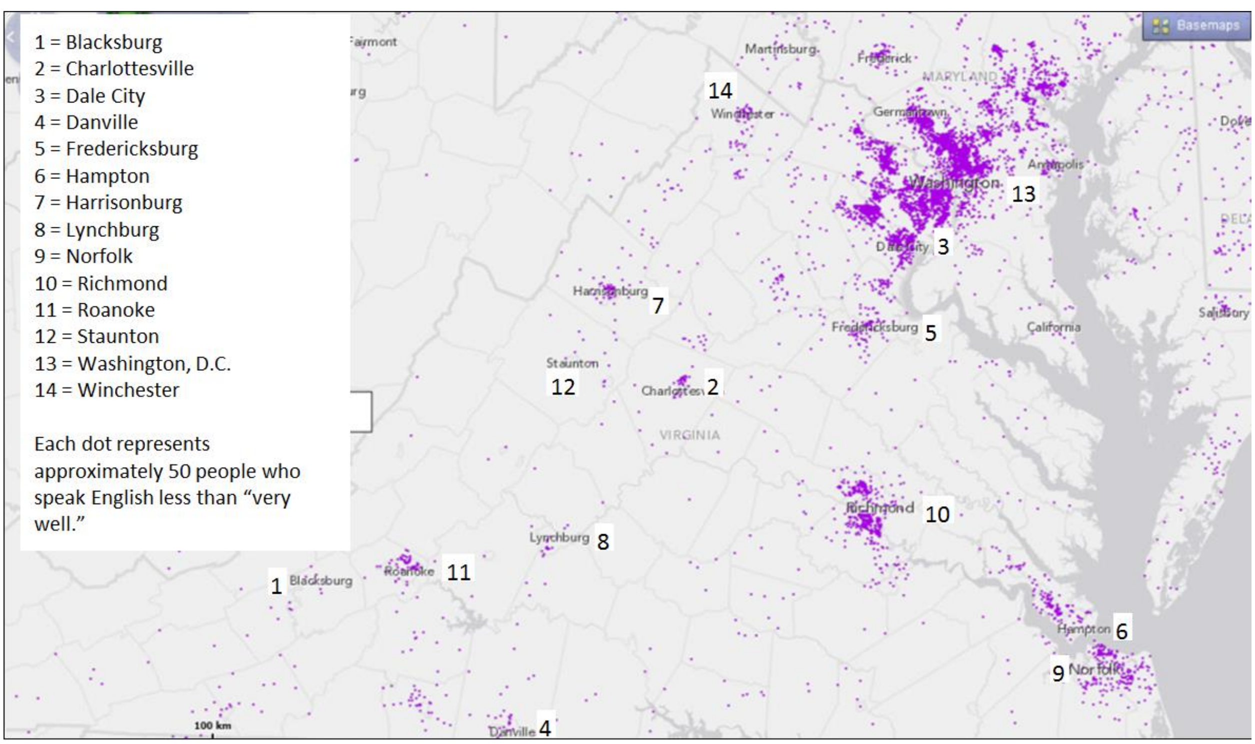

Figure A5. Spanish-Speaking Virginians Who Indicated They Speak English Less Than "Very Well": 2011. Data from U.S. Census Bureau, 2011 Language Mapper (U.S. Census Bureau, 2014c).

Virginia's large and small urban areas: Blacksburg, Charlottesville, Danville, Hampton Roads, Harrisonburg, Northern Virginia, Richmond, Roanoke, and Winchester (U.S. Census Bureau, 2014c).

Liu and Schachter (2007) note that although lower incomes may explain some of the higher transit use of the LEP population, other reasons may include greater familiarity with transit, the lack of a driver's license, or (based on a graphic provided by the authors) residence in a location where a vehicle is less necessary. In the case of an emergency evacuation, planners may need to consider whether there are adequate transit vehicles to evacuate the LEP population who depend on transit. These are all cases where the LEP population changes the face of transportation demand. They should be considered separately in the analysis of changing trends in transportation demand and therefore transportation.

Summary

- *Alternate population forecasts support growth in Virginia from 2012-2040*. Weldon Cooper (2012a) and Woods & Poole (2014) both forecast Virginia's population to grow by 2040. Woods & Poole forecast growth for all 21 PDCs, whereas Weldon Cooper forecast growth for 19 of Virginia's 21 PDCs. Four PDCs have local forecasts that represent all jurisdictions in the PDC (3 for 2040 and 1 for 2035), and all 4 forecast the population of the PDC will increase.

- *Population growth for Virginia varies by 14% across alternate forecasts*. Weldon Cooper (2012b) forecast Virginia's 2040 population to be about 10.5 million. Woods & Poole (2014) forecast Virginia's 2040 population to be about 11.7 million.

- *Forecast population change is similar in most PDCs across alternate forecasts*. For 2040, 18 of Virginia's 21 PDCs have a difference in projected growth between Weldon Cooper (2012b) and Woods & Poole (2014) of less than 50,000 and 20 PDCs have a difference in projected growth of less than 150,000. For 19 of the 21 PDCs, the percentage increase in population varies by less than 20%. For the 3 PDCs for which a local 2040 forecast is available, the local forecast is between the forecasts by Weldon Cooper and Woods & Poole, suggesting the two sources can provide a useful range for forecasts.

- *Most of the discrepancy in population growth for Virginia is attributable to the Northern Virginia PDC*. For this PDC, 2040 forecasts are 3.04 million (Weldon Cooper, 2012b) and 4.09 million (Woods & Poole, 2014), with the local forecast being similar to that of Weldon Cooper. The difference for this PDC—about 1.05 million—represents most of the difference (1.10 million) between Weldon Cooper and Woods & Poole (for some PDCs, Woods & Poole has a lower forecast than Weldon Cooper).

- *Licensure rates appear to be declining throughout Virginia*. Most (19) of Virginia's 21 PDCs had a declining licensure rate, and the statewide drop (from 1999-2012) is consistent with the drop in the rate reported in the body of the report. However, the average drop in the licensure rate statewide from 1999-2012 (from 88.1% to 85.6%) was less than the difference between the PDC with the highest licensure rate in 2012 (Middle Peninsula PDC with 93.4%) and the PDC with the lowest licensure rate in 2012 (New River Valley with 72.4%).

- *The large increase in the senior population (age 65+) may merit additional consideration for non-personal vehicle forms of transport.* Because the senior population is expected to almost double (79%) by the year 2040 and the disability rate among seniors in the past has been consistently high, paratransit services may see an increase in demand along with the increasing senior population.

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APPENDIX B

EMPLOYMENT AND INCOME FORECASTS FOR 2040

Employment has historically been more difficult to forecast than population. For example, calculations based on data provided by the National Capital Region Transportation Planning Board (2013) showed that a comparison of projected and actual values over a 20-year period yielded a larger percentage error for employment (12%) than for population (7%) for the region. For individual jurisdictions, the average percent error for employment (25%) was higher than that for population (11%). As another example, based on a review of 20-year forecast accuracy for a smaller region than that which was the subject of the study by the National Capital Region Transportation Planning Board (2013), McCray et al. (2008) suggested that a population error of ±39% and an employment error of ±136% should be presumed. The percentage errors will of course vary based on the length of the forecast period, the size of the geographical location, the method used to develop the forecast, and other factors, but the salient observation is that employment is more difficult to forecast than population. In fact, with the exception of 3 of Virginia's 21 PDCs, forecasts of employment for year 2040 for all jurisdictions therein are not available except from private sector sources.

Overview of Projected Employment Growth to 2040

A private sector source of employment forecasts available from Woods & Poole (2014) was obtained, and these forecasts by jurisdiction were aggregated to yield 2040 forecasts of employment for year 2040 at the PDC level. These forecasts are shown in Figure B1. For example, these projections suggest that the largest employment growth will be in the Northern Virginia, George Washington, and Richmond Regional PDCs, with percentage increases of 88%, 75%, and 68%, respectively; by contrast, the smallest employment growth will be in the West Piedmont, Cumberland Plateau, and Crater PDCs, with percentage increases of 21%, 19%, and 17%, respectively. The statewide employment growth is projected to be 60%; however, just 4 PDCs—Northern Virginia, George Washington, Richmond Regional, and Rappahannock-Rapidan—exceed this value, given the large increase in employment in Northern Virginia and Richmond and the large total number of jobs therein. A more appropriate statewide metric with regard to PDC-level growth is the median increase in employment, which is 35.7%, as shown in Figure B1.

Woods & Poole (2014) pointed out that its employment numbers tend to be higher than those reported from other sources, in part because of differences in how employment is measured. For example, in Woods & Poole, employment by a worker holding two part-time jobs would be counted as two positions whereas employment tabulated from a point of residence only might be counted as only one position in other sources. As another example, whereas Woods & Poole (2014) includes members of the military and proprietors, the Quarterly Census of Employment and Wages excludes these workers (Geographic Solutions, Inc., 2014b). The Quarterly Census of Employment and Wages numbers appear to be used by the VEC (Geographic Solutions, Inc., 2014c).

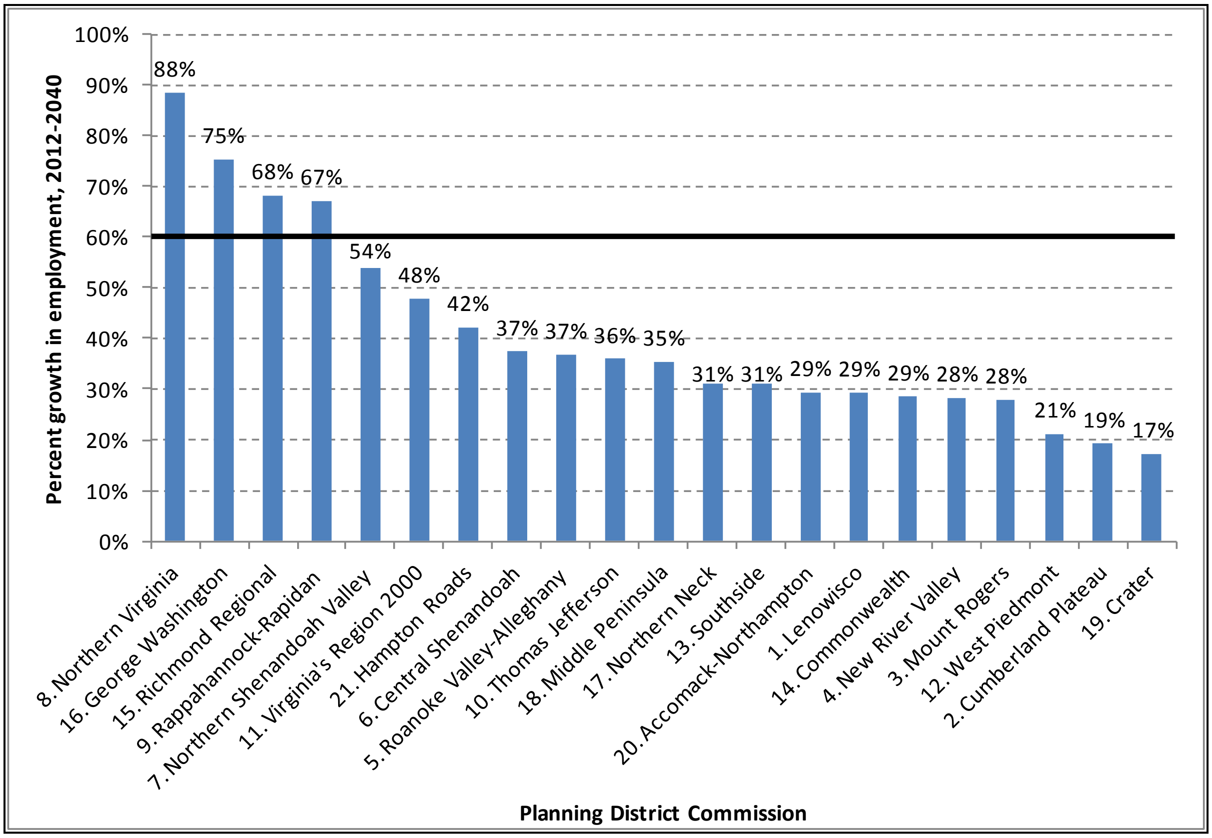

Figure B1. Forecast Percentage Growth in Total Employment in Virginia PDCs: 2012-2040. Data from Woods & Poole (2014). The solid line signifies the anticipated statewide growth in employment is 60%.

An Empirical Confidence Interval for Employment Forecasts

Unlike the case with population forecasts, the authors of this report do not have employment projections other than those from Woods & Poole (2014) except in the three PDCs where local employment projections are available. Accordingly, it is not clear what an expected error would be for these forecasts. For example, a forecast 60% increase in statewide employment from 2012-2040 is evident in Figure B1. Presumably, one has more confidence that the actual increase will be some number between 40% and 80% and less confidence that the actual increase will be some number between 59% and 61%. However, how can this confidence be quantified? Although it is not feasible to obtain a confidence interval in a statistical sense, it is possible to obtain a rough empirical confidence interval by considering alternative ways of generating a forecast and then examining the variation in these forecasts.

To obtain this empirical confidence interval, three steps were performed using VEC historical data (Geographic Solutions, Inc., 2014a).

Step 1. Generate three different forecasts for year 2040 employment. For each PDC, three models (A, B, and C) were used to develop a forecast. What is of interest is not the forecasts from the models (because the authors of this report do not believe them to be as accurate as those of Woods & Poole [2014]) but rather the percentage difference between them. The models are defined as follows:

- *Model A* is the simplest model and is based on a linear regression analysis, one for each PDC, using employment data from 2000, 2002, 2004, 2006, 2008, 2010, and 2012. This model follows the form

  Employment = a * (Year) + b

  where a and b are computed from regression.

  Year takes a value of 0 (for year 2000), 2 (for year 2002), and so forth up to 12 (for year 2012).

  Then, a 2040 forecast is generated by changing the value of Year to 40.

- *Model B* also uses linear regression, with a separate equation for each PDC. However, the data set for the regression differs from the data set of Model A. Rather than by the direct use of a 2000 employment value, the 2000 employment is developed by subtracting the actual 1996 employment from the 1998 employment and adding this difference to the 1998 employment. (This model represents an erratic set of base year data where the rate of change, or slope, based on the two previous years is used to determine the next 2 years of base year data.) This same approach yields values for 2002, 2004, 2006, 2008, 2010, and 2012, and these data are then used as a base data set for the regression analysis. From this regression equation, Year is replaced with a value of 40 to develop a 2040 employment forecast.

- *Model C* is identical to Model A with one exception: in addition the seven data points corresponding to years 2000, 2002, 2004, 2006, 2008, 2010, and 2012, the base data set includes an eighth data point corresponding to year 2020. The employment for year 2020 is a forecast value from the VEC. (Although VEC does not have 2040 employment forecasts, it does have 2020 employment forecasts [Geographic Solutions, Inc., 2014a].)

Step 2. For each PDC, find the difference in percentage employment growth between the model with the highest forecast and the model with the lowest forecast. For example, as shown in Table B1 for the Northern Virginia PDC, the highest 2040 forecast was 2,065,244 jobs (Model C) and the lowest 2040 forecast was 1,333,675 jobs (Model B). Given a 2012 employment of 1,163,367 jobs, Models B and C reflect respective percentage growth rates of 14.6% and 77.5%. Thus, the difference between these growth rates is 77.5% −14.6% = 62.9%.

Step 3. Compute a midpoint empirical confidence interval for each PDC by dividing the percentage shown in Step 2 in half and applying the percentage to the estimate by Woods & Poole (2014). For example, the percentage from Step 2 when divided in half yields 31.4%. Woods & Poole projected a 2040 employment value of 3,016,043. Thus, a confidence interval for this value is 3,016,043 ± 31.4% of this midpoint value. Thus, one might expect the 2040 employment to be within this interval—that is, from 2,069,005 to 3,963,081. (The "31.4%" described here is a rounded value; the exact percentage is 31.442%, which gives the confidence interval shown in Table B1).

The range of forecasts is shown in Table B1. For example, the authors of this report estimated that the confidence interval for the statewide forecast is ±18.1%. Using the Woods & Poole (2014) forecast as a midpoint (i.e., 7,803,245 jobs), one might expect this interval to range from 6,387,824 to 9,218,666 positions—that is, the statewide employment might range from an increase (relative to 2012) of 31% to 89%. To be clear, a greater understanding of employment uncertainty can be obtained if additional forecasts from other sources become available, but until then, the ranges shown in Table B1 give a rough approximation of the range of employment changes that might be expected by 2040.

Forecasts of Total Personal per Capita Income by PDC in 2040

Table B2 shows the projected increase in total personal per capita income from 2012-2040 based on Woods & Poole (2014) in 2009 dollars. This total personal income is larger than only wages as it includes earnings, dividends, interest income, rental income, government transfer payments, and a residence adjustment less contributions to social insurance. Table B2 suggests that on average, total annual personal income may increase by approximately 59% (in 2009 dollars, after controlling for inflation), with a median increase (when results are shown by PDC) of 50%.

For income, Woods & Poole (2014) reported that over a 10-year period, the average absolute percent error for income forecasts at the metropolitan area level has been 9%. As one would expect, the forecast errors are smaller at the state level (7.6%) and larger at the county level (14.1%). If one considers a PDC to be somewhat comparable to a metropolitan area in terms of size, one would expect the income forecast error to be larger than 9% for a PDC given that these forecasts reflect a horizon of 26 years rather than 10 years. Thus, there is some additional uncertainty associated with these forecasts.

Table B1. Forecast Employment by PDC for Year 2040

PDC	Virginia Employment Commission (VEC) Definition[a]				Woods & Poole Definition[a]		Forecast Range Estimated by Authors of this Report		
	2012 VEC	2040 Model A	2040 Model B	2040 Model C	2012 Woods & Poole	2040 Woods & Poole	2040 Empirical Confidence Interval (±)[b]	2040 Low	2040 High
Lenowisco	28,210	35,294	41,797	42,501	40,384	52,237	12.8%	45,564	58,910
Cumberland Plateau	35,051	35,994	36,391	48,534	47,470	56,618	17.9%	46,490	66,746
Mount Rogers	71,619	55,575	37,586	77,731	97,994	125,367	28.0%	90,231	160,503
New River Valley	66,370	62,325	37,573	69,557	88,693	113,860	24.1%	86,425	141,295
Roanoke Valley-Alleghany	155,214	137,294	94,919	175,910	204,528	279,738	26.1%	206,754	352,722
Central Shenandoah	121,220	126,589	87,887	146,122	163,954	225,265	24.0%	171,155	279,375
Northern Shenandoah Valley	84,566	92,366	61,072	101,100	118189	182,057	23.7%	138,970	225,144
Northern Virginia	1,163,367	1,559,559	1,333,675	2,065,244	1,600,683	3,016,043	31.4%	2,067,742	3,964,344
Rappahannock-Rapidan	49,354	64,270	49,066	69,930	83,488	139,589	21.1%	110,084	169,094
Thomas Jefferson	105,015	136,757	119,675	153,509	154,491	210,039	16.1%	176,204	243,874
Virginia's Region 2000	94,082	93,819	79,696	125,882	135,537	200,452	24.5%	151,250	249,654
West Piedmont	67,489	22,783	-1,985 [c]	58,102	89,668	108,703	26.2%	80,259	137,147
Southside	28,068	18,260	10,669	30,555	39,060	51,243	35.4%	33,090	69,396
Commonwealth	25,885	23,316	16,250	29,730	41832	53,791	26.0%	39,785	67,797
Richmond Regional	513,230	564,926	417,756	650,591	659,752	1,109,685	22.7%	857,972	1,361,398
George Washington	109,528	170,910	151,669	164,295	154,213	270,358	8.8%	246,611	294,105
Northern Neck	13,175	15,106	15,805	21,364	21,691	28,467	23.7%	21,706	35,228
Middle Peninsula	22,517	23,092	16,421	30,414	37,642	50,963	31.1%	35,128	66,798
Crater	68,186	66,286	53,021	81,283	91,451	107,286	20.7%	85,052	129,520
Accomack-Northampton	17,650	14,035	12,931	26,439	24784	32,072	38.3%	19,799	44,345
Hampton Roads	700,685	929,263	1,348,160	1,135,651	976,645	1,389,412	29.9%	974,089	1,804,735
Total	3,540,481	4,247,821	4,020,036	5,304,443	4,872,149	7,803,245	18.1%	6,387,824	9,218,666

[a] Note that employment as defined by Woods & Poole (2014) and the VEC (Geographic Solutions, Inc., 2014a, b, c) yield different values. For this reason, the employment numbers for VEC in the column titled "Virginia Employment Commission (VEC) Definition" and in the column titled "Woods & Poole Definition" are not directly comparable.

[b] The confidence interval reflects the authors' of this report expected range of values based on Models A, B, and C. For example, for Lenowisco, although 52,237 is the best midpoint forecast available, one might expect employment to range from a low of 52,237 − 12.8% (52,237) = 45,564 to a high of 52,237 + 12.8% (52,237) = 58,910.

[c] For the West Piedmont PDC only, the value associated with Model B was not used to compute a forecast range.

Table B2. Forecast Total Annual Personal Income in 2009 Dollars by PDC: 2012-2040 [a]

Planning District Commission	Annual Income 2012	Annual Income 2040	Percent Change 2012-2040
Lenowisco	$29,182	$44,404	52%
Cumberland Plateau	$30,374	$45,554	50%
Mount Rogers	$29,985	$45,390	51%
New River Valley	$28,845	$42,677	48%
Roanoke Valley-Alleghany	$37,474	$56,935	52%
Central Shenandoah	$31,894	$46,022	44%
Northern Shenandoah	$35,169	$52,147	48%
Northern Virginia	$62,403	$94,739	52%
Rappahannock-Rapidan	$42,617	$67,096	57%
Thomas Jefferson	$42,226	$61,052	45%
Virginia's Regional 2000	$32,661	$48,758	49%
West Piedmont	$29,515	$44,054	49%
Southside	$28,854	$46,812	62%
Commonwealth	$27,338	$40,265	47%
Richmond Regional	$43,015	$66,592	55%
George Washington	$38,862	$55,665	43%
Northern Neck	$37,101	$56,853	53%
Middle Peninsula	$38,291	$55,459	45%
Crater	$34,836	$52,226	50%
Accomack-Northampton	$33,488	$55,426	66%
Hampton Roads	$40,572	$64,433	59%
Virginia Average Annual Income	$44,765	$70,971	59%

[a] Based on aggregation of data from Woods & Poole (2014).

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APPENDIX C

DETAILS FOR POPULATION AND LAND USE DATA

This appendix provides three sets of supporting details: (1) caveats for interpreting the population data, (2) the method for making the calculations shown in Tables 1 through7 in the body of the report, and (3) the method for classifying Virginia jurisdictions based on land use types.

Caveats for Interpreting the Population Data

Population forecasts were from Weldon Cooper (2012a). Two key caveats for data interpretation concern uncertainty and immigration.

1. *Uncertainty*. Weldon Cooper used Census population data from 1950-2010 to project the total population in each locality based on regressions from the population counts of the prior two decades. The model was evaluated based on out-of-sample testing, in which the model is used to project a known outcome in order to determine the model's margin of error. Out-of-sample testing is accepted as a reputable and consistent method of determining the best model when data from the relevant population are unavailable, as is the case for population projections (Nematrian Extensions, 2013). Weldon Cooper (2012b) reported that their mean absolute projection error (MAPE) was 6% for 10-year projections, 15% for 20-year projections, and 24% for 30-year projections. Weldon Cooper (2012b) reported that county-level projections typically display MAPEs of 12% for 10-year projections, 24% for 20-year projections, and 36% for 30-year projections, indicating that their model performs better than the average for long-term projections. (To estimate future age distribution in Virginia, Weldon Cooper used the Hamilton-Perry method. Migration, death, and birth and rates were calculated for each locality for 1990-2000 and 2000-2010 and averaged together. These averages were applied to the 2010 base population to project the 2020 population, to the projected 2020 population to project the 2030 population, and to the projected 2030 population to project the 2040 population. The age projections were then controlled to equal the total population estimate for each locality as calculated by the model.)

2. *Immigration*. Immigration is projected to contribute to the changes in the population of the United States as a whole and Virginia in the coming decades. Passel and Cohn (2008) reported that 82% of the population increase expected within the United States from 2010-2050 will be attributable to immigrants and their descendants. In particular, immigration will mainly contribute to growth in the working-age and younger populations. Thus, Virginia's future population as well as the relative proportion represented by different age groups within the population will be highly dependent on the actual rate of immigration and on their location patterns. Changes to state or federal immigration policy would thus impact the accuracy of these projections.

Method for Making the Calculations in Tables 1-7 of the Report

Absolute changes in population were calculated by subtracting the 2012 population for a given locality from the projected 2040 population for the locality. Percent changes in population were calculated by subtracting the 2012 population for a given locality from the projected 2040 population for the locality and dividing the result by the 2012 population.

Figures 7, 13, and 20 provide the statewide proportion of people living in a locality for three subpopulations: age 65+, under age 20, and millennials. For a given subpopulation, such as people age 65+, the proportion was calculated as follows. First, the number of people age 65+ living in each locality was identified. Second, the number of people age 65+ projected to be living in each locality was summed to determine a statewide number. Third, the age 65+ population of each locality was divided by the statewide number to determine the percentage of the total age 65+ population represented in each locality. This calculation was repeated for the population under age 20 and the millennial populations.

Data for Bedford City and Bedford County were combined, as Bedford City reverted to a town status since the projections were performed. To combine data, the 2012 population for Bedford City was added to that of Bedford County, and the projected 2040 population for Bedford City was added to that of Bedford County. Subsequent calculations were performed as described for other localities.

Method for Classifying Virginia Jurisdictions Based on Land Use Types

This report classified each county or city as one of six land use categories: large urban, urban, exurban, central small urban area, outlying small urban area, or non-core. This section describes how this classification scheme was developed.

Although descriptors such as urban, suburban, and rural are commonly used in conversation, a challenge with using such terminology throughout Virginia is the geographic diversity of the state. For example, Fairfax County has almost 5 times the density of Chesapeake City, yet both are categorized as a "suburban feeder area" (in Virginia's 2035 surface transportation plan) and both are considered a "central" location within the appropriate CBSA (according to the U.S. Census Bureau). *Thus, any labeling system should have some relationship to geography*.

A related challenge is that ways of classifying jurisdictions may vary. For example, whereas Virginia's 2035 surface transportation plan designates Fredericksburg as a suburban feeder area (in the same vein as Fairfax County), the Census characterizes Fredericksburg as an "outlying" area. In fact, some literature focuses more on an area's geographical alignment with transportation; for instance, Rodrigue (2013) classified cities worldwide as one of four structures: completely motorized, weak center, strong center, and traffic limited in the urban core; respective examples given by Rodrigue (2013) were Los Angeles and Dallas (completely motorized), San Francisco (weak center), New York (strong center), and Stockholm (traffic limited in the urban core). It appears most of Virginia's locations would be in either the "completely motorized" or "weak center" area based on these examples. *Thus, any labeling system should have a definition that others can replicate*.

There are at least three schemes for classifying jurisdictions that have recently been applied in Virginia, based respectively on (1) *VTrans2035,* (2) Virginia's *Multimodal System Design Guidelines;* and (3) the U.S. Census Bureau. These systems are summarized here, and the approach used for VTrans2040 follows.

A Classification System Based on *VTrans2035*

VTrans2035 (Office of Intermodal Planning and Investment, 2010) used one of four geographical descriptors for various regions of Virginia: urban core, suburban feeder area, small urban, and non-urban. (Only two of Virginia's 133 jurisdictions had the label "urban core.")

Formal definitions are not given in the plan; however, one of the four labels can be determined for almost every jurisdiction by reviewing the plan. For example, in what the plan characterizes as the "Eastern" region, the jurisdictions within the Hampton Roads PDC (e.g., Norfolk, Virginia Beach, York County, and several others) are characterized as "suburban feeder area" whereas the counties of Accomack and Northampton are "non-urban." In Northern Virginia, Arlington and Alexandria are "urban core" with the remaining areas being "suburban feeder." In the Valley and Ridge region, the denser locations such as the cities of Bristol and Roanoke are "small urban" and the less dense locations such as Buchanan County are "non-urban."

It is generally easy to link specific jurisdictions to these categories except when a metropolitan planning organization (MPO) area includes only a portion of a jurisdiction (e.g., the Bristol MPO includes a portion of Scott County; in this case, the MPO designation was applied to the entire county). Figure C1 orders Virginia's jurisdictions from most dense (population plus jobs per square mile) to least dense and overlays the VTrans categories (urban core, suburban feeder area, small urban, and non-urban). As one might expect, there is a rough alignment between density and VTrans categories, where non-urban locations tend to have lower densities and more urban locations tend to have higher densities.

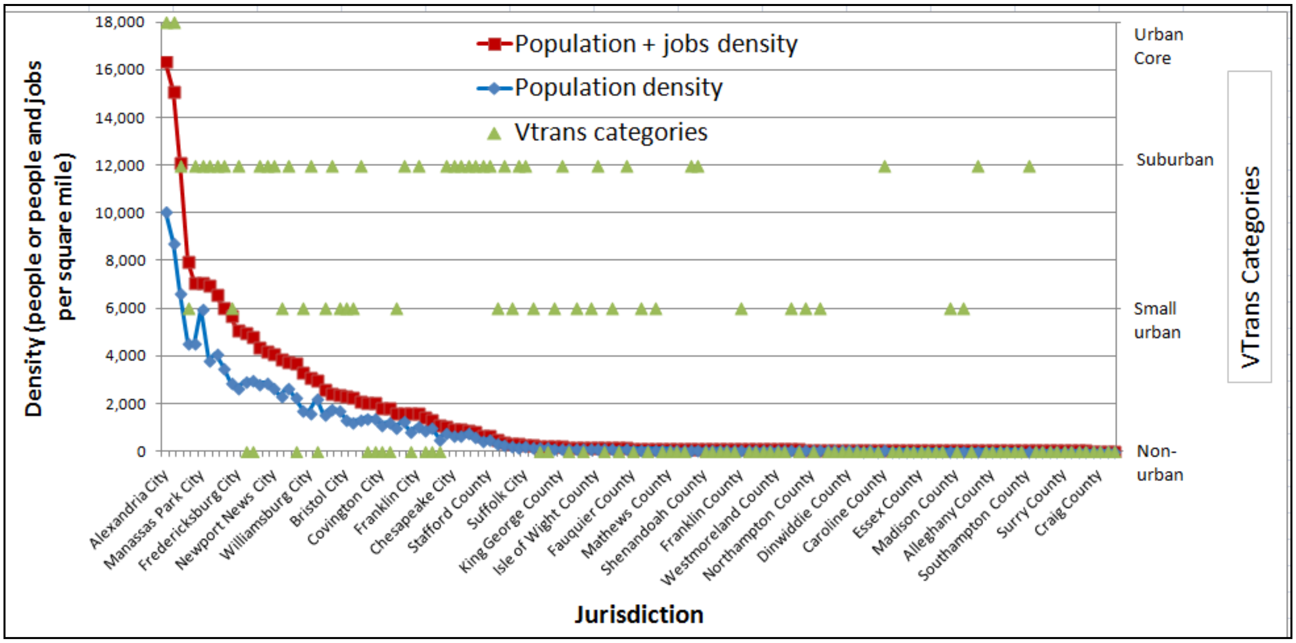

Figure C1. Virginia Jurisdictions Sorted by Density of Population (for year 2013) and Jobs (for 2012) With VTrans Categories. Data from Bureau of Labor Statistics (2013), Department of Rail and Public Transportation (2013), Office of Intermodal Policy and Investment (2010), U.S. Census Bureau (2013a), and Weldon Cooper Center for Public Service (2014).

A Classification System Based on Virginia's *Multimodal System Design Guidelines*

Virginia's *Multimodal System Design Guidelines* (Virginia Department of Rail and Public Transportation, 2013) classifies locations based on jobs and population per square mile. These labels do not encompass an entire jurisdiction but rather reflect centers of activity within a given jurisdiction. These classifications are urban core (P6), urban center (P5), large town or suburban center (P4), medium town or suburban center (P3), small town or suburban center (P2), and rural or village center (P1).

Definitions for each classification are given in part based on density. For example, an area that has a population plus jobs density of at least 44,800/square mile (e.g., Tysons Corner in Fairfax County or Ballston in Arlington County) is considered P6, whereas an area that has a jobs plus population density from 4,243 to 8,800 (e.g., Hollymead in Albemarle County or Stephens City in Frederick County) is P3. Although these designations do not reflect entire jurisdictions, a comparison of *jurisdiction* density and locations for some of these centers (see Figure C2) shows a rough correspondence between the scale of the center (e.g., P6, P5, etc.) and the jurisdiction's density (population plus jobs per square mile).

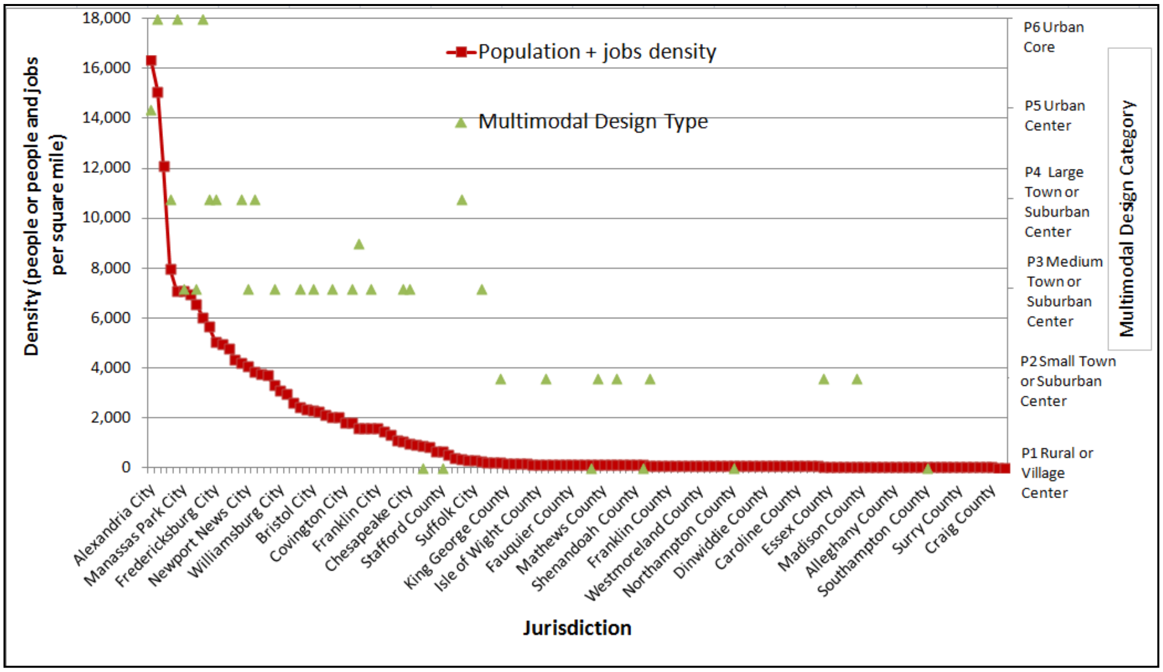

Figure C2. Virginia Jurisdictions Sorted by Population and Jobs Density and Multimodal Design Categories for years 2012-2013. Data from Bureau of Labor Statistics (2013), Department of Rail and Public Transportation (2013), Office of Intermodal Policy and Investment (2010), U.S. Census Bureau (2013a), and Weldon Cooper Center for Public Service (2014).

A Classification System Based on the U.S. Census Bureau

The U.S. Census Bureau classifies locations as being part of a metropolitan or micropolitan CBSA and then, within the CBSA, as being "central" or "outlying." A simplification of the concept behind a CBSA is that it contains an urban core along with adjacent jurisdictions that have a "high degree of social and economic integration" with this urban core (U.S. Census Bureau, 2013b). In practice, there are specific requirements for what constitutes a CBSA, which in turn is subdivided into an urban core and an outlying area. For example, to form a metropolitan CBSA, there must be a collection of contiguous census blocks or tracts with at least 50,000 people. Then, one criterion that allows a jurisdiction to be classified as "central" to the CBSA is if at least one-half of the jurisdiction's population is in an urban area with at least 10,000 people. A jurisdiction can be classified as in the CBSA but "outlying," rather than central if at least one-fourth of its residents work in the central area of the CBSA. Additional details for being included in a CBSA are given in the *Federal Register* (2010).

For example, within the Richmond CBSA, jurisdictions such as Richmond City, Petersburg, and Hanover are considered central whereas jurisdictions such as Caroline and Charles City County are considered outlying. The reason for this is that Richmond, Petersburg, and Hanover appear to meet the population requirements whereas Charles City County and Caroline, although not necessarily meeting the population requirements, may have substantial people commuting to work in the central areas of the CBSA.

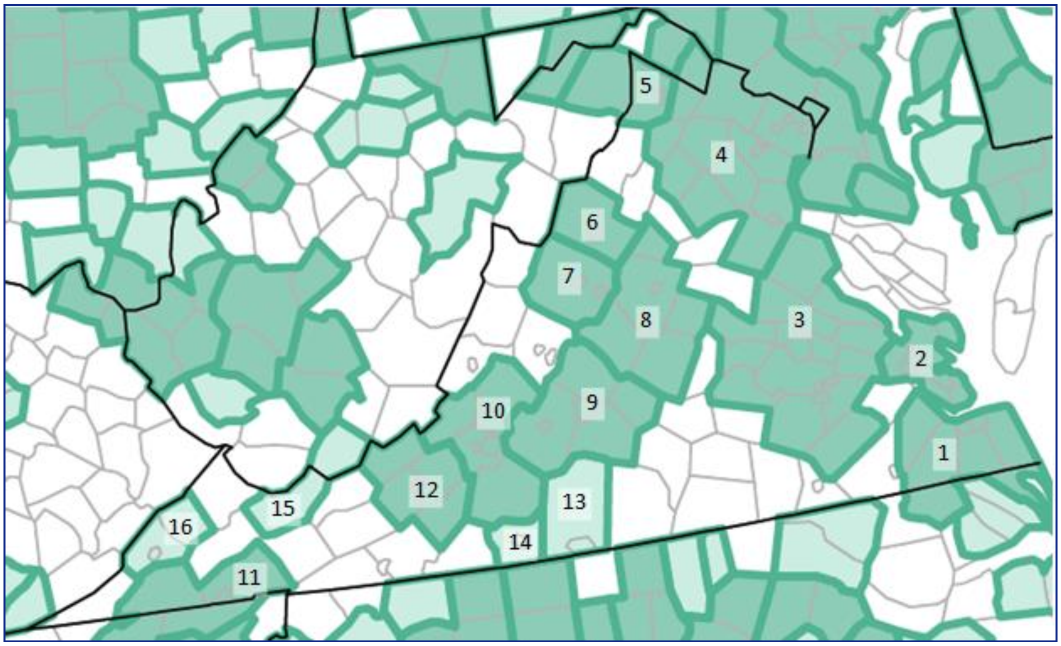

Figure C3. Excerpt of Map Showing 16 Core-Based Statistical Areas in Virginia (U.S. Census Bureau, 2013b). Numbers added by the authors of this report.

Roughly one-third (45) of Virginia's 133 jurisdictions, such as Accomack County and Alleghany County, are not part of any CBSA. A map of Virginia (Figure C3) suggests 16 CBSAs in Virginia. Statewide there is a rough correspondence between Census designation (central, outlying, or not a part of any CBSA) and population plus jobs density.

However, within a given CBSA, there generally is a much stronger relationship between designation and density, as shown in the case of the Richmond CBSA (Figure C4). A complication arises in some cases where, for very large CBSAs, some of the outlying jurisdictions have higher densities that are attributable to factors other than being part of the CBSA. For example, the "outlying" Fredericksburg City is both an older city with a higher density in its own right and an exurban location for the Washington, D.C.–Maryland–Virginia–West Virginia CBSA. As another example, as shown in Figure C5, which depicts the Virginia Beach–Norfolk–Newport News–North Carolina CBSA, the jurisdictions of Williamsburg and James City County have higher densities than those of Suffolk and Gloucester, even though the latter are outlying areas.

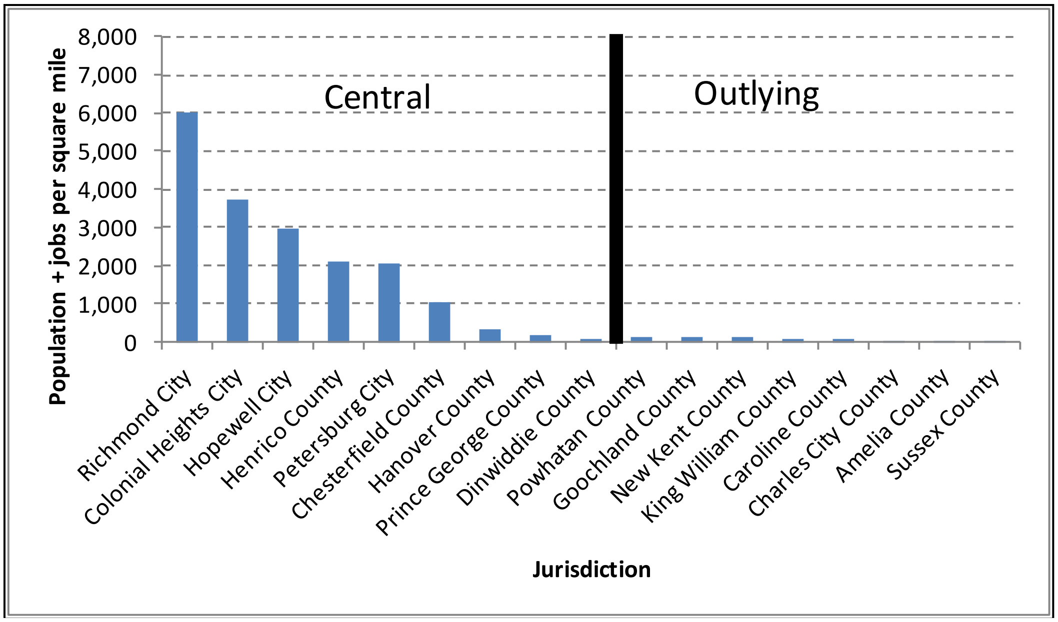

Figure C4. Richmond CBSA Jurisdictions Sorted by Census Designation (Central or Outlying) for Years 2012-2013. Data from Bureau of Labor Statistics (2013), U.S. Census Bureau (2013a), and Weldon Cooper Center for Public Service (2014).

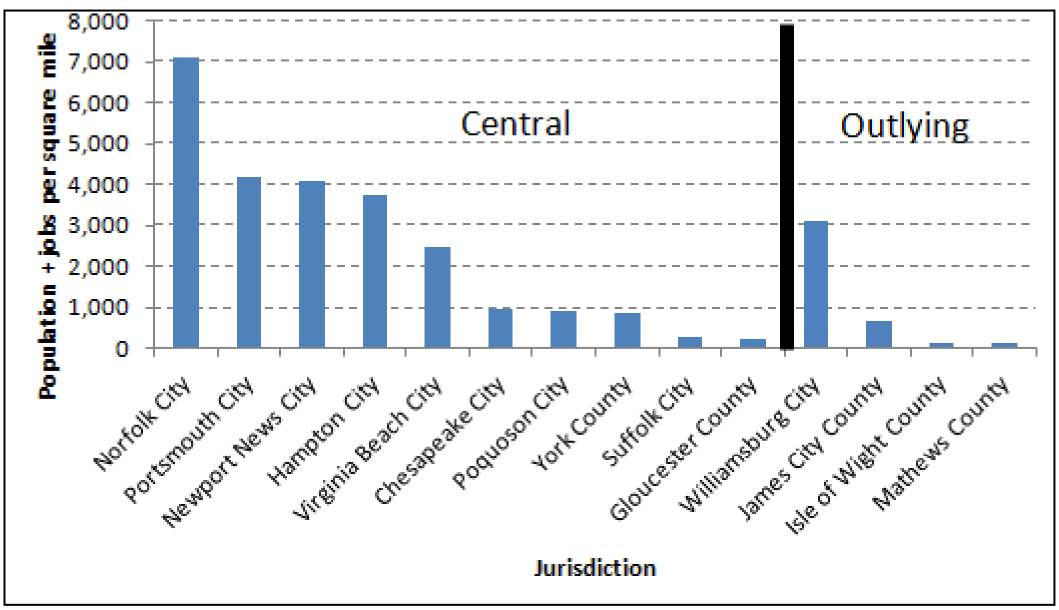

Figure C5. Virginia Beach–Norfolk–Newport News–North Carolina CBSA Jurisdictions Sorted by Census Designation (Central or Outlying) for Years 2012-2013. Data from Bureau of Labor Statistics (2013), U.S. Census Bureau (2013a), and Weldon Cooper Center for Public Service (2014).

Classification Used for VTrans2040

In recognition that any of the three schemes could be used in Virginia, an initial approach for classifying Virginia jurisdictions by land use type employed the categories of large urban core, suburban central, suburban outlying, central small urban area, outlying small urban area, and non-core. A comment in response to this initial taxonomy was that although the definitions were acceptable, use of the word "suburban" could be counterproductive in that some stakeholders might view such a label as having a negative connotation rather than being a descriptor of a land use type (N. Donohue, personal communication, 2014). After the word "suburban" was replaced with the word "exurban," a later comment (R. Case, personal communication, 2014) suggested that any label should be accompanied by a precise definition.

Thus, an approach for labeling jurisdictions was selected that met five criteria.

1. The taxonomy should avoid labels that some people might view negatively (e.g., avoid the use of the word "suburban").

2. The taxonomy should use criteria that can be replicated by others (e.g., if a label is used, show the definition for the label).

3. The taxonomy should be based at least in part on density (whether of population, jobs, or some combination thereof) given the role that density plays in Virginia's *Multimodal System Design Guidelines* and the previous classification system used in *VTrans2035.*

4. The taxonomy should be based at least in part on geography given the role that geography plays in all three classification systems.

5. The taxonomy should be applicable at the jurisdiction level given that much of the population forecasts are made at the jurisdiction, rather than census tract, level.

Table 2 in the body of the report presents an approach for labeling jurisdictions that meets these five criteria. The approach is based on the U.S. Census Bureau, which classifies locations as being part of a metropolitan or micropolitan CBSA and then, within the CBSA, as being "central" or "outlying." To enable a consistent designation of Virginia's jurisdictions, one of six location types is given for each jurisdiction: (1) Alexandria/Arlington; (2) Central Hampton Roads, Northern Virginia, Richmond; (3) Outlying Hampton Roads, Northern Virginia, Richmond; (4) central small urban area; (5) outlying small urban area; and (6) non-core area. These categories are based on the Census designations and are defined as follows:

- A jurisdiction that is not part of any census CBSA is called a *non-core area*. Although the term "non-urban" was used in *VTrans2035, non-core area* is more consistent with the Census definition.

- The jurisdictions of Arlington and Alexandria are given their own location type: *Alexandria/Arlington*. In *VTrans2035,* they were called "large urban core" and were the only jurisdictions that received this designation. At a combined 2012 density of 8,960/square mile (and a population of 367,000), their density is not quite double that of the next relatively large jurisdiction (Norfolk, with a population of 246,000 and the fourth highest density in Virginia of 4,541/square mile). The second and third most densely populated jurisdictions—the nonadjacent cities of Falls Church and Manassas Park—have a combined density of 6,403/square mile and a combined population of only 29,000. In short, based on 2012 data it does seem appropriate to give Alexandria and Arlington their own location type.

- The remaining jurisdictions are all a part of a CBSA and receive one of four labels.

1. *Central Hampton Roads, Northern Virginia, Richmond* if the jurisdiction is within the Richmond, Washington, D.C., or Virginia Beach CBSA and if the Census Bureau classifies the location as a "central" area. (In *VTrans2035*, the term "suburban feeder" was used for jurisdictions in roughly these areas.) The jurisdictions in these areas represent two-thirds of the population growth from 2012-2040.

2. *Outlying Hampton Roads, Northern Virginia, Richmond* if the jurisdiction is within the Richmond, Washington, D.C., or Virginia Beach CBSA and if the Census Bureau classifies the location as an "outlying" area. (In *VTrans2035*, the term "suburban feeder" was used for jurisdictions in roughly these areas.)

3. *Central* s*mall urban area* if the jurisdiction is part of a CBSA other than the Richmond, Washington, D.C., or Virginia Beach CBSA and if the Census Bureau classifies the location as a "central" area. (In *VTrans2035*, the term "small urban area" was used for jurisdictions in roughly these areas.)

4. *Outlying small urban area* if the jurisdiction is part of a CBSA other than the Richmond, Washington, D.C., or Virginia Beach CBSA and if the Census Bureau classifies the location as an "outlying" area. (In *VTrans2035*, the term "small urban area" was used for jurisdictions in roughly these areas.)

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APPENDIX D

POTENTIAL STAKEHOLDER INPUT EXERCISES

One reason for gathering demographic information is to solicit comments from stakeholders regarding development of the statewide multimodal transportation plan. Those comments should be based on the presentation to stakeholders of two or more alternatives, where stakeholders could give their reactions to the alternatives. For example, for the topical area of population growth, alternatives may be based on where the population growth occurs. For consistency of presentation, the information for each area is divided into three categories, with the language based on a presentation by Parkins (2014):

1. What the [trend] numbers say
2. What the experts say
3. What do [you] stakeholders say?

This appendix demonstrates how a stakeholder input exercise could be conducted with the use of three growth scenarios. The example concerns where within a given jurisdiction growth might occur and illustrates how various growth patterns might influence societal costs for transportation. At the end of the appendix, an outline for a second example is presented, based on the relationship between vehicle ownership and parking needs. Given that the literature suggests that some urban CBDs, such as Washington, D.C., devote one-half of their space to parking (Manville and Shoup, 2005), there may be an interest in examining how shared vehicles could affect parking demand.

What the [Trend] Numbers Say

The trend numbers are available in the report and indicate two elements:

1. By 2040 some jurisdictions are projected to grow substantially.
2. The amount of growth in a given jurisdiction is uncertain.

Because demand for transportation is influenced by population growth, changes in population affect changes in VMT.

What the Experts Say

Previous research suggests that the manner in which population will affect VMT is uncertain because of two factors.

1. *Location of population growth within a jurisdiction*. Meyer and Miller (2013) reported data showing that jurisdictions with a population density of 4,000-10,000/square mile (e.g., Arlington, Alexandria, and Norfolk) tend to have 25% lower

VMT per capita than jurisdictions with densities under 500/square mile (e.g., Page, Orange, and Suffolk). Figure 31 shows this relationship.

2. *Behaviors of people*. Dutzik and Baxandall (2013) developed three scenarios developed at the national level for future VMT changes. Each scenario is based on a particular belief regarding the VMT change observed from 2001-2009.

   - *The VMT reduction from 2001-2009 is temporary such that total VMT in 2040 [not per capita VMT] increases by 24% relative to 2007*.

   - *The VMT reduction from 2001-2009 represents a single long-term shift such that total VMT in 2040 increases by 7% relative to 2007*.

   - *The VMT reduction from 2001-2009 represents one of multiple declines in VMT such that total VMT in 2040 decreases by 19% relative to 2007*.

Clearly the factors that influence VMT, such as the substitutability of communications technologies for travel, the location preferences of various age groups, and economic growth, are not controlled by stakeholders. However, public policies may be able to influence some of these factors, such as through encouragement of higher or lower density growth, as density is one factor—albeit just one of many—that influences VMT.

VMT by itself may indicate positive impacts, such as increased ease of travel, which may mean greater opportunities for employment, education, and social exchange. However, VMT can also exert negative societal impacts—that is, costs that are not borne by the individual but rather by others. For example, research by Litman (2009) suggested that each additional VMT costs society an extra 27 cents (in rural areas) or 55 cents (in urban areas). These costs are not paid by motorists but rather reflect the monetization of negative effects such as environmental impacts (e.g., air pollution, greenhouse gases, noise, and water pollution); effects on other motorists (e.g., congestion, and crashes); ancillary transportation services (e.g., retiming of traffic signals); and opportunity costs (e.g., the land that is used for transportation is land that does not generate economic value through other means).

What Do You [Stakeholders] Say?

Stakeholders may be asked to consider the jurisdiction shown in Figure D1 and to envision three alternative growth cases. Possible responses could include the following.

1. *No further discussion is needed because our city, county, or region is already working to influence land development to the extent feasible within market constraints*.

2. *Further discussion is probably not needed because behavioral changes have lessened the importance of this concern*.

3. Discussion is appropriate because we are still concerned about future VMT growth.

Potential Growth Scenarios

Overview

These scenarios use a sample county but could conceivably represent any of the 133 jurisdictions in Virginia. (To make this exercise somewhat realistic, data were obtained from one county in central Virginia—Chesterfield—as an example.)

Figure D1 shows the population densities in 2010 for this county, which had a total 2010 population of 316,236. By year 2040, the county is expected to see an additional 256,459 people for a total population of 572,695. It is recognized that long-term forecasts are highly variable at the jurisdiction level; thus, if a typical jurisdiction forecast error of 24% is used, the total population could be as high as roughly 710,000 or as low as 435,000.

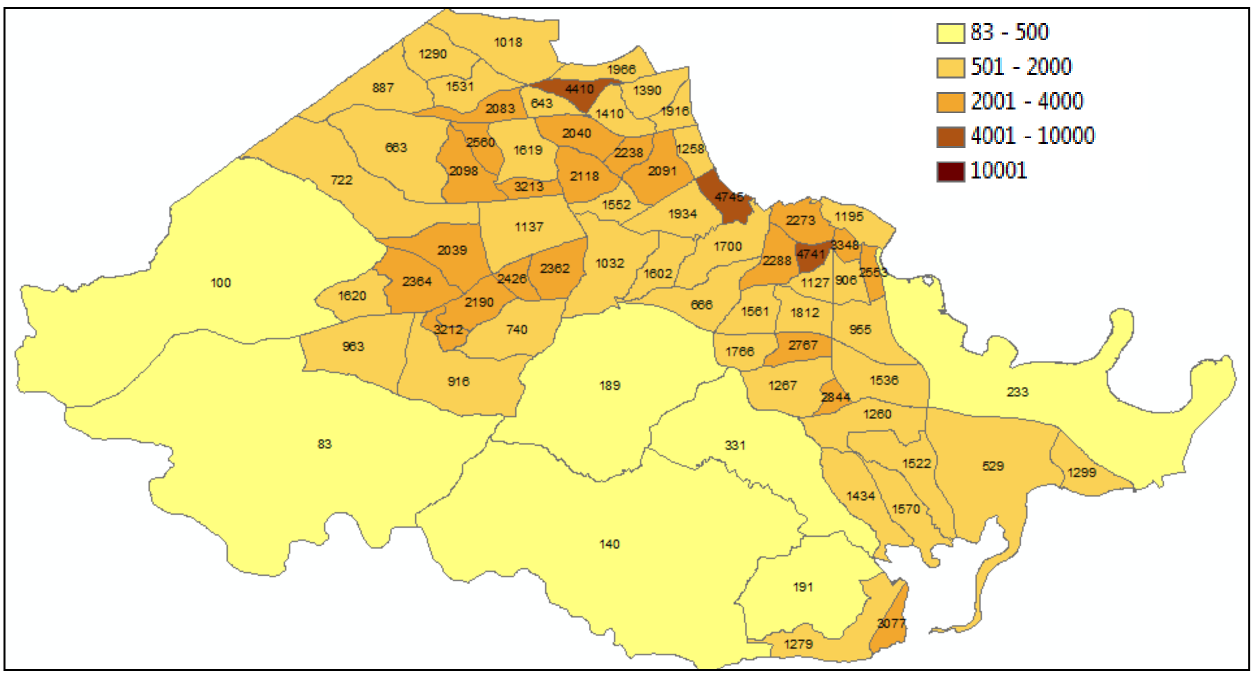

Figure D1. Population Density for Case Study County in 2010. Population per square mile. Data from U.S. Census Bureau (2011).

For simplicity, there are three cases that assume the same 2040 county population. The cases differ only in terms of where within the county the growth will occur.

- Scenario 1 assumes growth is dispersed (i.e., larger areas attract more growth).
- Scenario 2 assumes growth follows existing population (i.e., more populated areas attract more growth).

- Scenario 3 assumes compact growth (i.e., more dense areas attract more growth).

Scenarios

Scenario 1: Dispersed Growth

The new population disperses in the sense that census tracts with a larger area receive more people. For example, a given Census tract has 0.38% of the total area. Therefore, it is projected to receive roughly 0.38% of the 256,458 people by 2040. (An exception is made for a Census tract with a given state park where it is assumed no growth will occur.) The corresponding densities are shown in Figure D2.

A rough estimate of annual VMT produced by this jurisdiction in 2040 is 5.5 billion VMT. This estimate is based on Figure 31, where higher density locations might generate more VMT than lower density locations. Assuming external societal costs of 27 cents per mile—that is, costs that do not reflect monies paid by motorists but rather reflect health-related air quality impacts, other environmental impacts, crash risks, and opportunity costs from not being able to use land for other purposes—a rough estimate of these costs is $1.5 billion.

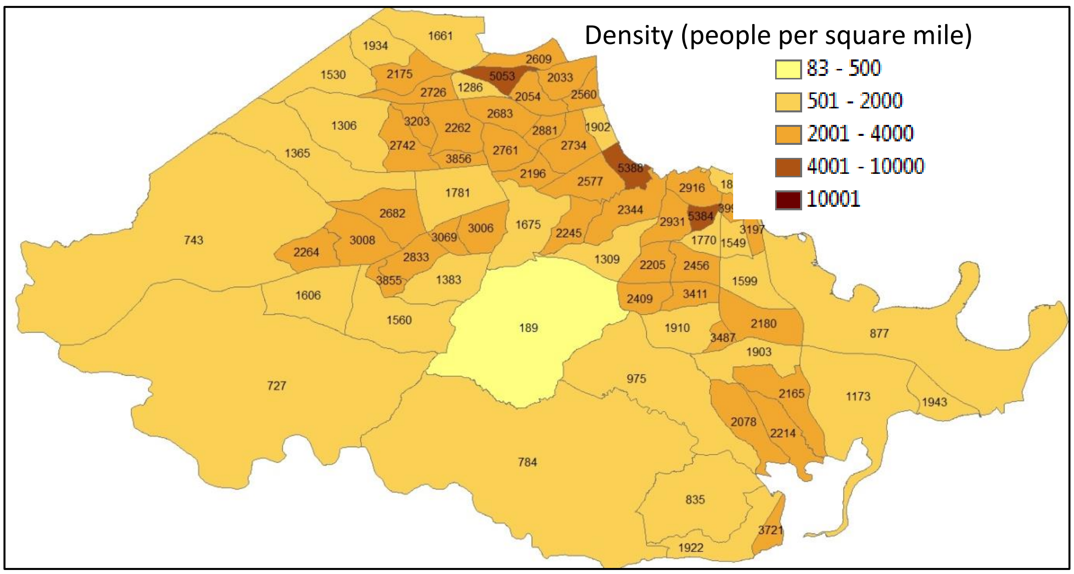

Figure D2. Population Density for Case Study County in 2040: Dispersed Case. Population per square mile. Values calculated by the authors of this report using data from U.S. Census Bureau (2011), Meyer and Miller (2013), and Weldon Cooper (2012).

Scenario 2: Moderately Dispersed Growth

The new population locates in a manner that is proportionate to the existing population. For example, a given census tract has 2.3% of the population in 2010. Therefore, it receives 2.3% of the 256,459 growth by 2040. The corresponding densities are shown in Figure D3. Based on the relationships between population density and VMT shown in Figure 31, the fact that more of the population growth is in the higher density locations than is the case with Case 1 means that the total VMT in 2040 generated by the county is 5.03% less than is the case with

Case 1. Thus, external societal cots of this VMT are also 5.03% less than is the case with Case 1. This is a trend case.

A rough estimate of annual VMT produced by this jurisdiction in 2040 is 5.2 billion VMT. This estimate is based on Figure 31, where higher density locations might generate more VMT than lower density locations. Assuming external societal costs of 27 cents per mile—again, costs, that do not reflect monies paid by motorists but rather reflect health-related air quality impacts, other environmental impacts, crash risks, and opportunity costs from not being able to use land for other purposes—a rough estimate of these costs is $1.4 billion.

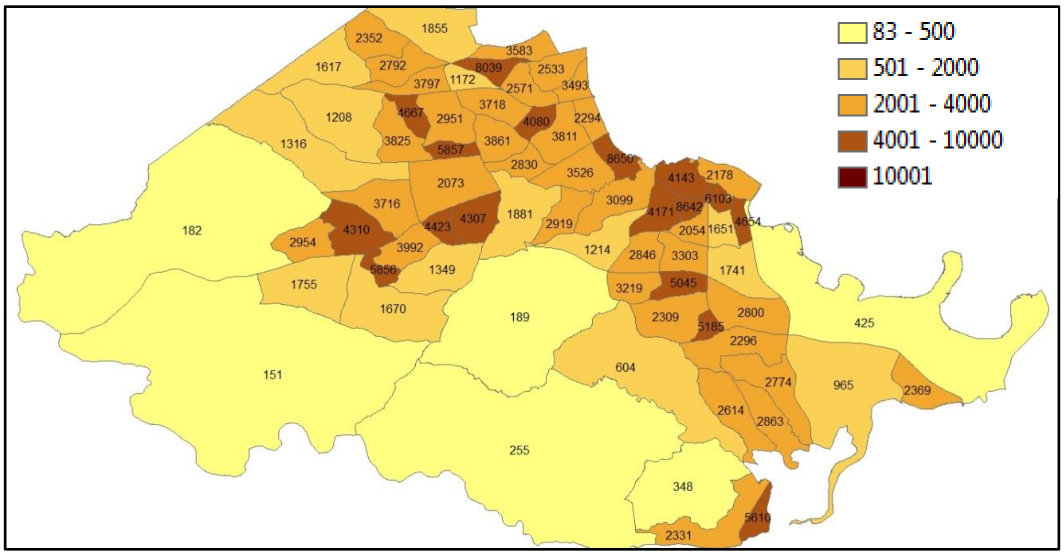

Figure D3. Population Density for Case Study County in 2040: Trend Case. Population per square mile. Values calculated by the authors of this report using data from U.S. Census Bureau (2011), Meyer and Miller (2013), and Weldon Cooper (2012).

Scenario 3: Compact Growth

The new population locates in a highly compact fashion, where the highest density tracts receive additional growth. That is, starting with the highest density tract in 2010, the tract's density is increased to 10,001/square mile. Then the second highest density tract sees its density also increased to 10,001/square mile. This is repeated with the next highest density tracts until all 256,459 people have been added to the county. The corresponding densities are shown in Figure D4. Based on the relationships between population density and VMT shown in Figure 31, the fact that most of the growth is in high-density locations means that the total VMT in 2040 generated by the county is 28.3% less than is the case with Scenario 1. This is a "compact" case.

A rough estimate of annual VMT produced by this jurisdiction in 2040 is 3.9 billion VMT. This estimate is based on Figure 31, where higher density locations might generate more VMT than lower density locations. Assuming external societal costs of 27 cents per mile—again, costs, that do not reflect monies paid by motorists but rather reflect health-related air quality impacts, other environmental impacts, crash risks, and opportunity costs from not being able to use land for other purposes—a rough estimate of these costs is $1.1 billion.

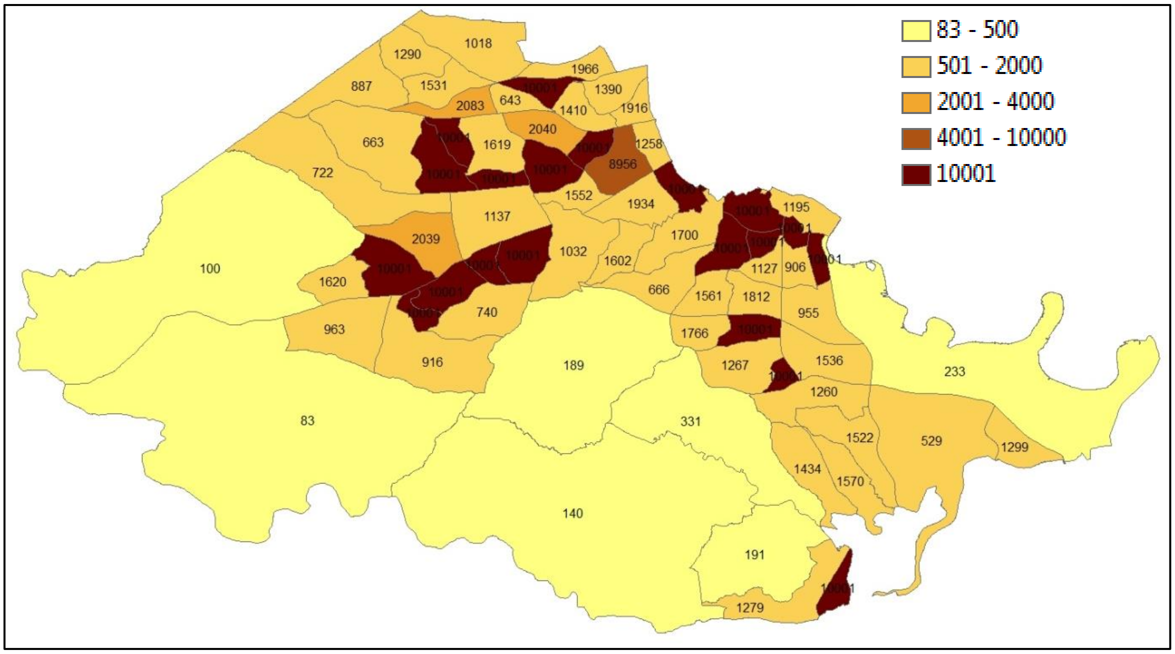

Figure D4. Population Density for Case Study County in 2040: Compact Case. Population per square mile. Values calculated by the authors of this report using data from U.S. Census Bureau (2011), Meyer and Miller (2013), and Weldon Cooper (2012).

Summary of Two Stakeholder Input Exercises

Table D1 summarizes the case as presented to stakeholders, following the structure of *what the numbers say*, *what the experts say*, and *what do you say*? Table D1 is thus based on the question of whether there should be active involvement at the local level in increasing density and originates from population trend information.

Table D2 summarizes a different public input stakeholder exercise. The key question concerns whether carsharing should be actively encouraged. These scenarios originate from the vehicle ownership trends.

Table D1. Summary of How to Use Population Trends with Stakeholders

Label From "A Structure for Public Input"[a]	**Description From "A Structure for Public Input"[a]**	**Example Based on Topic 1 (Socioeconomic Forecasts: Population)**
What the Numbers Say	Quantitative summary of trends from available data	By 2040, although Virginia may grow by 29%, *a minority of jurisdictions may see larger growth*. Ten jurisdictions, such as Chesterfield, may account for 71% of the 2012-2040 growth. A jurisdiction's population forecast has an empirical confidence interval of *roughly ±24%.*
What the Experts Say	Qualitative summary of trends from research (address likelihood and pervasiveness)	Population growth will affect VMT, but the nature of this relationship varies because: • *Behaviors may be changing*. At the national level, 3 forecasts of 2040 total VMT relative to 2007 peak total VMT have been generated: *an increase of 24%* (assuming the recent decreases in VMT are an aberration), *an increase of 7%* (assuming the previous per capita VMT reductions we have observed are permanent), and a *decrease of 19%* (if further reductions are to be expected.) • *Density influences VMT*, with the most dense locations having less than one-half the per capita VMT of the least dense locations. Thus, even if a single jurisdiction will grow by a given amount, where within the jurisdiction the growth is located matters. • *VMT matters because it can have negative consequences* such as adverse environmental impacts (e.g., respiratory problems attributable to air quality), lost opportunity costs (e.g., land for transportation improvements that cannot be used for another purpose), and adverse impacts on other motorists such as increased congestion. Assumptions will affect how these consequences are quantified, but one range of estimates is that the negative societal impacts are from 27 cents to 55 cents per VMT, depending on the time of day and the location of the VMT. • *VMT matters because it can also have positive consequences;* e.g., increased VMT may reflect greater ease of travel, which can result from increased trade (thereby reducing costs of goods and services) and increased social or economic opportunities such as access to employment sites.
What Do You Say?	Reactions (Stakeholders respond to the question of "how will these trends affect you?")	Imagine that 3 cases are applied to your county or city. What is your reaction? Possible responses could include (but are not limited to) (1) we are already working to influence land development and nothing needs to, or can, change; (2) given the possibility of a forecast VMT reduction, we have less concern for this type of question; and (3) we see some value in trying to influence land development further than is presently the case. For the same population increase, cases are: • *The new population disperses in the sense that census tracts with larger area get more people.* This will produce a certain baseline total VMT with negative societal costs of approximately $1.5 Billion. These costs reflect impacts that are not borne by the motorists but rather by society as a whole, such as health-related air quality impacts. • *The new population grows in proportion to current densities—higher density areas get more people, lower density areas get fewer.* Total VMT could drop by 5% relative to the baseline, reducing societal costs from $1.5 billion to $1.4 billion. • *The new population goes exclusively to the highest density areas.* Total VMT could drop by 28% relative to the baseline, reducing societal costs from $1.5 billion to $1.1 billion.

[a] Parkins (2014) presented an approach for performing the trends analysis for VTrans2040, and within the presentation was a slide titled "A Structure for Public Input" that gave guidance for material that should be included in the three sections shown in the table.

Table D2. Summary of How to Use Vehicle Ownership Trends With Stakeholders

Label From "A Structure for Public Input"	Description From "A Structure for Public Input"[a]	Example Based on Topic 1 (Socioeconomic Forecasts—Vehicle Ownership)
What the Numbers Say	Quantitative summary of trends from available data	• Approximately 6.3% of Virginia households do not have a vehicle (down from 8.8% in 1990). • Of Virginians age 20+, 87.3% have a license (down from 92.7% in 1990). • Although the vehicles available per person statewide (0.709) has increased since 1990 (0.668), this ratio has decreased since 2000 in 14 of Virginia's 30 largest jurisdictions including Alexandria, Frederick, Henrico, Loudoun, Montgomery, Norfolk, and Richmond City. • *Nationally*, BP and OPEC forecast U.S. vehicle ownership to remain flat through 2035 (which is as far as their forecasts go). *Locally*, vehicle ownership is influenced by income, density of destinations, and availability of transport alternatives—one of which is a carsharing program in which one pays for a vehicle by the mile or the hour.
What the Experts Say	Qualitative summary of trends from research (address likelihood and pervasiveness)	Carsharing programs *may* yield public benefits relative to vehicle ownership. *Potential benefits* from studies in large cities include the following: • VMT reductions ranging from 8% to 80%, which may have benefits in terms of congestion, crash risk, and reduced transportation costs. • Increased mobility options for people without a vehicle. • Increased fuel efficiency relative to the existing fleet (e.g., on average, shared vehicles had 10 mpg greater fuel efficiency than the vehicles they replaced) • Reductions in vehicle ownership and hence parking needs. These reductions may be quantified as reduced costs for individuals or society. For example, the annual costs for a parking space for a vehicle on a suburban street are cited as $765. *Caveats to these benefits* are that they may be highly variable based on local conditions (e.g., availability of transportation alternatives) and the needs of the local population). For example: • For persons without a vehicle, carsharing may increase VMT. • Annualized construction and operating costs per parking space vary: $765 (suburban street) or $3,835 (4-level garage)
What Do You Say?	Reactions (Stakeholders respond to the question of "how will these trends affect you?")	Should localities actively encourage carsharing? Responses could include: • No. (Reasons could be it is too early to tell if benefits will materialize in the long term or this is a market-based decision with no need for public intervention.) • Yes, and one way is to provide subsidized parking for carsharing organizations. (Reasons could be that the benefits such as increased fuel efficiency and reduced VMT appear realistic.) • Yes, but parking is not the appropriate mechanism. (An additional reason could be that given the land that would be used for parking has a more valuable use to either a private entity or the public.)

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APPENDIX E

FORECASTS OF FUEL USE

The U.S. DOE (2013a) defines an alternative fuel vehicle (AFV) as one that uses an alternative fuel (either solely or as an option along with a conventional fuel); based on the Energy Policy Act of 1992, alternative fuels include (but are not limited to) natural gas, ethanol, synthetic fuel derived from coal, electricity, propane, and hydrogen. In short, an AFV is a vehicle that uses a fuel other than gasoline or diesel (U.S. DOE, 2014b).

The use of BTUs enables one to compare alternative fuel consumption given that alternate fuels have different energy contents; for example, gasoline has 116,090 BTUs/gal, and CNG has 74,720 BTUs/gal; thus, to get the energy content of 1 gallon of gasoline, one would need 116,090/74,720 = 1.55 gal of CNG (U.S. DOE, 2013b).

Fuel Price Forecasts

The U.S. EIA (2014) forecast a 2040 fuel price of $3.90 per gallon of gasoline and $4.73 per gallon of diesel (referred to in the report as distillate fuel oil) in 2012 dollars, including federal, state, and local taxes. To be clear, this 2040 forecast is a "reference" case that reflects several assumptions such as (but not limited to) an increase in VMT of 30% from 2012-2040; a 2040 U.S. population of 380 million (which in turn is based in part on immigration); the maintenance of expected 2025 Corporate Average Fuel Economy (CAFÉ) standards through year 2040; real growth in the gross domestic product (GDP) of 2.4% annually; and light duty vehicle VMT that is 29% higher in 2040 than in 2012. The U.S. EIA (2014) also has a variety of alternative forecasts; for example, under a "high oil and gas resource" scenario, the increase in light duty vehicle VMT from 2012-2040 is projected to be 33% rather than 29%.

The documentation associated with the reference forecast includes not just a numerical value but also several observations with respect to energy use and VMT which are used to develop the forecast. First, there is an expected decrease in energy use (measured in BTUs) of 4.6% from 2012-2040. This decrease reflects a drop in energy use in light duty vehicles (24%), an increase in energy use of heavy duty vehicles (43%), and changes in other modes such as rail, for which there is an increase in energy use of (9.3%). The primary reason for this decrease in energy use is largely attributed to increased fuel efficiency, with estimates of almost 56 mpg for passenger cars and 41 mpg for light duty trucks in 2040. Thus, according to the U.S. EIA (2014), the decrease in fuel use is not attributable to a reduction in VMT. Second, in the reference case, the U.S. EIA (2014) projected that *total* light duty VMT will increase by 29% from 2012-2040. However, annual VMT *per licensed driver* is 12,800 in 2040 (compared to 12,500 in 2012). However, the U.S. EIA does not presume a steady increase in per-driver VMT but rather shows a decrease from 2005-2020 and then an increase to 2040; further, the projected 12,800 in 2040 is lower than the observed high of 12,900 in 2005).

The price of fuel in Table E1 is based on the reference case of a barrel of oil rising from $112 in 2012 to $141 in 2040 (in 2012 dollars). The U.S. EIA (2014) pointed out that this price requires assumptions regarding production costs and demand, and although the assumptions for the reference case reflect "current judgment," these can certainly change over time. As a consequence, the U.S. EIA (2014) developed two alternative scenarios. The first is a combination of factors that results in a lower fuel price based on factors such as (1) lower economic growth in the Middle East and China, (2) lower costs of producing bitumen in Canada, and (3) lower costs of producing renewable fuels in Brazil. Thus, low and high forecasts are provided, which range from $2.61 (the low price for 1 gallon of gasoline) to $6.23 (the high price for 1 gallon of diesel). As shown in Table E1, these prices are in 2012 dollars; the price in 2040 dollars could be higher.

Booz Allen Hamilton (2014) suggested that the increase in world oil prices relative to the 1960s, along with increased demand for fuel worldwide, has rendered investments in alternative fuels, such as shale oil and synthetic fuels (derived from coal or biomass), financially viable. As a consequence, the author suggested that fuel prices may be relatively stable in the medium term. Looking to year 2040, Booz Allen Hamilton (2014) considered four scenarios of the future based on economic growth and oil prices; the author began with an older set of projections made by the U.S. EIA and then extended these forecasts to year 2050 based on interviews with "subject matter experts." The four scenarios suggested a 2040 fuel price range of $5.41 to $8.82 per gallon in 2008 dollars, which is a $5.71 to $9.41 in 2012 dollars (Bureau of Labor Statistics, 2014).

Three of these forecasts—$5.41, $5.76, and $6.05 per gallon—refer to low, moderate, and high GDP growth futures, respectively, where "alternative fuels" account for less than 16%, 18%, and 20%, respectively, of transportation fuels consumed. Further, among the scenarios, the amount of electricity that comes from "clean coal and noncarbon sources" increases from "some" in the moderate growth case to "most" in the high growth case. Booz Allen Hamilton (2014) included a fourth scenario where (as is the case with the high growth scenario) alternative fuels represent one-fifth of those consumed by transportation sources and (as is the case with the medium growth scenario) "some" electricity comes from clean coal and other sources that do not rely on carbon; in this fourth scenario, fuel costs $8.82 per gallon in 2040.

Although the focus of work by Erdogan et al. (2013) was to determine how fuel prices and fuel efficiency might influence land development and travel demand (in terms of VMT, mode, and route) in the Washington, D.C./Baltimore "megaregion"), their work illustrates a range of possible fuel prices and fuel efficiencies envisioned by a set of researchers that did not use, in some form, forecasts from the U.S. EIA. Two fuel prices were considered: a low price of $3.88 per gallon and a high price of $15.52 per gallon, along with two possible average fuel economies: 27 mpg and 52 mpg. Erdogan et al. (2013) explained that this high price is based on historical trends and no "policy intervention."

Table E1. Possible Prices for One Gallon of Fuel in 2040

Currency	Fuel	Low	Reference	High
In 2012 dollars	Gasoline	$2.61	$3.90	$5.04
	Diesel	$3.11	$4.73	$6.23
In 2040 dollars	Gasoline	$4.17	$6.47	$8.68
	Diesel	$4.97	$7.84	$10.72

Data from U.S. EIA (2014), Table 5.

Factors That Influence Demand for Alternative Fuels

The consumption of alternative fuels is driven by the demand for such vehicles, which is difficult to forecast and hence explains why alternative scenarios for fuel consumption have been developed by the U.S. DOE. In fact, in 2008 a report completed for *VTrans2035* had concluded that despite growth over almost a decade in hybrid electric vehicle (HEV) purchase, the following was the case: "Conditions are unstable, however, for making a reliable forecast of the market share at which HEV sales could level off" (Virginia Transportation Research Council, 2008).

The U.S. DOE (2014b) detailed two major logistical factors that affect the growth of AFVs (and which, by extension, would affect demand for alternative fuels). The first factor that may be more apparent to consumers is the higher price of AFVs. For example, based on data from the U.S. DOE Alternative Fuels Data Center, a Ford Focus electric vehicle is 50% higher ($11,655) than a comparable gasoline powered vehicle with an automatic transmission (U.S. DOE, 2013b).

The second logistical factor is the lack of refueling stations. Data available as of 2014 suggested that the current price of fuel on a per-mile basis for an electric powered vehicle (3 cents) is slightly more than one-fifth the price of fuel for a gasoline powered vehicle (14 cents); at 8 cents per mile, a natural gas powered vehicle is slightly more than one-half the per-mile fuel price of a gasoline powered vehicle (U.S. DOE, 2014b). However, the capital costs of refueling stations for alternative fuels are higher than those for conventional fuels; whereas a conventional refueling station might have a cost of $50,000 to $150,000, the cost of a natural gas refueling station ranges from $350,000 to $1 million (U.S. DOE, 2014b). Because of uncertainty about demand for these stations and lower revenue from such stations, the U.S. DOE (2014b) suggested that publicly available stations might not become widely available without either (1) additional subsidies for such stations and/or (2) increased assurances of demand. The U.S. DOE (2014b) also pointed out that the potential feasibility for home-based refueling differs by type of fuel: whereas a "home charging station" for an electric powered vehicle can be feasible (with a suggested price of $400 to $5,500), it may not be feasible to have a natural gas charging station at home, and where this is feasible, the costs are higher ($5,000 not including installation).

The U.S. DOE (2014b) suggested that although technological improvements may help address both the high capital costs of AFVs and the lack of refueling stations, a lack of information—for both consumers and private sector investors—further impedes widespread adoption of such vehicles. This market uncertainty has ancillary impacts. For example, the high capital cost of an AFV, much of which is attributable to batteries, may be considered. One way to reduce battery cost is to develop a market for rentable batteries. However, the lack of detailed information regarding battery life, the ensuing market for people who would be willing to rent rather than buy batteries, and public sector policies may inhibit entrepreneurs (or investors from providing loans for such ventures).

TIAX LLC (Undated), in a report for the America's Natural Gas Alliance (Undated) pointed out that because LNG has a lower energy content than diesel fuel (e.g., the U.S. DOE [2013a] indicated that 1 gallon of LNG has only about 57% of the energy content of 1 gallon of diesel), for heavy vehicles, one would need almost twice the density of fueling stations or additional fuel storage capabilities on existing trucks.

Pei and Parker (2014) pointed out that that other initiatives, such as (1) providing a lower interest loan or a direct subsidy to defray the cost of station refueling infrastructure, (2) reducing the tax on a particular fuel type, and (3) policies that encourage AFVs, will naturally influence forecasts.

2040 Projected Energy Consumption for Select Transportation Fuels

When the U.S. EIA (2014) considers energy consumption within the transportation sector, they consider 11 fuels: (1) regular gasoline, (2) diesel, (3) CNG or LNG, (4) E85 (also known as flex-fuel), (5) electricity, (6) propane, (7) jet fuel, (8) residual fuel oil (which in transportation can be used for large ships), (9) other petroleum (e.g., coke, asphalt, road oil), (10) pipeline fuel natural gas (an example being natural gas used to fuel compressor stations for pipelines [Discovery Drilling Funds, 2005]), and (11) liquid hydrogen. This list of fuels thus includes some fuels that are not directly related to surface transportation modes; for example, the seventh fuel cited (jet fuel) would not affect fuel use of automobiles, trucks, and rail.

Although the use of BTUs allows one to present only energy *prices* on a uniform basis, BTUs do not account for the fact that energy *efficiency* may vary with technology. For example, the 2012 price for 1 million BTUs from electricity is slightly higher (by 2.4%) than the 2012 price for 1 million BTUs from gasoline (U.S. DOE, 2013a). However, the operating cost for an electric “passenger vehicle” is about 75% less than the operating cost for a conventional passenger vehicle because the former’s drivetrain is much more efficient than that of the latter (U.S. DOE, 2014b).

Figure E1 shows the projected transportation energy consumption for the first 5 fuels, which account for 81% of the projected consumption in the transportation sector. (Jet fuel, residual fuel oil, and pipeline fuel natural gas account for 97% of the remaining consumption.) As noted by the U.S. EIA (2014) and the Government Accountability Office (GAO) (2014), projected consumption is affected by regulatory and economic factors; for instance, the GAO (2014) noted that the economic recession (defined therein as 2007-2009) contributed to a reduction in U.S. petroleum consumption from 2005 to 2012. (Other factors contributed to this decrease, but the drop in consumption for the 2007-2009 period, as depicted by the GAO [2014], clearly illustrates the potential effect of economic forces on fuel use.)

For electricity, two indicators of consumption are given: the amount of electricity received at the source and the amount of electricity lost in transmission; for example, in 2040, it was projected in the U.S. EIA (2014) reference case that 180 trillion BTUs in electricity will be consumed, of which 60 trillion BTUs would be delivered for transportation purposes and 120 trillion BTUs would be lost in transmission. (That said, these numbers are relatively small compared to the 25.62 quadrillion BTUs estimated to be consumed by the transportation sector in the 2040 reference case.)

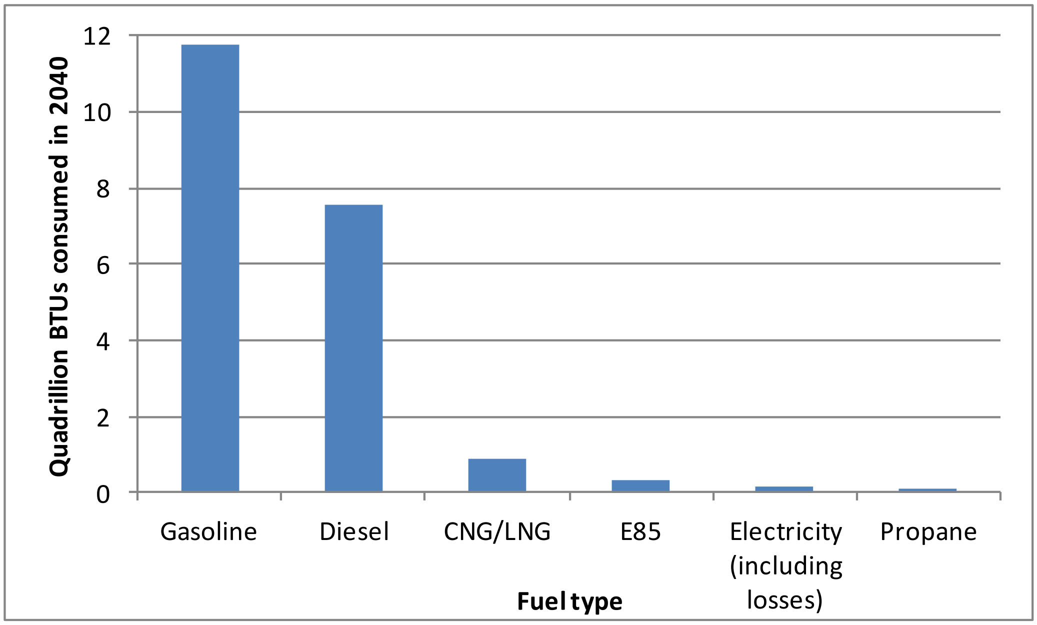

Figure E1. 2040 Projected Energy Consumption for Select Transportation Fuels. Data from U.S. EIA (2014).

On a BTU pricing basis, the cost per million BTUs for natural gas (in 2012 dollars) was projected to be $19.67 in the U.S. EIA reference case, which is lower than the price for diesel ($34.53). Not surprisingly, the U.S. EIA projected in the reference case that LNG could account for more than one-third (35%) of freight rail energy consumption, with the possibility that this share could increase to 95% in a "high rail LNG" scenario. Such a scenario could result if the industry adopted LNG technology for locomotives in the 2020s and 2030s in a manner comparable to when the industry adopted diesel technology in the 1940s and 1950s (U.S. EIA, 2014). Figure E2 shows the projected 2040 prices for 1 million BTUs for the same fuels shown in Figure E1.

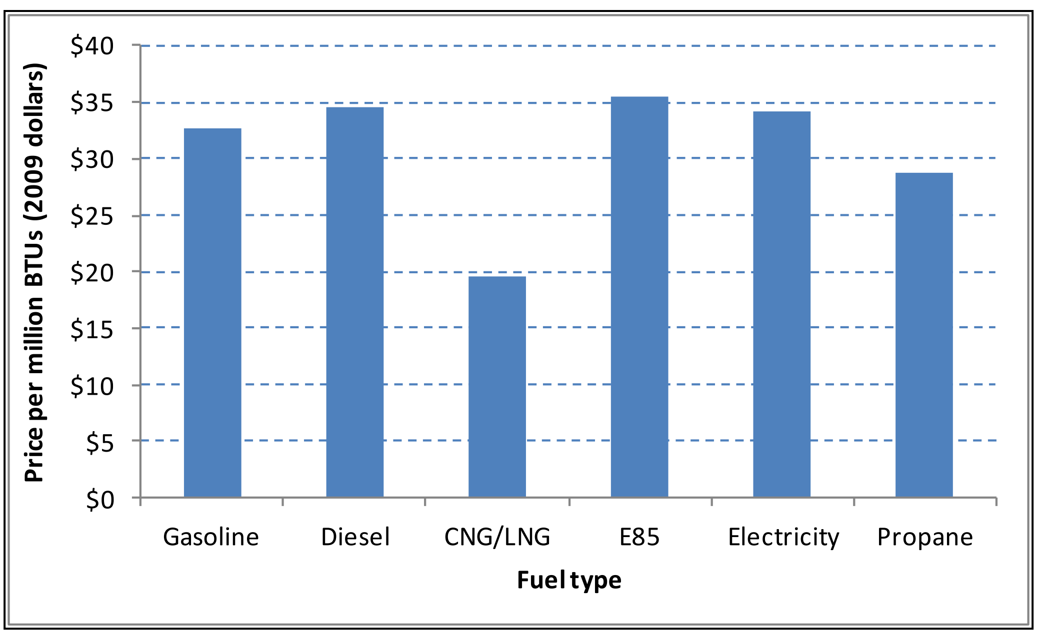

Figure E2. Projected 2040 Fuel Prices. Data from U.S. EIA (2014).

The U.S. EIA (2014) forecast that although CNG/LNG will grow by a factor of almost 20 (from 43 trillion BTUs in 2012 to 863 trillion BTUs in 2040), such fuel will account for 3% of total BTUs consumed by the transportation sector. Most of this consumption of CNG/LNG is by either medium duty or heavy duty vehicles (71%) or freight rail (17%). In the 2040 reference case, on a BTU basis, for just regular gasoline, E85, diesel, and CNG/LNG, the percentages were regular gasoline (57%), E85 (2%), diesel (37%), and CNG/LNG (4%). That said, the numbers by energy use do not fully explain the types of new light duty vehicles that are expected to be sold in 2040. Roughly one third (33%) are expected to be hybrid vehicles that use gasoline or diesel but that are not plugged in. Other types of electric vehicles—notably, all electric vehicles, plug-in hybrid vehicles, and gas or diesel hybrid vehicles that use stored electric energy to move (rather than just at idle)—account for 7% of new light duty vehicle sales, and vehicles that can be fueled by E85 account for 11% of light duty vehicle sales.

Freight plays a major role in energy use. In the 2040 base case, when only light duty vehicles, freight trucks, rail, and air are considered, the percentages of BTUs consumed are, in decreasing order, light duty vehicles (53%), freight trucks (33%), air (12%), freight rail (2%), and passenger rail (less than 1%).

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APPENDIX F

PLANNING-RELATED USES OF THIS WORK

Excerpts of this work have been presented to the Office of Intermodal Planning and Investment's Multimodal Working Group (in 2014), the Virginia Planning and Programming Annual Meeting (in February 2015), and the Charlottesville Albemarle Transportation Training Academy (in October 2015). The findings herein may be of interest to two distinct audiences: (1) local planners or regional planners who are interested in performing scenario analyses such as those mentioned in Appendix E, and (2) local transportation agency staff who want to investigate some of the factors that may influence travel demand for specific modes, such as the factors that influence the likelihood of driving alone as suggested in Figure 27. As shown in the presentation slides that follow (formatting edited slightly since the presentation), the material herein could be used to support at least two types of considerations:

1. An uncertainty analysis, where, for example, one might adjust a population or employment number based on the difference between forecast and observed results reported previously. (For example, for a 30-year population forecast at the county level, one might increase population by 20% and see how that affects the analysis.)

2. An analysis of how transportation demand may change from the present, where, for example, an agency might assess how the increase in people age 85+ might affect demand for paratransit or other types of transportation. As another example, an agency might assess whether local population changes are likely to affect the feasibility of fixed-route public transportation in a given location.

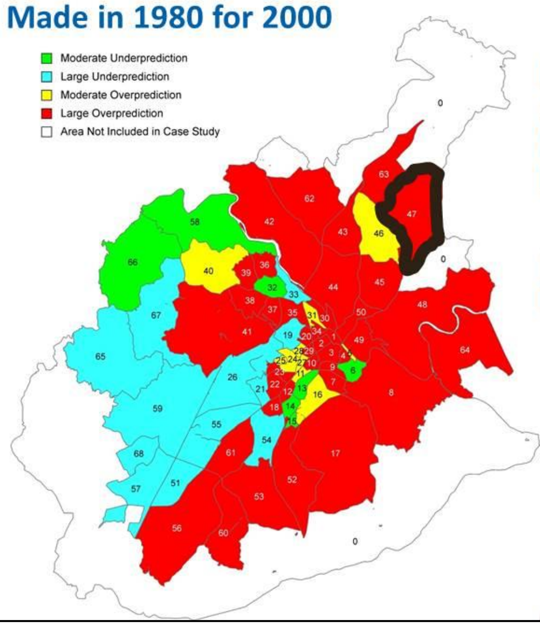
Virginia Department of Transportation

Socioeconomic Trends: Accuracy and Forecasts!

February 4, 2015

John Miller

Example 1: Lynchburg Area Population Forecasts Made in 1980 for 2000



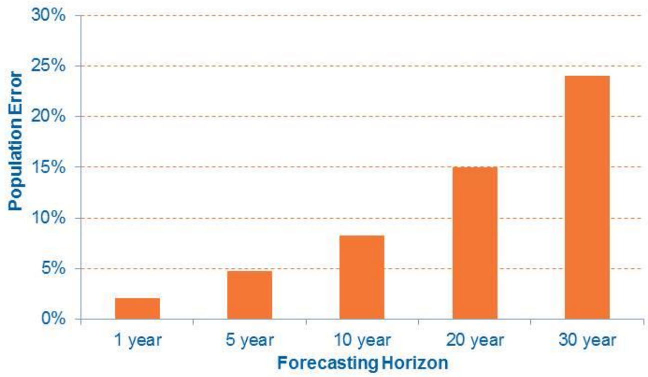
Entire Region

Actual:	114,000
Forecast:	26,000
Error:	**10%**

Individual Zones

Error:	**39%**

Example 2. Expected County Level Forecast Errors



Drawn from: Woods & Poole Economics, Inc., *Virginia, Maryland, and District of Columbia 2014 State Profile: State and County Projections to 2040*, Washington, D.C., 2014, and Weldon Cooper Center for Public Service, Inc., *Virginia Population Projections Methodology*, Charlottesville, 2012.

3 VDOT

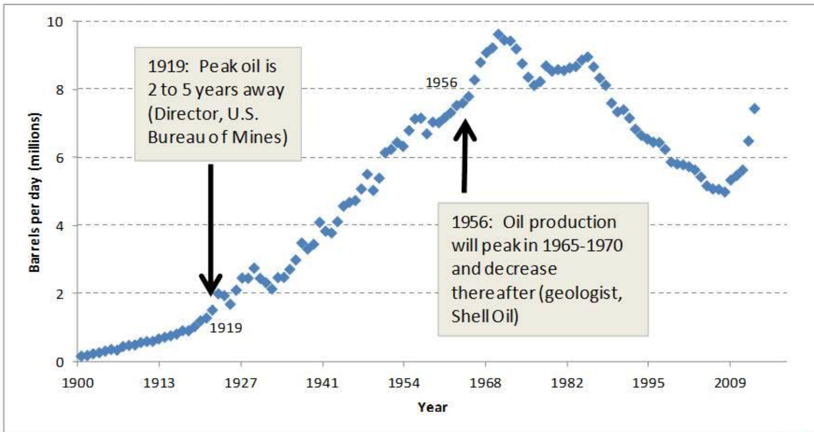
Example 3. Metropolitan Washington Forecasts Made in 1990 for 2010

	Population	Employment
Regional error	8%	12%
Jurisdiction error	11%	25%

Calculated from the following source: National Capital Region Transportation Planning Board, *Accuracy of Growth Forecasts Made 20 Years Ago Varied From Jurisdiction to Jurisdiction*, TPB Weekly Report, Metropolitan Washington Council of Governments, January 8, 2013.

4 VDOT

Example 4: Forecasts for Peak Oil Production Made in 1919 and 1956



Drawn from data available from the U.S. Energy Information Administration (U.S. Field Production of Crude Oil, 2014) and annotated based on information provided by Russell Gold in "Why Peak-Oil Predictions Haven't Come True—and Probably Won't," *The Wall Street Journal*, September 29, 2014, pp. R1-R2.

5 VDOT

Summary About Forecasting Accuracy

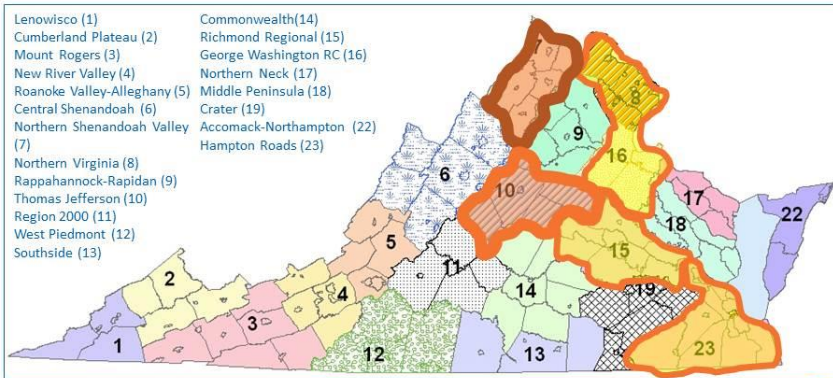
It is easier to make forecasts for

- **A shorter time horizon than a longer one**
- **A larger geographical area than a smaller one**
- **A demographic trend than a behavioral trend**
- **A conventional technology than a new one**

Easier to Forecast	Harder to Forecast
Virginia's population in 2020	Proportion of Richmond residents taking a shared autonomous vehicle to the grocery store in 2040

6 VDOT

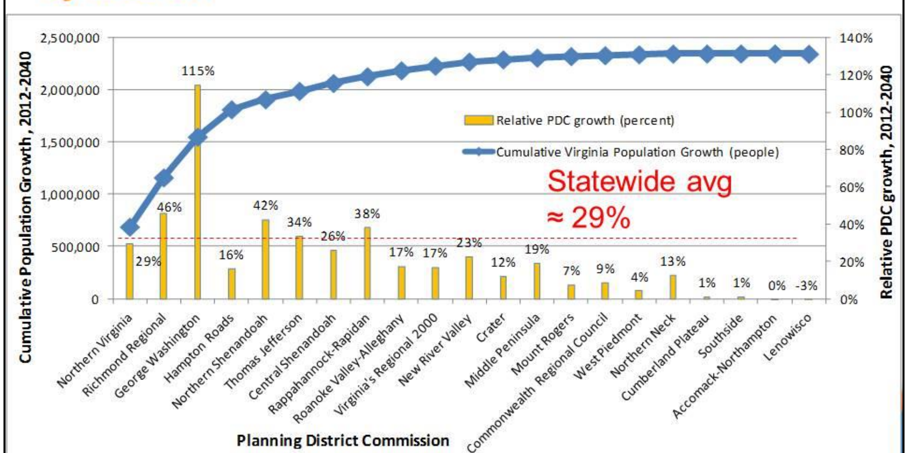
Where Is Growth Headed by 2040?
77% of Growth in 4 PDCs
85% of Growth in 6 PDCs



Take-away: An increase of between 2.3 million and 3.5 million people in these 6 PDCs

VDOT

Projected Population Growth Is Not Uniform by Location

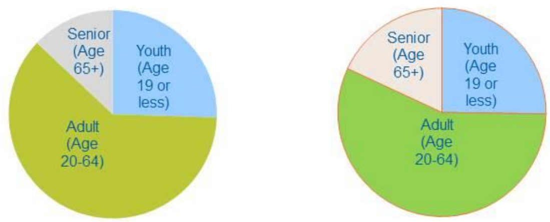


8 Take-away: An "average" growth forecast for Virginia does not tell the full story

VDOT

Growth Is Not Uniform by Age Group

Ages	2012 Population	2040 Population	Change
Youth (0-19)	2.1M	2.7M	27%
Senior (65+)	1.1M	1.9M	79%

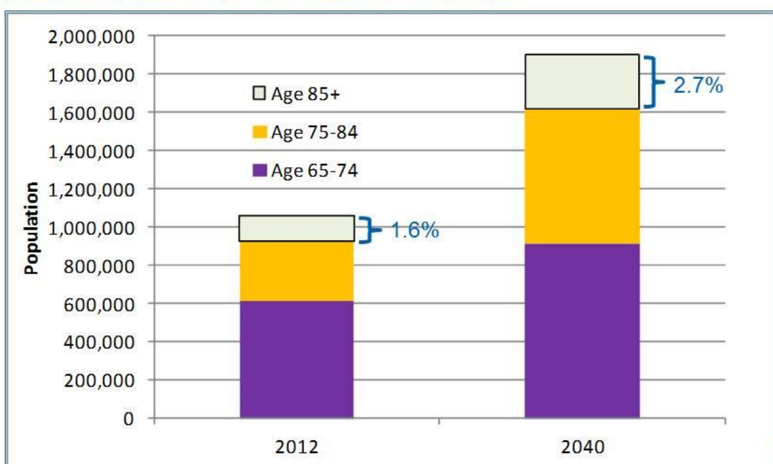


2012 2040

Data obtained from the Weldon Cooper Center for Public Service, Demographics & Workforce Group, *2020, 2030, and 2040 Population Projections by Age and Sex for Virginia and Its PDCs and Member Localities*, Charlottesville, 2012.

VDOT

Population of Mature Seniors Is Growing Faster Than Population of Youthful Seniors



10

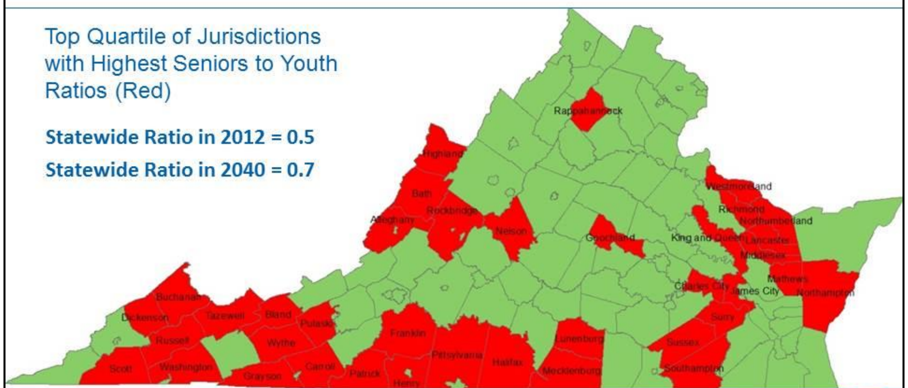
VDOT

2040 Ratios of Seniors to Youth

Top Quartile of Jurisdictions with Highest Seniors to Youth Ratios (Red)

Statewide Ratio in 2012 = 0.5

Statewide Ratio in 2040 = 0.7

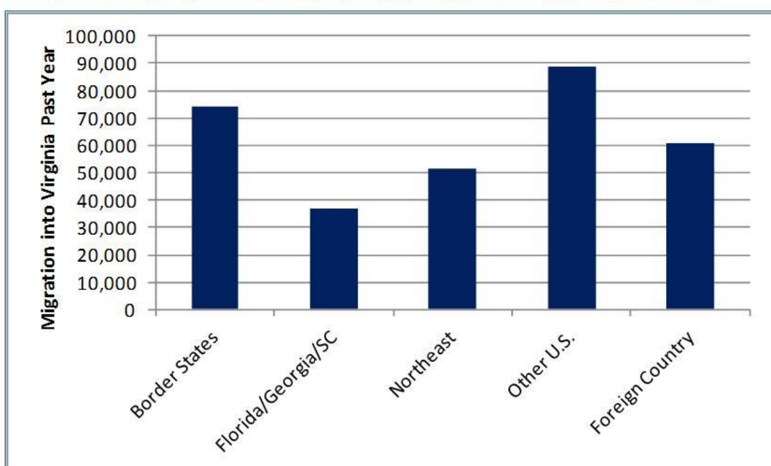


Example in 2040:
Age 65+ 6,300
Age 19 and under: 22,000
Ratio: ≈ **0.3**

11

VDOT

About Half Our Population Growth Depends on Domestic Migration and International Immigration



12

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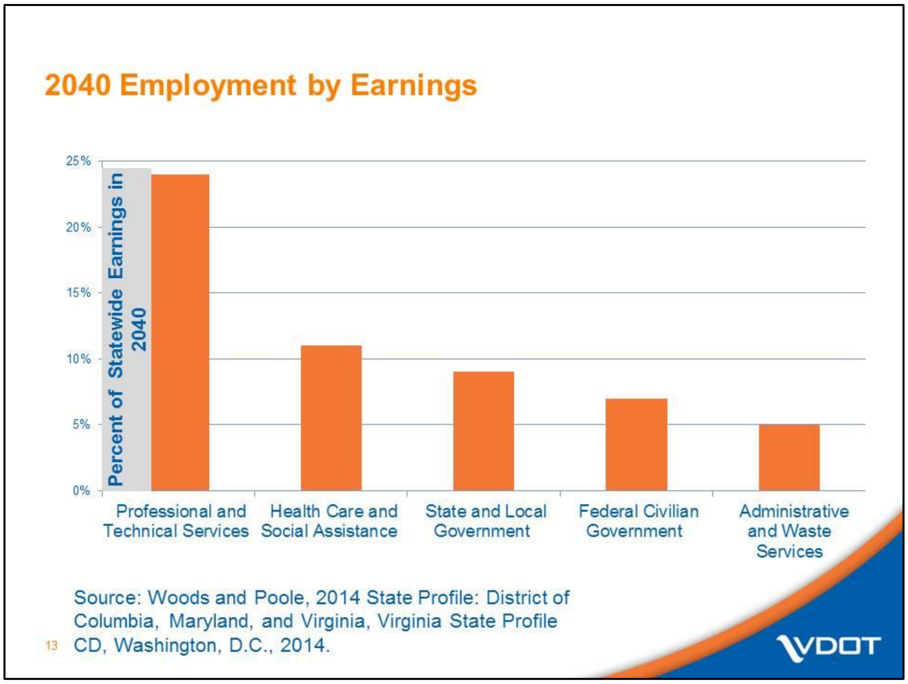
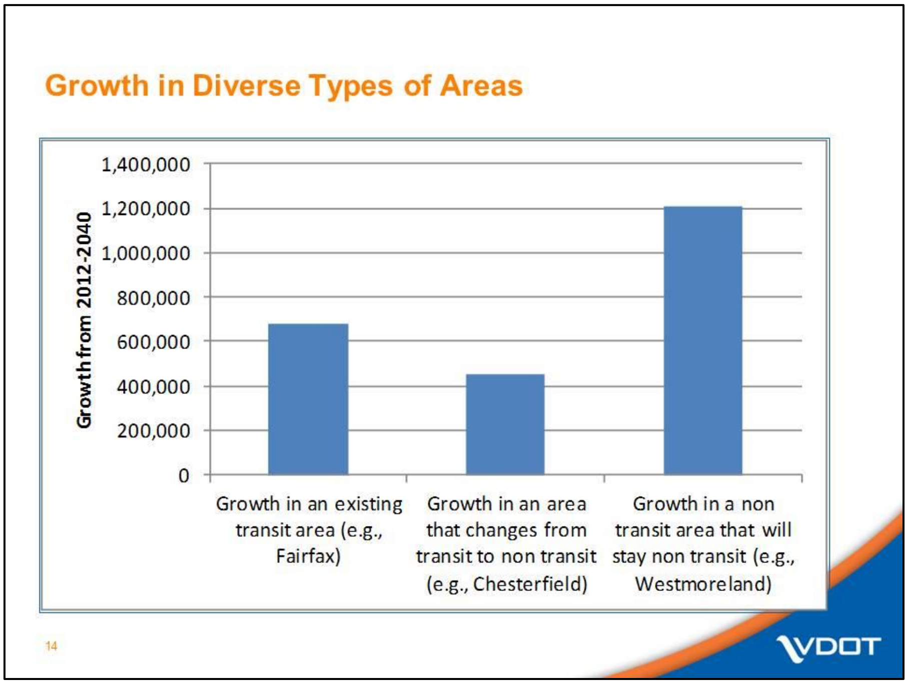

2040 Employment by Earnings
25%
20%
15%
10%
5%
0%
Percent of Statewide Earnings in 2040
Professional and Technical Services
Health Care and Social Assistance
State and Local Government
Federal Civilian Government
Administrative and Waste Services
Source: Woods and Poole, 2014 State Profile: District of Columbia, Maryland, and Virginia, Virginia State Profile CD, Washington, D.C., 2014.
13
VDOT


Growth in Diverse Types of Areas
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Growth from 2012-2040
Growth in an existing transit area (e.g., Fairfax)
Growth in an area that changes from transit to non transit (e.g., Chesterfield)
Growth in a non transit area that will stay non transit (e.g., Westmoreland)
14
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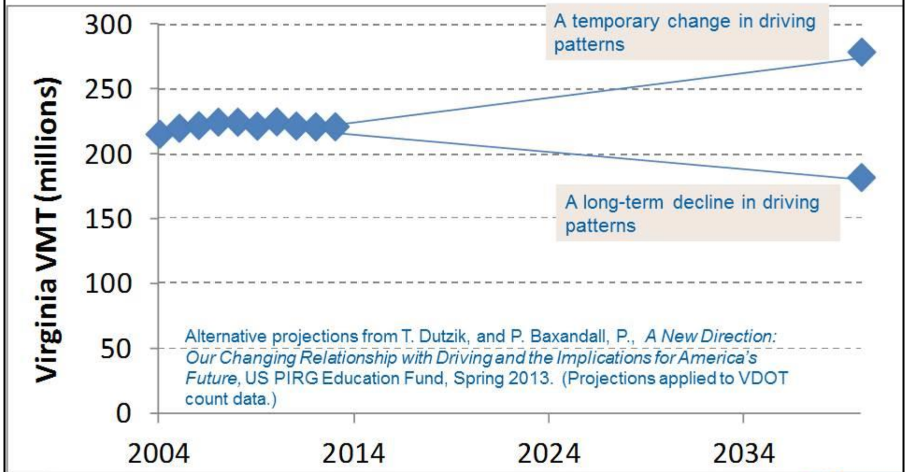
Changes in Vehicle Miles Traveled (VMT)



15

VDOT

Trend Summary

1. Forecast uncertainty is large for both population forecasts (trends) and travel impacts (behaviors).
2. Four PDCs account for three-fourths of Virginia's 2.3 million to 3.5 million additional people. Growth is uneven by jurisdiction.
3. One-half of Virginia's growth depends on people moving to Virginia.
4. More than a one-third of Virginia's growth is attributable to people age 65+. The population of mature seniors is growing faster than the population of youthful seniors.
5. Professional and technical services is one projected driver of the economy in 2040.
6. Roughly one-half of the population growth is expected in areas that, in 2040, would have densities of at least 1,200 people/mi^2.

16

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