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An Interim Update to the 2035 Socioeconomic and Travel Demand Forecasts for Virginia

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In support of the update to Virginia's 2035 Statewide Multimodal Plan, this report provides an update to select socioeconomic forecasts initially made in 2009 based on a review of data from national sources and the literature. Mobility needs exist for diverse Virginia subpopulations, such as persons without access to a vehicle (6.3% of statewide households or 8.8% of the state's workforce); non-drivers (a group whose composition is changing, with recent decreases in the percentage of Virginians age 15-24 with a driver's license contrasted with increases in the percentage of females age 65 or older [65+] with a driver's license); persons age 65+ (e.g., in 2010, the number of Virginians age 65+ outnumbered those age 19 or younger in only 1 of Virginia's 21 regions; by 2035, this will be the case in 8 of Virginia's 21 regions); and persons protected by environmental justice regulations (e.g., the income of 17.3% of Virginians was below 150% of the poverty level for 2006-2010, and the minority population was 35.2% of Virginia's population in 2010).

Subpopulations may also be defined by geography. Although a projected increase in fuel prices between 2010 and 2035 of 48% for autos and 50% for trucks is expected to reduce highway travel more than would be the case without a price increase, the increase in population that is expected based on 2010-2035 levels may offset this decrease; with a variety of assumptions including elasticity of demand, an expected congestion cost in urban areas approaches $5.7 billion based on delay and costs associated with excess fuel consumption. In non-urbanized areas, a rough order of magnitude estimate of the cost of delays, derived in this report, is $285 million at present. Geographical differences are apparent; notably, the largest group of workers by income using public transportation in the Northern Virginia region and, just to its south, the George Washington Regional Commission comprised those with an income of $75,000 or more; by contrast, in the Richmond and Hampton Roads regions, the largest group comprised workers with an income below $10,000. Another geographical difference is that the percentage of those who speak English less than "very well" varies by region, from 0.6% to 13.4%.

Implications of these forecasts are noted. For example, because more than one-third of the population age 65+ has a disability compared with about 7% of the population under age 65, the increase in persons age 65+ suggests that the percentage of Virginians with disabilities may also increase. As another example, despite the relatively large costs of congestion in Virginia's urbanized areas, other sources suggest that crash costs may be approximately 2.4 times as large as these congestion costs. As a third example, ways to increase motorist and transit passenger comfort may merit exploration as a means to reduce the perceived cost of travel. Because these implications transcend regional boundaries, they may offer opportunities to garner consensus on some transportation improvements and thus are appropriate to consider in future planning efforts.

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FINAL REPORT

AN INTERIM UPDATE TO THE 2035 SOCIOECONOMIC AND TRAVEL DEMAND FORECASTS FOR VIRGINIA

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In Cooperation with the U.S. Department of Transportation
Federal Highway Administration

Virginia Center for Transportation Innovation and Research
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

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PREFACE

Since the publication in 2009 of socioeconomic forecasts for Virginia for the year 2035, new information, such as the 2010 census estimates, has become available that might influence these forecasts. This report addresses four types of related questions that are of interest to Virginia's Office of Intermodal Planning and Investment for its use in updating the 2035 Virginia long-range multimodal transportation plan:

1. *What new information is available related to population forecasts?*

   For instance, how did the annual rate of recent population growth in Virginia's planning district commissions PDCs from 2000 to 2010 compare with annual rates of projected population growth (2010 to 2035)? Other topics include an interim 2040 population forecast, growth in the percentage of Virginians age 65 or older, an estimation of auto ownership, the number of persons with disabilities, expected changes in income, and the impact of the decisions of the 2005 Defense Base Closure and Realignment Commission on travel demand in the vicinity of Virginia military bases.

2. *What percentage of Virginians is choosing to use transportation modes of interest to the Office of Intermodal Planning and Investment, and what percentage of Virginians is protected by environmental justice regulations?*

   Information about modes of interest concerned the number of people working from home (telecommuting), the percentage of persons with a driver's license, and the income distribution of persons who use public transportation. Low-income populations and minority populations are protected under Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations; thus, information about the distribution of these populations and the variation in the cost of living throughout Virginia was sought.

3. *What are the new findings with respect to congestion costs?*

   For instance, how do congestion costs compare in urban and non-urban areas? How may increased fuel prices influence travel demand and such congestion costs? What are the societal costs associated with greenhouse gas emissions attributable to excess fuel consumption that results from congestion in urban areas?

4. *Given that travel time savings are a major impetus for various types of transportation improvements, how should travel time be valued?*

   The monetization of travel time delays in response to Question 3 is influenced by several assumptions about the value of time. How does changing these assumptions influence the estimated congestion cost? What are potential region-specific values of 1 hour of delay?

EXECUTIVE SUMMARY

In support of the update to Virginia's 2035 Statewide Multimodal Plan, this report provides an update to select socioeconomic forecasts initially made in 2009 based on a review of data from national sources (e.g., the U.S. Census Bureau American Community Survey) and the literature. (The updates pertain to revised forecasts for year 2035 for some data elements or, in cases where forecasts were not feasible, better base year information than was available in 2009.) The information in this report should be made available to interested participants in the development of Virginia's statewide multimodal plan.

Mobility needs exist for diverse Virginia subpopulations:

- *Persons without access to a vehicle.* Presently, 186,322 households (representing 6.3% of the statewide total) and approximately 333,000 workers (about 8.8% of the state's workforce) do not have access to a vehicle.

- *Non-drivers.* The composition of this group is changing: the percentage of Virginians age 15-24 with a driver's license decreased over from 1990 to 2010 (72% to 58%), whereas the percentage of females age 65 or older (65+) with a driver's license increased (58% to 76%) over the same period.

- *Telecommuters:* The number of telecommuters (i.e., those who work from home) increased from a statewide average of 3.2% in 2000 to 4.2% for the 2006-2010 period.

- *Persons who speak English less than "very well":* Currently, the percentage ranges from 0.6% to 13.4% depending on the region.

- *Persons age 65+ and persons with disabilities:* In 2010, the number of Virginians age 65+ outnumbered those age 19 or younger in only 1 of Virginia's 21 regions; by 2035, this will be the case in 8 of Virginia's 21 regions. Because more than one-third of the population age 65+ has a disability compared with about 7% of the population under age 65, the increase in persons age 65+ suggests that the percentage of Virginians with disabilities may also increase.

- *Transit users:* Regional differences are apparent; notably, the largest group by income using public transportation in both the Northern Virginia region and, just to its south, the George Washington Regional Commission comprised those with an income of $75,000 or more; by contrast, in the Richmond and Hampton Roads regions, the largest group comprised persons with an income below $10,000.

- *Persons protected by environmental justice regulations:* The income of 17.3% of Virginians was below 150% of the poverty level for 2006-2010. The minority population was 35.2% of Virginia's population in 2010.

- *Persons living in urban areas*. Although a projected increase in fuel prices between 2010 and 2035 of 48% for autos and 50% for trucks is expected to reduce highway travel more than would be the case without a price increase, the increase in population that is expected based on 2010-2035 levels may offset this decrease; with a variety of assumptions including elasticity of demand, an expected congestion cost in urban areas approaches $5.7 billion based on delay and costs associated with excess fuel consumption. Other sources suggest that crash costs may be more than twice as large as these congestion costs.

- *Persons living in non-urbanized areas*. In non-urbanized areas, a rough order of magnitude estimate of delays, derived in this report, is $285 million at present.

Despite regional differences, there are some similarities that cross regional boundaries. For instance, there are workers without access to a vehicle in all Virginia regions; the population of persons age 65+ is growing statewide; and travel delays, including those that result from maintenance-based detours, affect both urban and rural Virginians. These statewide transportation challenges may offer planners an opportunity to garner consensus on transportation improvements that would offer benefits throughout Virginia.

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FINAL REPORT

AN INTERIM UPDATE TO THE 2035 SOCIOECONOMIC AND TRAVEL DEMAND FORECASTS FOR VIRGINIA

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INTRODUCTION

Transportation is a derived demand, driven by social and economic activity. Tourism, employment, shopping, recreation, education, and other forms of exchange generate some type of trip. Because these trips are a response to socioeconomic activity, changes in total travel demand may be forecast by examining how the generators of social and economic activity, such as population, employment, and disposable income, will change. Further, trips may manifest in the form of a freight delivery by a professional truck driver, a walk to a local elementary school, a bus ride to work, an auto trip to a mall, or a broadband Internet connection used by a telecommuter. Although each of these trips is driven by a social or economic need, the choice of mode (e.g., auto or walking), length (e.g., 2 miles and 30 minutes), and frequency (e.g., daily or weekly) of each trip are affected also by transportation supply characteristics, such as availability of routes, the price of fuel, and the distance between residences and destinations.

An anecdote by Coyle et al. (2011) and the Association of American Railroads (2011) illustrates the importance of both the socioeconomic and transportation supply characteristics for forecasting travel. The association reported a 94% correlation between consumer confidence and automobile sales, and hence a strong correlation (91%) between consumer confidence and the demand for railcars to transport automobiles and parts. Because approximately 70% of new automobiles are moved by rail (Spraggins, 2010), there is a strong relationship between activity (in this case, the purchase of automobiles) and travel demand (measured as the number of carloads of autos and auto parts). However, the transportation supply characteristics affect whether these autos are transported by motor carrier or train: in 1960, only 10% of new automobiles were transported by train (TTX, 2012), but the railroad industry gained market share relative to the trucking industry because of the introduction of a rail car that could accommodate new automobiles and lower rates (Coyle et al., 2011).

In 2009, socioeconomic projections for the year 2035 in support of Virginia's statewide multimodal transportation plan were made in a report entitled *Socioeconomic and Travel Demand Forecasts for Virginia and Potential Policy Responses: A Report for VTrans 2035: Virginia's Statewide Multimodal Transportation Plan* (Miller, 2009). These projections covered socioeconomic activity (e.g., population) and transportation supply (e.g., fuel prices), which together were used to estimate total transportation demand in terms of passenger-miles by auto and passenger-miles by transit. Since the publication of that report, new information became available, notably, the results of the 2010 decennial census. This new information may be used to update select elements of the 2009 report and to provide insight into new topics thought to be relevant by Virginia's Office of Intermodal Planning and Investment. The current report provides those updates in four main areas: changes related to population growth; changes related to specific transportation modes and subpopulations of interest to the Office of Intermodal Planning and Investment; changes in congestion; and the valuation of travel time.

For this interim update, information is organized by modified planning district commission (PDC) boundaries, where PDCs are defined as shown in Figure 1, consistent with the manner in which PDCs were defined in the 2009 report. These modified PDC boundaries follow the "regular" PDC boundaries except in cases where a county is a member of two or more PDCs or no PDCs: the modification is that all counties have been placed in exactly one PDC or region.

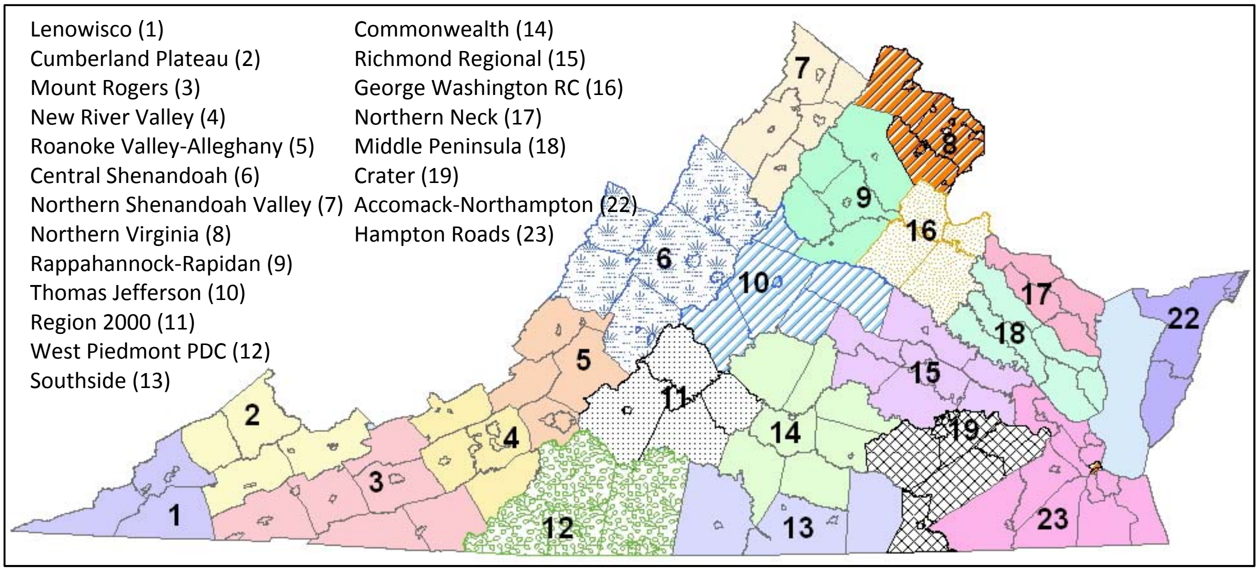

Figure 1. Virginia's Modified Planning District Commissions. Numbers in parentheses indicate the identification number of the PDC.

PURPOSE AND SCOPE

The purpose of this study was to provide base year and, where possible, forecast year (i.e., 2035) socioeconomic and transportation mode use information to support the development of the update to Virginia's 2035 statewide multimodal transportation plan. This information was sought across four categories: (1) population growth; (1) specific subpopulations and transportation modes of interest to Virginia's Office of Intermodal Planning and Investment (e.g., groups protected by environmental justice regulations, persons who worked from home, and transit users); (3) travel time costs attributable to delay; and (4) travel time valuation.

The scope had three limitations, each of which could be the genesis of further work:

1. Where possible, the study updated 2035 socioeconomic forecasts reported previously rather than generating new forecasts.

2. The study did not determine if regional differences (e.g., in the number of persons with disabilities) were statistically significant (e.g., Cambridge Systematics, Inc., et al., 2007).

3. The study did not identify the reasons behind findings, such as the reason for differences in transportation mode choices by age and sex.

METHODOLOGY

To achieve the study objectives, base year data (usually 2010) were acquired and, where feasible, forecasts (usually for 2035) provided in the year 2009 study were updated. For example, the 2009 report forecast population growth from 2010 to 2035, using forecasts performed prior to the publication of 2010 census data. Since the 2010 decennial census data are now available, the actual 2010 population estimates may replace the forecast 2010 populations in updating the 2035 forecasts.

The base year was usually 2010; however, exceptions were made based on data availability. For example, some data were not available from the 2010 decennial census but rather from the 5-year, 3-year, or 1-year American Community Survey (ACS) data reflecting, respectively, the periods 2006-2010, 2008-2010, and 2010. When ACS data were required, there was a tradeoff between the geographic level of detail and the age of the data: although all datasets provided a statewide value, only the oldest 2006-2010 ACS dataset provided values for all jurisdictions. The more recent 2008-2010 ACS dataset provided values for jurisdictions of 20,000 or more, which in Virginia accounted for 92% of the population and 79 of Virginia's 134 jurisdictions. The most recent 2010 ACS dataset provided values for jurisdictions of 65,000 or more, which in Virginia accounted for 71% of the population and 30 of Virginia's 134 jurisdictions.

In addition, although 2035 was usually the forecast year, in one instance, 2040 population forecasts were developed at the request of the Department of Rail and Public Transportation (DRPT), which is participating in the development of the updated 2035 statewide multimodal transportation plan. In this instance, the 2035 forecasts were extended by 5 years based on previous annualized growth rates. For some data elements, it did not appear feasible to develop a credible 2035 forecast based on the information available. In those cases, no forecasts were made.

Comments from attendees at the monthly multimodal working group meetings associated with VTrans2035, which included participants from the Virginia Department of Transportation (VDOT), the Department of Rail and Public Transportation, the Department of Aviation, and the Department of Motor Vehicles, and the technical review panel for this study influenced the types of analysis that were undertaken.

The methodology was applied through four sequential steps.

1. *Update population-related forecasts and base year information.* Regional population forecasts for year 2035 reported in Miller (2009) were updated based on 2010 population data that had not been available at the time the forecasts were made, and 2040 regional population forecasts were generated by extrapolating 2035 forecasts by two different annual population growth rates (the actual rates for the period 2000-2010 and the forecasted rates for the period 2010-2035). Forecasts were also generated for percentage of persons age 65 or older (65+) and income growth. Ancillary to income, the relative purchasing power of each region was determined through the use of regional price parities from the literature. For regions that did not have such a statistic, a regional price parity was estimated based on the ratio of other available indices, such as the cost of living, and then related to the regional price parity as discussed in the Appendix. Base year information, but not forecasts, was generated for the percentage of Virginians with disabilities and auto ownership. For one recent population redistribution event—decisions by the 2005 Defense Base Closure and Realignment Commission—the population, employment, and transportation impacts were obtained from the literature. Computational details are provided in the Appendix.

2. *Document base year information, trends, or forecasts for modes and subpopulations of interest to Virginia's Office of Intermodal Planning and Investment.* Base year information concerning the relationship between income level and transportation mode choice for work trips was obtained from the ACS, and the percentage of persons using public transportation for each group within each region was tabulated. National forecasts for changes in minority populations were obtained from the U.S. Census Bureau, and base year information for poverty level distributions was obtained from the 2006-2010 ACS. The 2006-2010 ACS was used to determine the percentage of Virginians who indicated they speak English less than "very well." Changes in trends (since 1990) for the percentage of Virginians who have a driver's license by sex and age group were determined from data collected by the Federal Highway Administration (FHWA) and the U.S. Census Bureau; changes in the number of persons who worked from home (i.e., telecommuted) were determined by comparing 2000 decennial census data and 2006-2010 ACS data.

3. *Collect information about the costs of congestion in urban and non-urbanized areas.* The costs of congestion in three Virginia urban areas (i.e., Northern Virginia, Hampton Roads, and Richmond) in terms of excess fuel and delay were obtained from Schrank et al. (2011), and a third cost, i.e., the societal cost of greenhouse gas emissions resulting from the additional fuel consumption, was added to these costs based on a review of the literature, with details given in the Appendix. The impact on the costs of congestion of (1) a hypothetical increase in fuel prices to $10 per gallon and (2) an expected increase in 2035 fuel prices forecast by the U.S. Energy Information Administration (U.S. EIA) was determined based on elasticities available in the literature. The present-day cost of detours attributable to construction in Virginia locations outside the three urbanized areas studied was also estimated based on available information about these detours and literature sources that converted delay to monetary losses.

4. *Document how the valuation of travel time affects the costs of congestion given in Task 2.* The literature was reviewed to determine assumptions that influence the value of travel time. Examples are trip purpose; base income level; the year in which the study was conducted; and for freight movements, the value of the commodity being transported. The range of hourly costs for each assumption was noted. Then, the impact of changing select assumptions, such as the study year, on the costs of congestion in the three urban areas computed in Task 2 was determined.

RESULTS

Population-Related Forecasts

As of January 2012, no new population projections for Virginia were available and the U.S. Census Bureau had no plans to develop state-level projections because of budgetary constraints (Jennifer Ortman, personal communication, December 20, 2012). Further, updated state-level projections were not available from the Virginia Employment Commission (VEC) (Larry Robinson, personal communication, August 15, 2011). The Weldon Cooper Center for Public Service anticipated making updated projections by age, sex, and race for 10-, 20-, and 30-year intervals (Achsah Carrier, personal communication, January 4, 2012), and such forecasts should be available in 2013 (Weldon Cooper Center for Public Service, 2012).

Changes in Population Forecasts Since 2009

New population information has become available since the completion of the 2009 report. With 2010 census data now becoming available, it is possible to compare the growth in the 21 Virginia PDCs for the period 2000-2010 with the projected growth for the period 2010-2035. Generally, the trends observed in the 2000-2010 data appear consistent with projected patterns of 2010-2035 population growth: 4 Virginia PDCs are expected to account for 76% of the state’s population growth for 2010-2035, and the same 4 PDCs accounted for 79% of the state’s population growth for 2000-2010. Expansion of this list to 8 PDCs (see Figure 2) raises these percentages to 91% and 93%, respectively.

Figure 2 shows some relatively modest changes in terms of population trends (from 2000-2010 versus 2010-2035). Figure 2 shows that although the Northern Virginia Regional Commission is expected to grow the most of any region, it would account for 37% of the state’s population growth for 2010-2035, compared with 45% of the state’s growth for 2000-2010. Hampton Roads, which accounted for 10% of the state’s 2000-2010 growth, is expected to account for 14% of the state’s 2010-2035 growth. The George Washington Regional Commission, which accounted for 9% of the state’s 2000-2010 growth, is expected to account for 11% of the state’s 2010-2035 population growth. There is a slight shift for the Richmond Regional PDC, which accounted for 14.8% of the 2000-2010 growth and is expected to account for 14.3% of the 2010-2035 growth.

Thus there are some minor population shifts in the sense that compared to the past decade, the statewide share of the population increase captured by the Northern Virginia Regional Commission will drop measurably (from 45% to 37%), with the relative share increasing in most other regions (the exceptions being the Richmond Regional PDC (14.8% to 14.3%) and the Central Shenandoah PDC (3% of the 2000-2010 growth compared to 2.6% of the 2010-2035 growth). That said, the overall implication of Figure 2 remains that three-fourths of the 2010-2035 population growth is concentrated in just four regions, with the Northern Virginia Regional Commission alone accounting for more than one-third of the population growth—trends that are consistent with those of the past decade.

Figure 3 shows the annual percentage change in population for the periods 2000-2010 and 2010-2025. There is generally congruence except for the Accomack-Northampton PDC, which lost population at an annualized rate of 1.2% for 2000-2010 but is expected to grow at an annualized rate of 0.6% for 2010-2035. Of note is that the greatest annual rates of growth are not necessarily in the most populous regions: on a percentage basis, the three largest rates of growth are for the George Washington Regional Commission (2.3% per year forecast for 2010-2035); the Rappahannock-Rapidan Regional Council (1.9%); and the Northern Shenandoah Valley Regional Commission (1.5%). The largest region (the Northern Virginia Regional Commission) has an annual 2010-2035 forecast growth rate of 1.27%, which makes it only the fifth largest rate of growth; the fourth largest is the Thomas Jefferson PDC with a rate of 1.28%. Thus individual regions may see more dramatic growth relative to their baseline conditions in 2010.

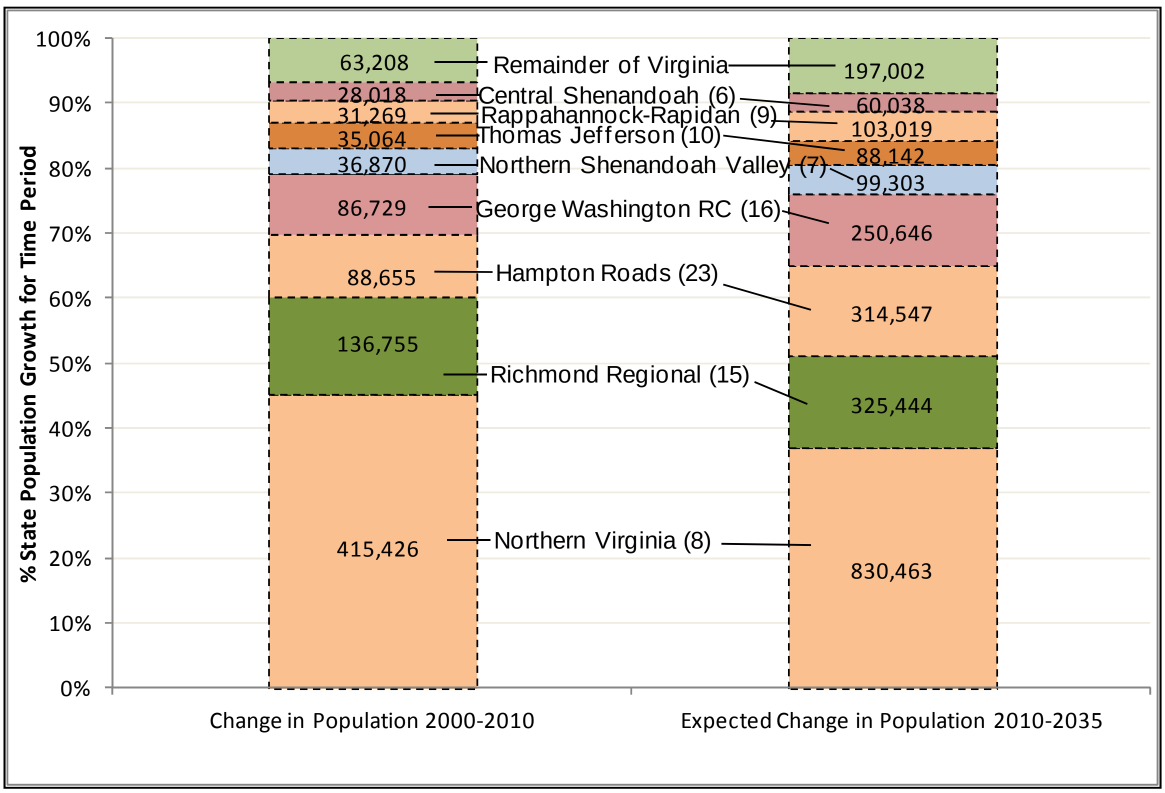

Figure 2. Population Growth in Virginia PDCs: 2000-2010 (actual) and 2010- 2035 (expected). For example: From 2000 to 2010, the Northern Virginia Regional Commission (PDC 8) grew by 415,426, which accounted for 45% of the state population growth for that period. The same region is expected to grow by 830,463 from 2010 to 2035, which will account for 37% of the state's population growth for that period.

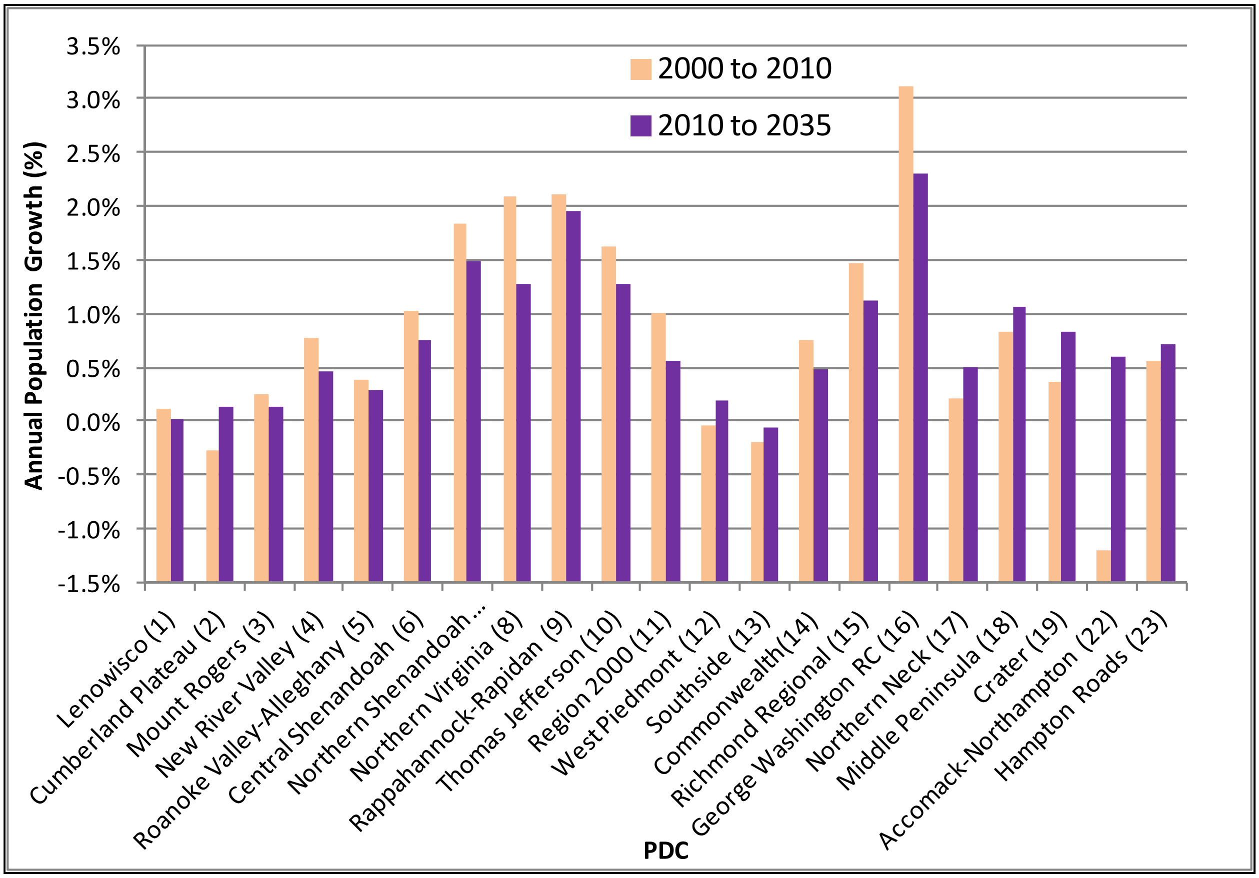

Figure 3. Annualized Percentage Population Growth by Planning District Commission. Numbers in parentheses indicate the identification number of the PDC.

Table 1 shows interim 2040 population projections based on extrapolating the 2035 projections from either the 2000-2010 average annual growth rate or the 2010-2035 expected average annual growth rate. As a consequence, a range of population forecasts for 2040 is given.

Change in Percentage of Population Age 65+

Rationale for Examining the 65+ Age Group

There is no consistent definition of the age that defines a person as being older. The U.S. Census Bureau (undated, a) categorized persons age 65+ as "elderly" and persons age 55 or older as "older." The Age Discrimination Act of 1975 does not specify for the U.S. Department of Transportation (U.S. DOT) a particular age that should be defined (U.S. Department of Health and Human Services, 1979) but rather requires each agency to determine its own rules as specified in the Code of Federal Regulations (CFR) at 45 CFR Part 91 (Brenda Kragh, FHWA, personal communication, April 13, 2012). In terms of defining *elderly* drivers, an attorney with the FHWA's Division of Civil Rights noted that *elderly* must at a minimum include persons age 65+ and that additional ages (e.g., 55+) are permissible (Candace Groudine, personal communication, April 13, 2012). This threshold of including all persons age 65+ as well as optionally including additional ages is also specified in 49 CFR Appendix A to Part 609. For the purposes of this interim update, the 65+ age group was examined.

Table 1. Interim 2040 Population Projections for Virginia Regions

Modified PDC[a]	Change in Decennial Census Population 2000- 2010	2010 Population	Expected Change in Population 2010-2035[b]	Updated 2035 Population Forecast[c]	Annual Growth Rate[d]		2040 Population Assuming a 2035-2040 Annual Growth Rate Equal to the Annual Growth Rate From[e]	
					2000-2010	2010-2035	2010-2035	2000-2010
Lenowisco PDC (1)	1,069	94,174	473	94,647	0.114%	0.020%	95,189	94,742
Cumberland Plateau PDC (2)	-3,253	113,976	3,822	117,798	-0.281%	0.132%	116,152	118,578
Mount Rogers PDC (3)	4,611	193,595	7,088	200,683	0.241%	0.144%	203,116	202,131
New River Valley PDC (4)	13,091	178,237	21,573	199,810	0.766%	0.458%	207,578	204,428
Roanoke Valley-Alleghany Regional Commission (5)	10,218	274,759	20,193	294,952	0.380%	0.284%	300,594	299,165
Central Shenandoah PDC (6)	28,018	286,781	60,038	346,819	1.033%	0.763%	365,113	360,258
Northern Shenandoah Valley Regional Commission (7)	36,870	222,152	99,303	321,455	1.831%	1.489%	351,989	346,110
Northern Virginia Regional Commission (8)	415,426	2,230,623	830,463	3,061,086	2.082%	1.274%	3,393,335	3,261,110
Rappahannock-Rapidan Regional Council (9)	31,269	166,054	103,019	269,073	2.108%	1.949%	298,658	296,343
Thomas Jefferson PDC (10)	35,064	234,712	88,142	322,854	1.631%	1.284%	350,059	344,112
Virginia's Regional 2000 Local Government Council (11)	24,018	252,634	37,721	290,355	1.004%	0.558%	305,226	298,550
West Piedmont PDC (12)	-1,013	249,182	12,245	261,427	-0.041%	0.192%	260,897	263,947
Southside PDC (13)	-1,747	86,402	-1,074	85,328	-0.200%	-0.050%	84,478	85,115
Commonwealth PDC (14)	7,507	104,609	13,378	117,987	0.747%	0.483%	122,463	120,861
Richmond Regional PDC(15)	136,755	1,002,696	325,444	1,328,140	1.477%	1.131%	1,429,171	1,404,943
George Washington Regional Commission (16)	86,729	327,773	250,646	578,419	3.121%	2.298%	674,498	648,002
Northern Neck PDC (17)	1,076	50,429	6,657	57,086	0.216%	0.497%	57,705	58,519
Middle Peninsula PDC (18)	7,142	90,826	27,652	118,478	0.822%	1.069%	123,430	124,946
Crater PDC (19)	6,334	173,463	39,873	213,336	0.373%	0.831%	217,341	222,349
Accomack-Northampton PDC (22)	-5,845	45,553	7,401	52,954	-1.200%	0.604%	49,852	54,573
Hampton Roads PDC (23)	88,655	1,622,394	314,547	1,936,941	0.564%	0.711%	1,992,135	2,006,820
Total	921,994	8,001,024	2,268,604	10,269,628			10,998,982	10,815,603

[a]Modified PDC as explained in the 2009 socioeconomic forecasts, where each jurisdiction is included in exactly one PDC.
[b]The 2009 socioeconomic forecasts provided (1) a 2035 population (based on extending Virginia Employment Commission [VEC] information) and (2) a 2010 population projection (also based on VEC). This column is the difference between those two projections.
[c]The expected change in population 2010-2035 is added to the 2010 population to yield an updated 2035 population forecast.
[d]For example, Hampton Roads had a 2010 population of 1,622,394. If its population increases 1,936,941 in year 2035, this will be an annual growth rate of 0.711%. By contrast, from year 2000-2035, the annual growth rate for Hampton Roads was 0.564%.
[e]2040 prediction assuming either the 2000-2010 or 2010-2035 annual growth rate applies from 2035 to 2040. For example, if from 2035 to 2040 Hampton Roads grows at a rate of 0.564% per year, then the 2040 Hampton Roads population would be 1,992,135. A rate of 0.711% per year for 2035-2040 yields a 2040 population of 2,006,820.

Overview of the 65+Age Group

Figure 4 shows the percentage of persons age 65+ in the 21 Virginia PDCs as well as the percentage of persons under age 20 (20-). Nationally, the population is growing older. Vincent and Velkoff (2010) reported that 19.3% of the U.S. population will be age 65+ by 2030 and that the percentage will climb to 20% by year 2040 (compared with 13% in 2010). The Virginia percentages are close to the national values; for 2010, the U.S. Census Bureau (2011a, Table QTP1) showed that 12.2% of Virginians were age 65+; the VEC (2007a) projected that by year 2030, the percentage would rise to 18.1%. As shown in Figure 4, the percentage of persons age 0-19 is larger than the percentage of persons age 65+ in 20 of Virginia's 21 PDCs.

Figure 5 shows the percentage of persons age 65+ estimated by the author by using data from the VEC (2007a), the decennial census, and Vincent and Velkoff (2010). By 2035, 8 of Virginia's PDCs will have more persons age 65+ than age 0-19 compared with just 1 PDC where that is presently the case. Even in PDCs where there are still more persons age 0-19 than age 65+ in 2035, the gap between these groups narrows relative to 2010. In all PDCs except the Northern Neck PDC, the percentage of persons age 65+ is expected to grow from 2010 to 2030 such that the 2010 statewide average of 12.2% (U.S. Census Bureau, 2011a, Table QTP1) changes to a 2030 statewide average of 18.1%. Applying a straight-line change in the 2030 to 2040 national rates to Virginia's 2030 values yields an average age 65+ population percentage of about 18.5% in year 2035. In terms of real values, this would be an almost 2-fold increase in persons age 65+, from 976,937 (in 2010) to 1,896,253 (in 2035).

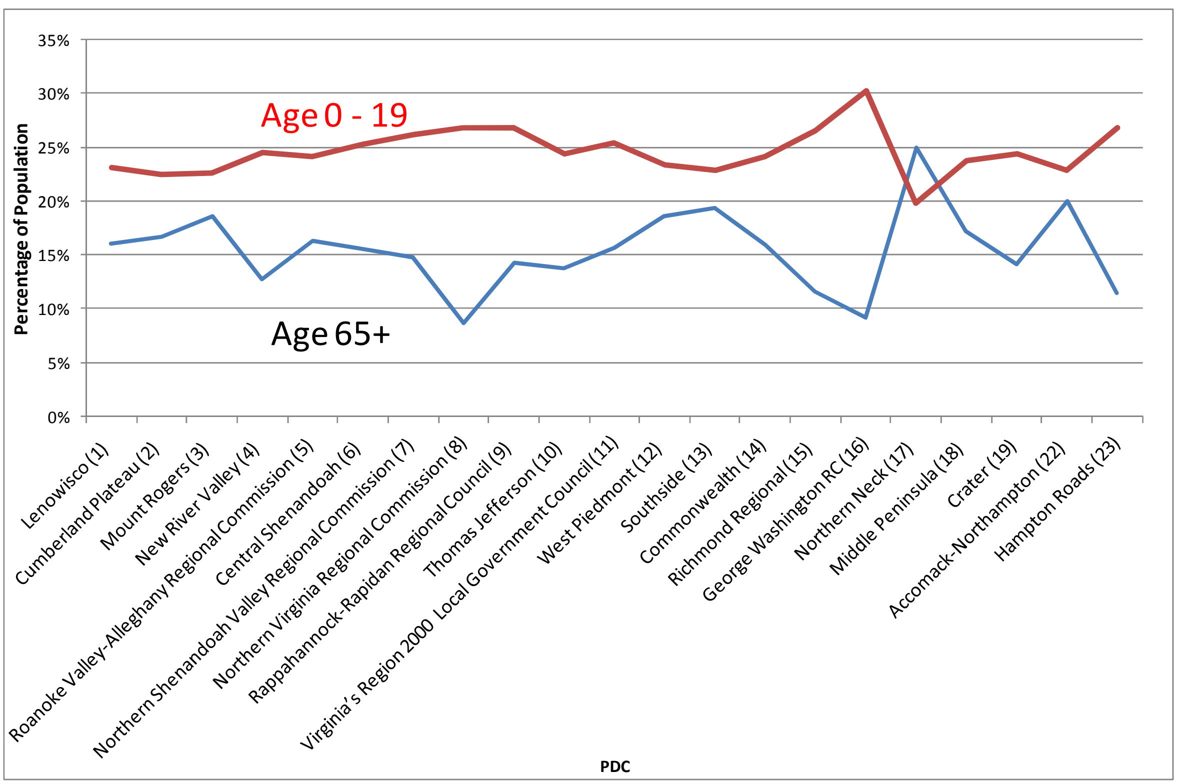

Figure 4. Percentages of Population Age 65+ and Age 0-19 in Virginia PDCs in Year 2010. Numbers in parentheses indicate the identification number of the PDC. Estimates were calculated from the 2010 decennial census (U.S. Census Bureau, 2011a, Table QTP1).

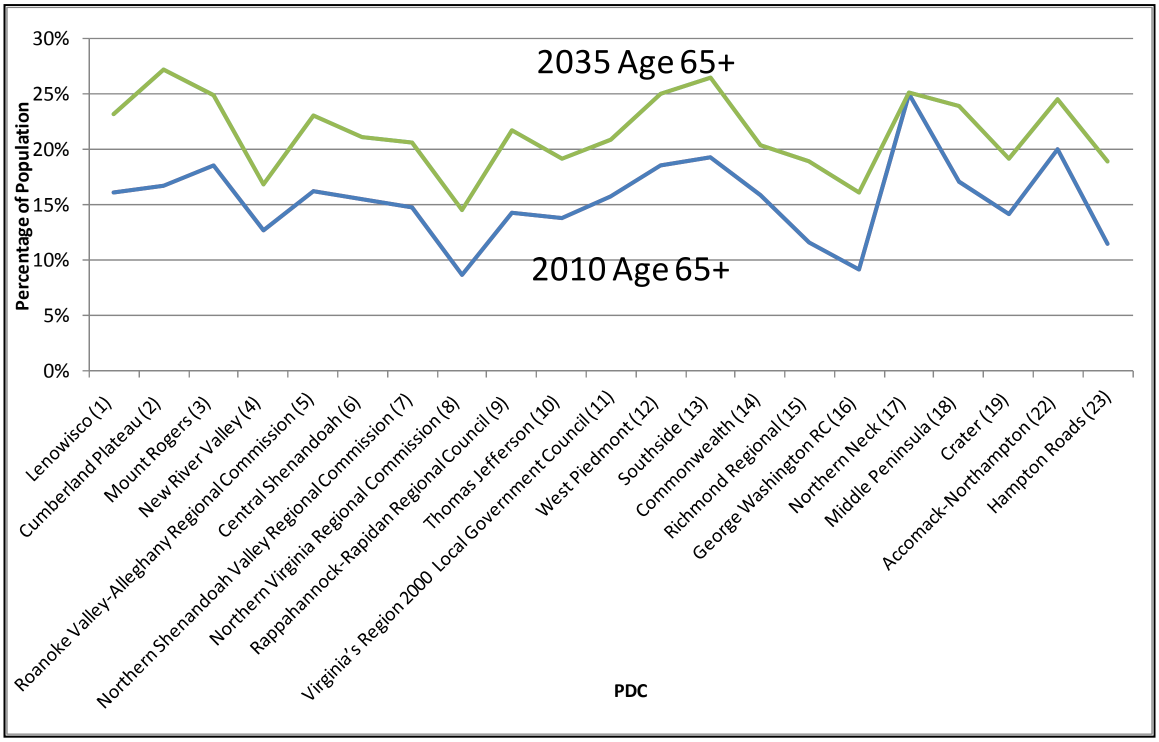

Figure 5. Percentages of Population Age 65+ in Virginia PDCs in Years 2010 and 2035. Numbers in parentheses indicate the identification number of the PDC. Percentages were calculated from information provided by the 2010 decennial census (U.S. Census Bureau, 2011a, Table QTP1), the Virginia Employment Commission (2007), and (Vincent and Velkoff, 2010).

Change in Percentage of Persons With Disabilities

As of March 14, 2012, data for the number of persons with disabilities were not available from the 2010 decennial census at the county level in Virginia. However, data from Tables DP02 and B18101 of the 1-year 2010 ACS (U.S. Census Bureau, 2011f) showed that approximately 844,951 persons—representing 10.8% of the civilian non-institutionalized population—had some type of disability.

Nominally, the percentage of persons with disabilities varies substantially by age and less so by sex, as shown in Figure 6: whereas 5.7% of males age 5-17 have some type of disability compared to 3.1% of females in the same age range, these percentages increase to 11.8% and 10.8%, respectively, for males and females age 35-64. For the age range of 65-74, the respective percentages are 24.4% and 24.3%; approaching 50% if only persons 75 and older are considered.

For persons under age 5, *disability* includes a hearing or vision difficulty; for persons age 5-17, additional disability categories include cognitive, self-care, and ambulatory difficulty; and for persons age 18+ the category of independent living facility is added. The data on disability types suggest some relationship between disability type and age; for instance, Table S1810 from the 2010 ACS (U.S. Census Bureau, 2011f) showed that of the persons who have a disability, the percentage of persons with an ambulatory disability is 53% for those age 18-64 and 65% for those age 65+. Although an ambulatory disability is the most common type of disability for

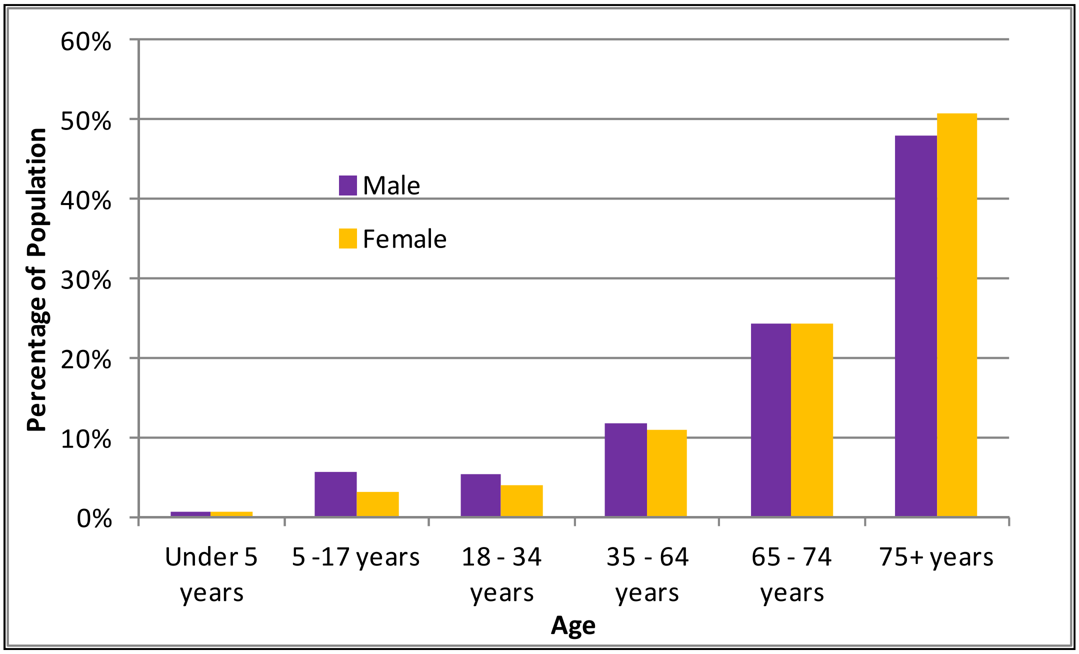

Figure 6. Percentage of Virginians by Age With a Disability. Data from the 2010 American Community Survey 1-Year Estimates, Tables DP02 and B18101 (U.S. Census Bureau, 2011f).

those age 18-64 and those age 65+, the second and third most common types for those age 18-64 are cognitive difficulty (affecting 39% of persons in that group with a disability) and independent living difficulty (34%); the second most common type of disability for those age 65+ is independent living difficulty (44%) followed by hearing loss (40%). Because such disabilities do not affect the need for transportation services in the same manner, as pointed out by a reviewer of this work, the absolute number of disabilities is a blunt category. Further, persons may have more than one disability; for example, in the 18-64 age group, there are about 1.8 times as many disabilities listed as there are persons who have a disability; for the age 65 group, this ratio is 2.1. That said, figures on number of disabilities can suggest the extent to which some type of specialized transportation service may be required.

Percentage of Persons With Disabilities by Region

As of March 14, 2012, recent disability data at the city or county level could be obtained in two ways. For jurisdictions with a population of 20,000 or more, data from Table S1810 or Table B18101 can be found in the most recent (2008-2010) *3-year* ACS estimates for such jurisdictions (U.S. Census Bureau, 2011e). Such jurisdictions account for approximately 89% of all persons with disabilities. For jurisdictions with a population of less than 20,000, no disability information is given at the individual jurisdiction level. However, because Tables S1810 and B18101 also give the total number of persons in Virginia with disabilities, the number of persons with disabilities in jurisdictions with less than 20,000 may be estimated by apportioning to such jurisdictions the 11% of Virginians with disabilities based on the population of those jurisdictions. That is, Table B18101 showed that the jurisdictions with 20,000 or more in population had a total of 742,915 persons with disabilities, which, according to the same table, is 89% of the statewide total of 838,852 Virginians with disabilities. Figure 7 shows current estimates of the number of Virginians with disabilities.

Although it is not surprising that the number of persons with a disability is largest in the most populated Virginia regions, it is interesting to note that that percentages of persons with a disability are not uniform but rather higher in some of the less populated regions. For example, whereas 11% of the population in Hampton Roads has a disability (total population of the region is 1.6 million in the 2010 decennial census), this percentage climbs to 24% for the Lenowisco PDC (total population is about 0.1 million).

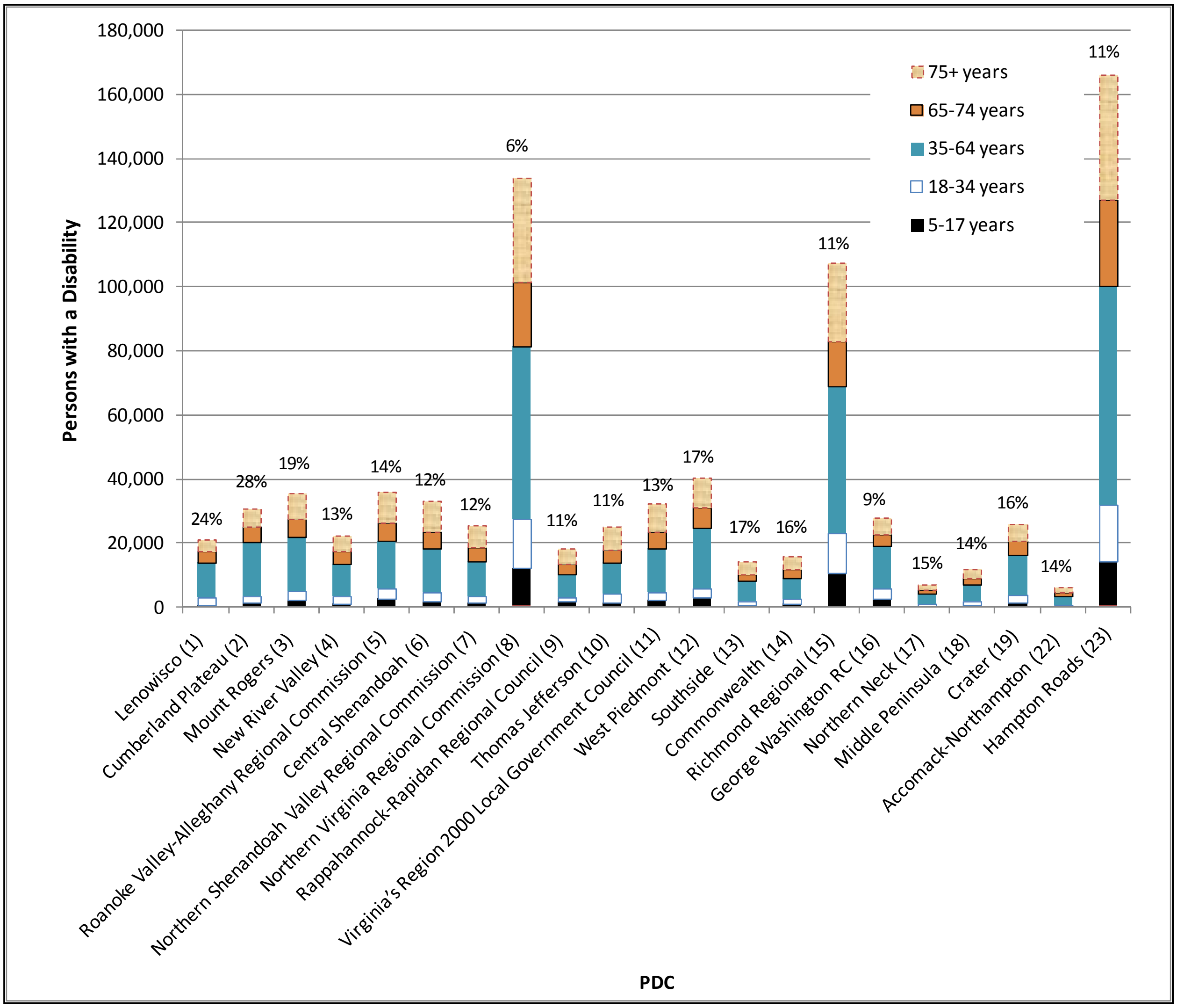

Figure 7. Number of Persons in Each Virginia PDC With a Disability. Numbers in parentheses indicate the identification number of the PDC. The percentage shown indicates the percentage of the total population in the PDC with a disability. For example, the Hampton Roads PDC has a population of about 1.56 million and about 166,000 persons have a disability, which is about 11% of the population of the PDC. The number of persons with a disability in each jurisdiction was taken directly from the 2008-2010 American Community Survey 3-Year Estimates, Table B18101 (U.S. Census Bureau, 2011e) for jurisdictions with 20,000 people or more, a process described in the Appendix was used to estimate the persons with disabilities in smaller jurisdictions, and these results were combined to yield estimates by PDC. The percentage of persons in the "under 5 years" category is not shown in the legend because it is comparatively small and thus not visible when compared to the other age groups.

It is plausible, but not proven, that part of this difference may be attributable to the difference in ages of the populations. For example, 16% of the population in the Lenowisco PDC was age 65+ in the decennial census compared to 11% of the population over age 65+ in the Hampton Roads. PDC To the extent that the trend of persons age 65+ being more likely to have a disability holds (for example, 35.1% of the population age 65+ in Virginia has a disability compared to an estimate of 7.4% of the population age 64 and under), it is not surprising that regions with a larger percentage of persons age 65+ have a larger percentage of persons with disabilities. One potential future implication is that with the overall population growing by 2035 and the percentage of Virginians age 65+ also increasing (from 12% of the 2010 population to 18.5% of the 2035 population), that the number of persons with disabilities will increase.

To be clear, age is not the sole predictor of disabilities. That is, the percentage of persons age 65+ does not perfectly forecast the percentage of persons with a disability. However, modest correlations are noted between these two percentages: the correlation is 0.53 (at the PDC level) and 0.60 (at the jurisdiction level). The correlation calculation at the jurisdiction level excludes jurisdictions with fewer than 20,000 people, which account for about 8.3% of the state's population and 11.4% of the persons with disabilities.

Why There Are More Persons With Disabilities in the Middle Age Group

Although the *percentage* of persons with a disability is highest for the oldest age group (age 75+), second highest for the second oldest age group (age 65-74), and third highest for the third oldest age group (age 35-64), the greatest *number* of persons with a disability is in the third oldest age group. The reason appears to be that age groups have different numbers of persons; according to Table B18101 of the 2008-2010 ACS (U.S. Census Bureau, 2011e), whereas the two oldest groups (age 75+ and age 65-74) account for 7% and 5% of Virginia's population, respectively, the third oldest age group accounts for 41% of Virginia's population. O'Leary (2012) further noted the higher survival rate of the 35-64 age group relative to the 75+ age group, which increases the total population of the younger group. Based on the same dataset, Figure 8 shows for one region—the George Washington Regional Commission—that although the percentage of persons with a disability is highest in the age 75+ group, the number of persons with a disability is highest in the age 35-64 group.

Change in Auto Ownership

Tables B08201, B08203, and B01841 of the 2006-2010 American Community Survey 5-Year Estimates (U.S. Census Bureau, 2011d) provide information pertaining to vehicle availability. Using the formal title "vehicles available," Tables B08201 and B08203 give five indications: "no vehicles available," "1 vehicle available," "2 vehicles available," "3 vehicles available," and "4 or more vehicles available." Table B08141 uses similar language but only four indications: "no vehicles available," "1 vehicle available," "2 vehicles available," and "3 or more vehicles available." The U.S. Census Bureau (2012) defined *vehicles available* as "the number of passenger cars, vans, and pickup or panel trucks of one-ton capacity or less kept at home and available for the use of household members."

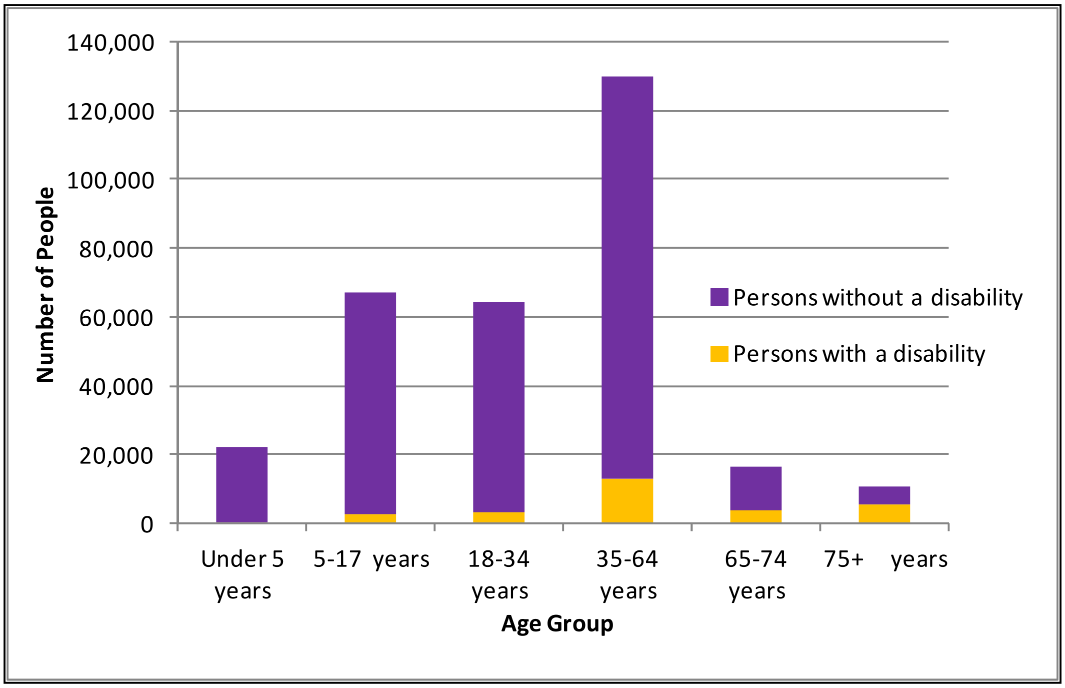

Figure 8. Number of Persons With a Disability by Age Group in the George Washington Regional Commission. Data are based on 2008-2010 American Community Survey 3-Year Estimates, Table B18108 (U.S. Census Bureau, 2011e). This region was chosen because its jurisdictions all have a population of 20,000 or more and are thus represented in this dataset.

Figure 9 confirms that the PDCs with the largest number of carless households—i.e., those with no vehicles available—were in the regions with the largest number of households overall; the Hampton Roads PDC, the Northern Virginia Regional Commission, and the Richmond Regional PDC accounted for more than one-half of the total households in Virginia (59%) and more than one-half of the total households not having a vehicle available (56%). The percentage of households without vehicles, however, was not consistent across regions, and, on a percentage basis, it was not the case that the most populous regions had the highest percentages of non-vehicle households. The percentage of households without a vehicle available exceeded 9% in four regions, all of which are relatively rural: the Lenowisco (PDC 1), the Accomack-Northampton PDC (PDC 22), the Cumberland Plateau (PDC 2), and the Southside PDC (PDC 13). By contrast, in the three most populous regions (i.e., Northern Virginia, Hampton Roads, and Richmond) these percentages were between 5.0% and 6.8%. Thus, at the regional level, there are substantial population segments without a vehicle throughout Virginia, and thus not all of these are necessarily in areas with well-developed transit systems. Overall, a total of 186,322 households—representing 6.3% of the total households in Virginia (2,974,481)—were without a vehicle.

It is not the case that necessarily every household has a worker: of the 2.974 million Virginia households, more than one-fifth (23%) has no workers. Thus a separate question can be asked regarding how many workers have a vehicle available. As detailed in the Appendix, two methods can be used to estimate this number based on the fact that Table B08141 (means of transportation to work by vehicles available) and Table B08203 (number of workers in households by vehicles available) can each be used to determine the number of workers.

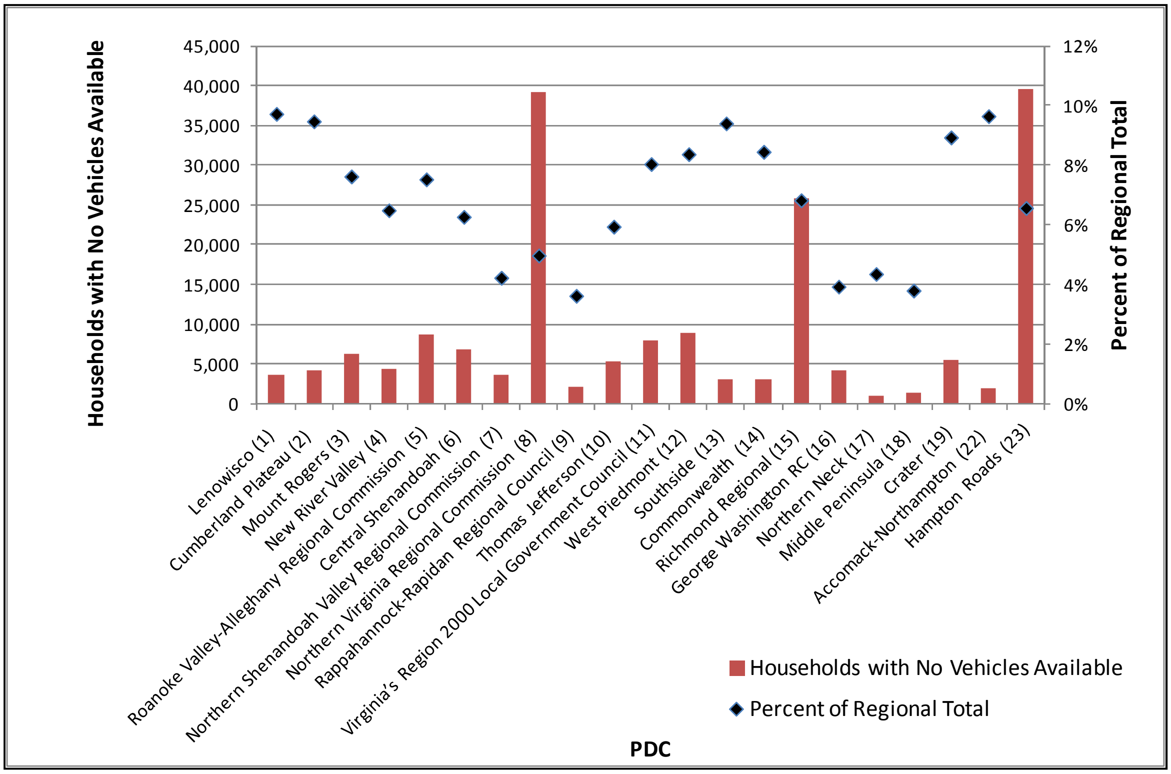

Figure 9. Number of Households with No Vehicles Available by PDC and Percentage of Regional Total. Based on data extracted from 2006-2010 American Community Survey 5-Year Estimates, Table B08201 (U.S. Census Bureau, 2011d), which provides the following indications for each household size: "no vehicles available," "1 vehicle available," "2 vehicles available," "3 vehicles available," and "4 or more vehicles available." For example: In the Rappahannock-Rapidan Regional Council (PDC 9), 2,148 households have no vehicles available, which represents 3.6% of the total households in that region.

For Virginia, the results of the two methods suggest between 330,110 and 336,559—about 8.8% of the state's workforce—do not have a vehicle. For larger populated areas, the difference in the results between the two methods is relatively small, which may relate to the larger sample sizes available. In addition, the percentage of workers without a vehicle tends to be higher in the more populous regions; for example, the highest percentage of workers without a vehicle based on the midpoint of the results of the two methods, is 10.7% (the Northern Virginia Regional Commission). Figure 10 shows the percentage of workers without a vehicle by regions; the endpoint of the horizontal bars indicates the percentages based on the two methods, such that there is a relatively tight tolerance for the Hampton Roads PDC (between 9% and 9.6% of workers do not have a vehicle) and a considerably larger tolerance for the Crater PDC (between 7.9% and 11.9% of workers do not have a vehicle).

Based on the average values from Methods 1 and 2, the three most populous regions represent 71% of Virginia's carless workers (the Northern Virginia Regional Commission with 125,293 workers, the Hampton Roads PDC with 72,384 workers, and the Richmond Regional PDC with 38,804 workers). Figure 11 shows the number of workers without vehicles for the

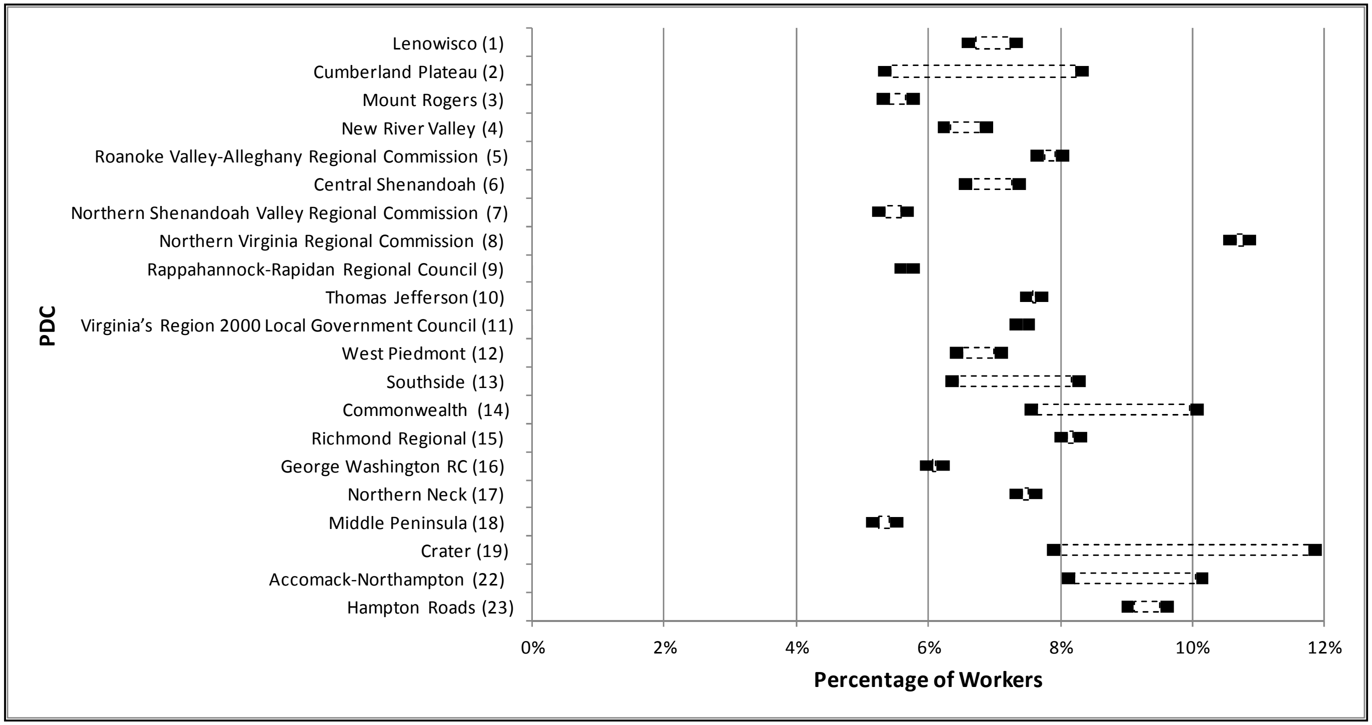

Figure 10. Estimated Percentage of Workers Without a Vehicle Available by PDC. Based on data extracted from 2006-2010 American Community Survey 5-Year Estimates, Tables B08203 and B08141 (U.S. Census Bureau, 2011d). Two methods can be used to estimate the number of workers without a vehicle: (1) match the number of workers at a statewide level only, or (2) match the number of workers at each jurisdiction level (see the Appendix). The endpoint of the horizontal bars indicates the percentages based on the two methods. Dashed lines clarify which estimates correspond to which PDCs. For example: One method suggests that for the Northern Virginia Regional Commission (PDC 8), 10.6% of all workers do not have a vehicle and the other method suggests the estimate is 10.9%.

remaining regions. The regions with the largest number of workers without vehicles shown in Figure 11—the Roanoke Valley-Alleghany Regional Commission, George Washington Regional Commission, and Central Shenandoah PDC—all have between 6% and 8% of their workers without a vehicle as per Figure 10.

There are three interpretations of Figures 10 and 11. From Figure 10 only, the largest percentage of workers without a vehicle tends to be in the more populous areas. In addition, there is no region—regardless of how rural—where less than 5% of all workers do *not* have a vehicle. From Figure 11, the number of workers without a vehicle is not negligible; for example, in the Cumberland Plateau PDC, which represents a comparatively small slice of statewide carless workers, there are 2,698 workers without a vehicle.

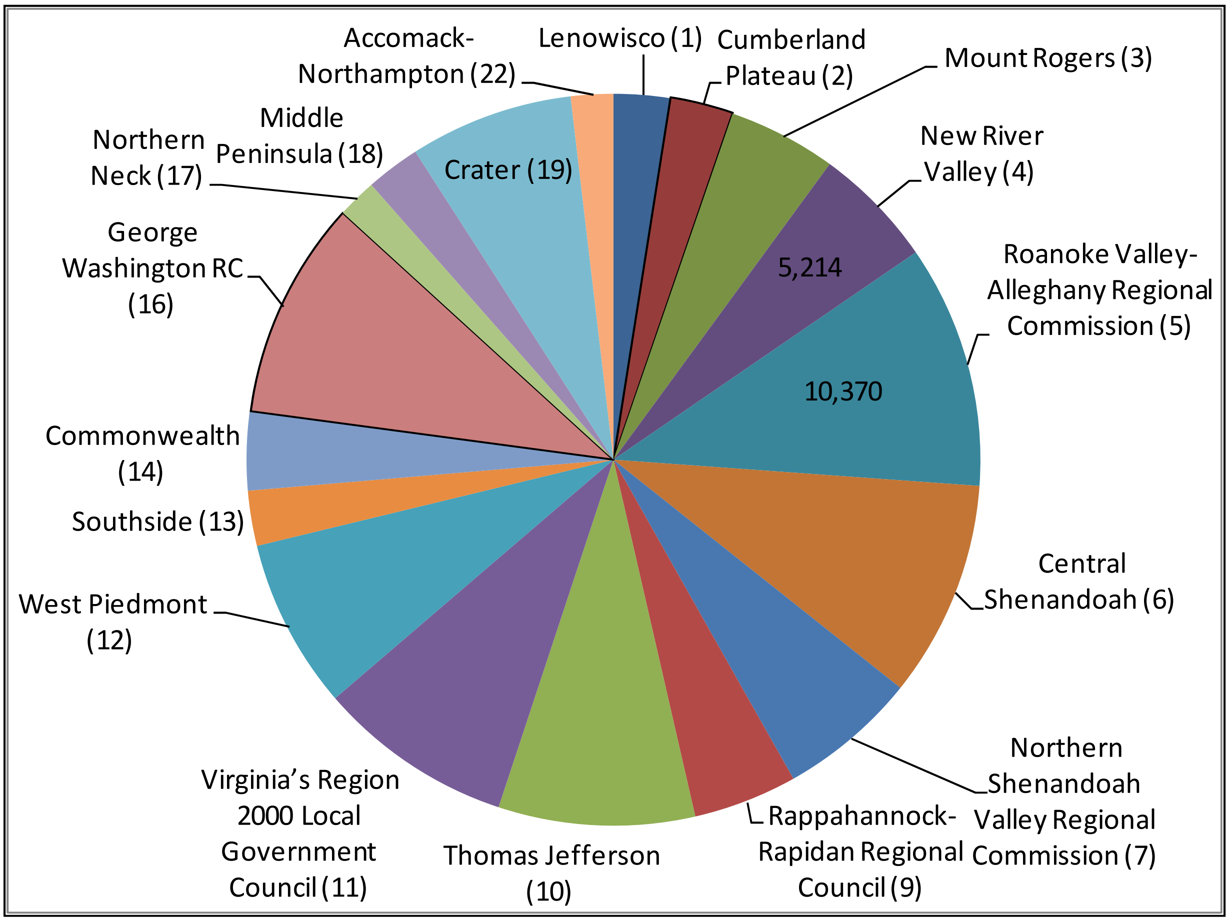

Figure 11. Relative Number of Workers Without a Vehicle Available by PDC. Based on data extracted from 2006-2010 American Community Survey 5-Year Estimates, Tables B08203 and B08141 (U.S. Census Bureau, 2011d). For example: The Roanoke Valley-Alleghany Regional Commission (PDC 5) has 10,370 workers without a vehicle, which is approximately twice the number (5,214) for the New River Valley PDC (PDC 4). Figure 11 represents a total of 96,854 workers and excludes those from the three most populous regions of Northern Virginia, Hampton Roads, and Richmond Regional.

Change in Income

The Bureau of Economic Analysis (BEA, 2011a) defines *personal income* as “the income received by all persons from all sources.” Such income includes, but is not limited to, earnings (e.g., wages), rental income, interest, and health insurance (BEA, 2011a, 2012). Although long-range forecasts of income are not publicly available at the jurisdiction level, data from two sources—the BEA and the Congressional Budget Office (CBO)—may be used to develop order of magnitude forecasts.

Change in Income From 2011 to 2035

Quarterly personal income data are available from the state as a whole (BEA, 2011b) and annual personal income data are available for Virginia city and county “areas” (BEA, 2011c). In some cases, these areas are a single jurisdiction as is the case with the City of Richmond; in other instances, an area is a combination of two or more jurisdictions, as is the case with Dinwiddie County, Colonial Heights, and the City of Petersburg. The 2010 populations and 2010 personal incomes from BEA (2011c) were updated with the ratio of the 2011 and 2010 consumer price indices (Bureau of Labor Statistics, 2012c) to obtain a 2011 estimate of personal income for each Virginia region.

Different definitions of *income* exist. In its discussion of gross national product rather than gross domestic product, the CBO (2011) noted that the former includes income that U.S. residents earn from investments in other countries but excludes incomes that nonresidents earn in the United States. The CBO (2011) also explained that several factors affect income growth, such as investment and taxing policies. Aside from this caveat, the baseline scenario used by the CBO (2011) is that real income, assuming all income derives from compensation, will increase by an estimated 49.7% (in 2011 dollars) by 2035. (The CBO uses the terms “to 2035” and “through 2035,” but the author’s interpretation is that real income for year 2035 would be 49.7% higher than for year 2011.) If this percentage growth is applied to Virginia jurisdiction estimates and the results for each PDC are summed, the disparity in per-capita income would be expected to remain in 2035, with the six highest PDC per-capita incomes being the Northern Virginia Regional Commission, the Richmond Regional PDC, the Thomas Jefferson PDC, the Rappahannock-Rapidan Regional Council, the Hampton Roads PDC, and the George Washington Regional Commission.

Regional Variation in Income

Figure 12 pinpoints relatively advantaged or disadvantaged regions on a per-person basis. For example, the Lenowisco PDC’s per-capita income is two-thirds of the statewide value. Incomes for each region are given in Table A4 in the Appendix. The Appendix also shows regional incomes based on a different set of data—that of the U.S. Census Bureau (2011d). Although incomes differ between the two datasets, common trends are evident; for example, based on the U.S. Census Bureau (2011d) dataset, the Lenowisco PDC has one-half, rather than two-thirds, of the statewide value.

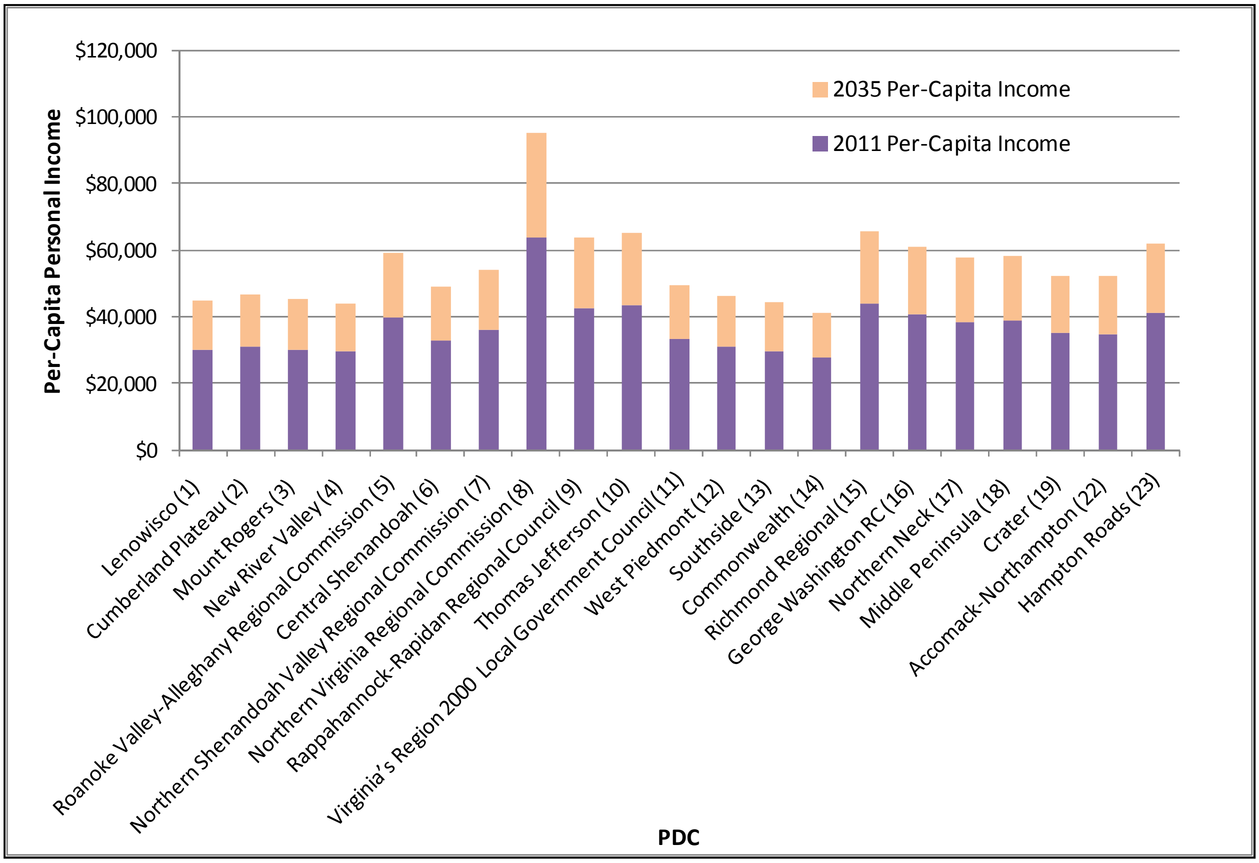

Figure 12. Per-Capita Personal Income in 2011 Dollars for Years 2011 and 2035 by PDC. Numbers in parentheses indicate the identification number of the PDC. Based on 2010 data extracted from databases maintained by the Bureau of Economic Analysis (2011c), converted to 2011 dollars based on the consumer price index available from the Bureau of Labor Statistics (2012c), and adjusted with forecasts obtained from the Congressional Budget Office (2011).

Per-capita incomes do not show total wealth by PDC, which is a function of individual wealth and population. Figure 13 shows that 70% of Virginia's total personal income, as extracted by databases maintained by the BEA (2011c), is concentrated in three PDCs (the Northern Virginia Regional Commission, the Hampton Roads PDC, and the Richmond Regional PDC); these PDCs in 2010 had 61% of Virginia's population. Alternatively, 79% of Virginia's personal income is concentrated in six PDCs that have 70% of Virginia's population: the same three PDCs plus the George Washington Regional Commission, the Roanoke Valley-Alleghany Regional Commission, and the Thomas Jefferson PDC.

As shown in Table A4 in the Appendix, the Roanoke Valley-Alleghany Regional Commission's per-capita personal income based on data from the BEA (2011c) is seventh largest in Virginia, just behind the Rappahannock-Rapidan Regional Council, but because it has a larger population, it has a larger percentage of statewide income.

Regional Price Parities

One factor that influences interpretation of these incomes is their purchasing power. Aten et al. (2011) recommended the use of regional price parities provided by the BEA to

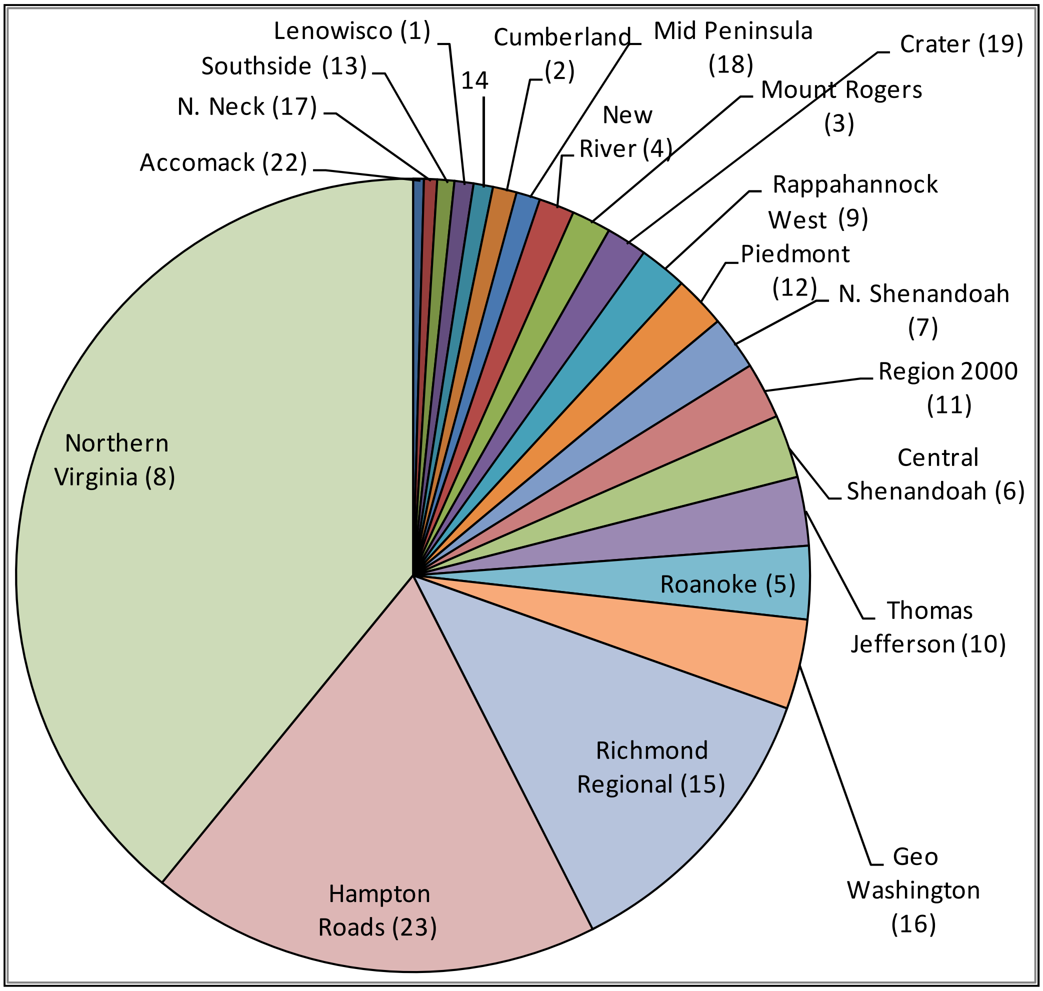

Figure 13. Personal Income by PDC (Year 2010). The numbers in parentheses indicate the number of the PDC. The number *14* at the top of the graph represents the Commonwealth PDC. Data were extracted from databases maintained by the Bureau of Economic Analysis (2011c).

compare differences in prices for goods and services across locations (e.g., the Southside PDC versus the Northern Virginia Regional Commission). Regional price parities reflect the price for goods and services indexed to a national average of 100, and the ratio of two regional price parities gives the percentage difference in prices for the two regions. For example, the regional price parties for Danville (84.1) and Bristol (81.6) (Aten et al., 2011) suggest that both locations have lower prices for goods and services than the national average (100) and that the price of goods and services in Danville is about 3% higher than in Bristol (since 84.1/81.6 = 1.03).

Table 2 shows the estimated regional price parities for Virginia. Not surprisingly Virginia has substantial variation; with a statewide average of 101.5, most Virginia regions are below this average. One region is substantially higher (the Northern Virginia Regional Commission, with 115.2) and two other regions (i.e., the Rappahannock-Rapidan Regional Council and the George Washington Regional Commission), both of which share a border with Northern Virginia, are nominally higher. The Northern Virginia Regional Commission has a regional price parity that is about 41% higher than the lowest regional price parity (Mount Rogers PDC) and 20% higher than the next largest urban area (Hampton Roads).

Table 2. Estimated Regional Price Parities for Virginia's Regions

Region	Regional Price Parity	Source
Lenowisco PDC (1)	81.6	Assumed to have the same value as PDC 3 based on its proximity to that region
Cumberland Plateau PDC (2)	81.6	
Mount Rogers PDC (3)	81.6	Aten et al. (2011)
New River Valley PDC (4)	84.0	
Roanoke Valley-Alleghany Regional Commission (5)	88.2	
Central Shenandoah PDC (6)	86.6	
Northern Shenandoah Valley Regional Commission (7)	88.1	
Northern Virginia Regional Commission (8)	115.2	
Rappahannock-Rapidan Regional Council (9)	106.2	Estimated as proportionate to cost of living data (Advameg, Inc., 2012)
Thomas Jefferson PDC (10)	96.8	Aten et al. (2011)
Virginia's Regional 2000 Local Government Council (11)	85.9	
West Piedmont PDC (12)	84.1	
Southside PDC (13)	88.3	Estimated as 87% of the state average (Chmura Economics & Analytics, 2010)
Commonwealth PDC (14)	88.3	
Richmond Regional PDC (15)	94.2	Aten et al. (2011)
George Washington Regional Commission (16)	105.5	Estimated as proportionate to cost of living data (Advameg, Inc., 2012)
Northern Neck PDC (17)	88.3	Estimated as 87% of the state average (Chmura Economics & Analytics, 2010)
Middle Peninsula PDC (18)	88.3	
Crater PDC (19)	87.2	Estimated as proportionate to cost of living data (Advameg, Inc., 2012)
Accomack-Northampton PDC (22)	88.3	Estimated as 87% of the state average (Chmura Economics & Analytics, 2010).
Hampton Roads PDC (23)	96.2	Aten et al. (2011)

Impacts of the 2005 Defense Base Closure and Realignment Commission

One type of population shift that affects Virginia results from military base personnel changes, which affect the bases and the surrounding communities. The 2005 Defense Base Closure and Realignment Commission (2005) recommended a series of military base closures and, in the case of Virginia, expansions. The acronym *BRAC* has been used by the aforementioned source as well as the Transportation Research Board's (TRB) Committee on Federal Funding of Transportation Improvements in BRAC Cases (TRB, 2011). The acronym may refer to (1) the general "base closure and realignment" process (2005 Defense Base Closure and Realignment Commission, 2005, Chapter 1); (2) a specific commission, as in "Defense Base Closure and Realignment Commission" (TRB, 2011, Preface); or (3) "Base Realignment and Closure" (TRB, 2011, Title). Throughout this report, *BRAC* refers to the Virginia base closures and realignments resulting from the decisions made by the 2005 Defense Base Closure and Realignment Commission.

Impacts on Population

Although the closure or expansion of military bases in the United States is not new, TRB (2011) reported that the round of closures and realignments established in 2005—and that have recently been enacted in Virginia—are "fundamentally different" from previous base realignment and closure decisions for two reasons.

First, this round of closures does not reduce excess infrastructure at bases but rather increases the population (including persons residing on the base or near the base) at 18 locations, many of which are in major metropolitan areas. Six bases are in Maryland (Aberdeen Proving Ground, National Naval Medical Center, and Fort Meade) or Virginia (Fort Belvoir, Quantico Marine Corps Base, and Fort Lee). Including military workers, civilian workers, and their dependents, these realignments comprise an increase of 355,000 people at 18 bases during the period 2005-2012; more than one-fifth of that increase (75,500 people) occurs at the six bases named. A way to conceptualize this increase is to note that the increase at the six bases (75,500) is roughly similar to the total 10-year population growth for either the Hampton Roads PDC (88,655) or the George Washington Regional Commission (86,729), as reflected in Figure 14.

Second, the rate of change is relatively rapid according to TRB (2011) and coincident with two other large-scale military realignments in the United States: the movement of 70,000 people (military and civilians) from abroad to U.S. bases (referred to as the Global Defense Posture Realignment initiative) and the addition of 101,000 personnel to the U.S. military (referred to as the Grow the Force initiative). TRB (2011) emphasized that as a result of the additional personnel on and in the vicinity of the bases, traffic congestion will increase at those bases located in urban areas. For instance, with regard to Fort Belvoir, where a total population increase of 36,800 employees and dependents is expected, the increase covers three disconnected geographic locations. The main base is located east of I-95 near Newington; the area called Fort Belvoir North is located about 2 miles away and is west of I-95; and the Mark Center is located 8 miles away in Alexandria (TRB, 2011). Changes at each of these bases will affect employment and thus traffic conditions.

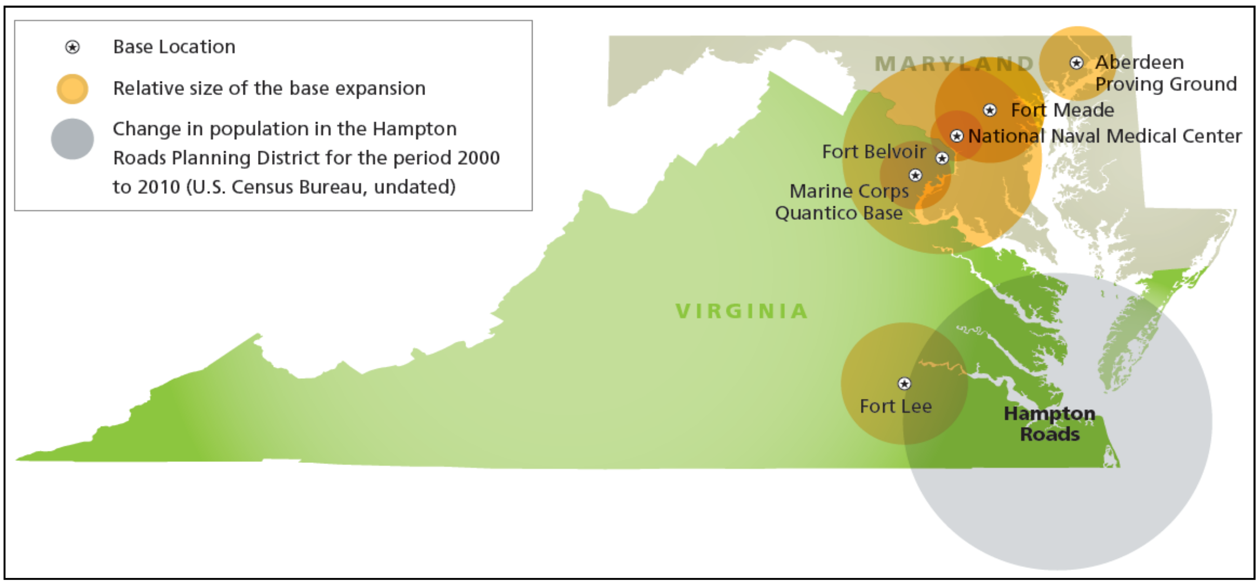

Figure 14. Change in Population Resulting from Virginia and Maryland Base Realignments. For the six bases indicated, the figure reflects the change in the numbers of military workers, civilian workers, and their dependents resulting from the realignment (Transportation Research Board, 2011). The areas of the circles are proportional to the change in population. By comparison, the bottom circle represents the change in population in the Hampton Roads PDC for the period 2000 to 2010 (Weldon Cooper Center for Public Service, 2011). Graphic created with the help of Robert Perry.

Impacts on Transportation

Short-term transportation impacts (see the Appendix) and longer term transportation impacts of the realignments are expected. For example, with regard to the Mark Center, where 10,000 new employees are expected by 2035 (VDOT, 2010), although immediate improvements at the site are being made, longer term improvements that are sought by 2035 (VDOT, 2010) are not yet in the appropriate planning documents such as the Transportation Improvement Program, the city's comprehensive plan, or the VDOT Six-Year Improvement Program. Without these improvements, VDOT (2010) simulation models describe "complete gridlock conditions" on the arterial network in the vicinity of the Mark Center, with critical approaches to the signal being at Level of Service F. On I-395, congestion levels match the "severe" condition, with densities in the vicinity of 100 vehicles per hour per lane (for example, traffic will be sufficiently congested such that there is less than 40 feet between vehicles).

As a consequence, an alternatives analysis was conducted for moving traffic from I-395 to the Mark Center and vice versa; of seven alternatives examined, the one recommended is a ramp from the I-395 high occupancy/toll (HOT) lanes to the Mark Center. This alternative will still yield congestion in the severe range but will be an improvement relative to the no-build scenario. For example, microscopic modeling (VDOT, 2010) suggested that without construction, in 2035, the speed on the I-395 northbound merge section in the vicinity of Route 236 (Little River Turnpike) will be about 5 mph; with the preferred build alternative, the speed would rise to 17 mph for that section. Larger improvements are noted on some of the mainline sections; for example, between Route 236 and Seminary Road, VDOT (2010) reported that speeds would rise from 6 mph (no build scenario) to 52 mph (build scenario). The extent of the improvement varies by location, and an example of this variation is shown in Figure 15.

Although the transportation impacts of the BRAC are substantial at the Mark Center, impacts of base expansions elsewhere are noted. For example, the City of Petersburg Virginia (2011) noted that the expansion of Fort Lee will place pressure on Route 460 and I-95 in addition to the Route 36 corridor.

Impacts on Employment

Although TRB (2011) did not provide information about secondary impacts on the bases, this information was available from other sources—albeit with limitations. For example, whereas TRB (2011) reported a total growth in employment by the Fort Lee Department of Defense (DOD) (military and civilian both on and off the base) of 10,200 between FY2006 and FY2012, the City of Petersburg Comprehensive Plan (City of Petersburg Virginia, 2011) reported an *on-base only* growth of 3,300 jobs (which presumably is included in the DOD total) plus an additional 6,500 jobs by 2013 (which do not appear to be military based). That said,

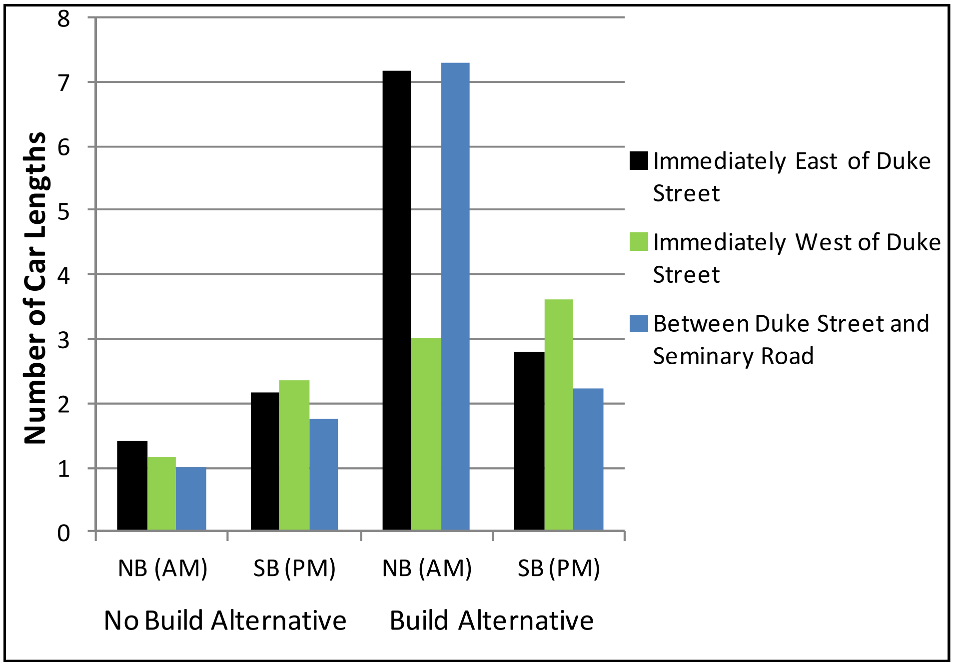

Figure 15. Expected Number of Car lengths Between Bumpers on I-395 in Alexandria for 2035. Calculated based on the densities provided in Tables 8-4 (Sections F-1, F-2, and F-3) and 8-1 (Sections F-13, an average of sections F-11 and F-12, and F-10) (Virginia Department of Transportation, 2010) and presuming an vehicle length of 5 m (16.4 ft) based on information provided in Cheung et al. (2005). NB AM = northbound morning peak; SB PM = southbound evening peak.

the VEC (2007b) pointed out that some of these positions are temporary construction positions (although growth in employment is still expected relative to 2006). The City of Colonial Heights Virginia (undated) reported that the impact of Fort Lee will be an additional $500 million for regional businesses.

Regarding Fort Belvoir and Quantico, whereas the Center for Regional Economic Competitiveness and the Center for Regional Analysis (2007) reported a total DOD-related employment growth of 22,416 positions from both bases combined, TRB (2011) reported the slightly higher number of 27,700 (quite plausible owing to the difference in the year the estimates were published). The Center for Regional Economic Competitiveness and the Center for Regional Analysis (2007) reported that an additional 8,658 net indirect jobs may also result from these DOD realignments, as summarized in Table 3. Table 3 does not include 31,000 temporary construction jobs attributable to the $4 billion construction effort at the two bases (Center for Regional Economic Competitiveness and the Center for Regional Analysis, 2007).

Table 3. Summary of BRAC Employment Impacts

Base	Growth in Military and Civilian Employment[a]	Growth in Spinoff Employment	Total Employment Resulting From BRAC
Fort Lee	10,200	6,500[b]	16,700
Fort Belvoir	24,100	8,658[c]	36,358
Quantico	3,600		

BRAC = 2005 Defense Base Closure and Realignment Commission.
[a]Transportation Research Board (2011).
[b]City of Petersburg Virginia (2011).
[c]Center for Regional Economic Competitiveness and the Center for Regional Analysis (2007).

Modes and Subpopulations of Interest to Virginia's Office of Intermodal Planning and Investment

Subpopulations may be defined based on transportation mode (e.g., transit usage); whether they are protected under environmental justice regulations (i.e., low-income populations and minority populations); English-speaking proficiency; possession of a driver's license; and whether they work from home.

Influence of Income Level on Transportation Mode Choice

Figures 16 and 17 show data from Table B08119 of the 2006-2010 ACS (U.S. Census Bureau, 2011d) and reflects the mode of choice for commuters statewide. Generally the data showed that the percentage of commuters who walked or carpooled to work decreased with income. For example, 6% of all persons who made less than $10,000 annually walked to work compared with 1% of persons making $35,000 or more. The percentage of persons who carpooled was between 12% and 14% for those with incomes below $25,000 annually; this percentage dropped to 8% for those with annual incomes of $65,000 or more.

Figure 17 suggests that the percentages of commuters who drive alone, use public transportation, or work from home do not follow a continually increasing or decreasing trend with respect to income. Rather, the percentage of persons who use public transport was minimized at a middle income range (between $25,000 and $34,999) and the percentage of persons who worked from home was minimized at another middle income range (between $35,000 and $49,999). The percentage of persons who drive alone increased with income until about $50,000, at which point further nominal increases were not noted.

Figure 16. Percentages of Workers Who Carpooled or Walked to Work by Workers' Earnings in Virginia. Data extracted from 2006-2010 American Community Survey 5-Year Estimates, Table B08119 (U.S. Census Bureau, 2011d). The "loss" noted in the category "$1 to $9,999 or loss" is the original language used in Table B08119 and is assumed by the author to reflect individuals who suffered a net loss in earnings. Dollar amounts are workers' earnings in the past 12 months in 2010 dollars. For example: Of the workers who earned $9,999 or less (including those who suffered a net loss) over the past 12 months, approximately 14% carpooled to work, 6% walked to work, and 80% used some mode other than carpooling or walking.

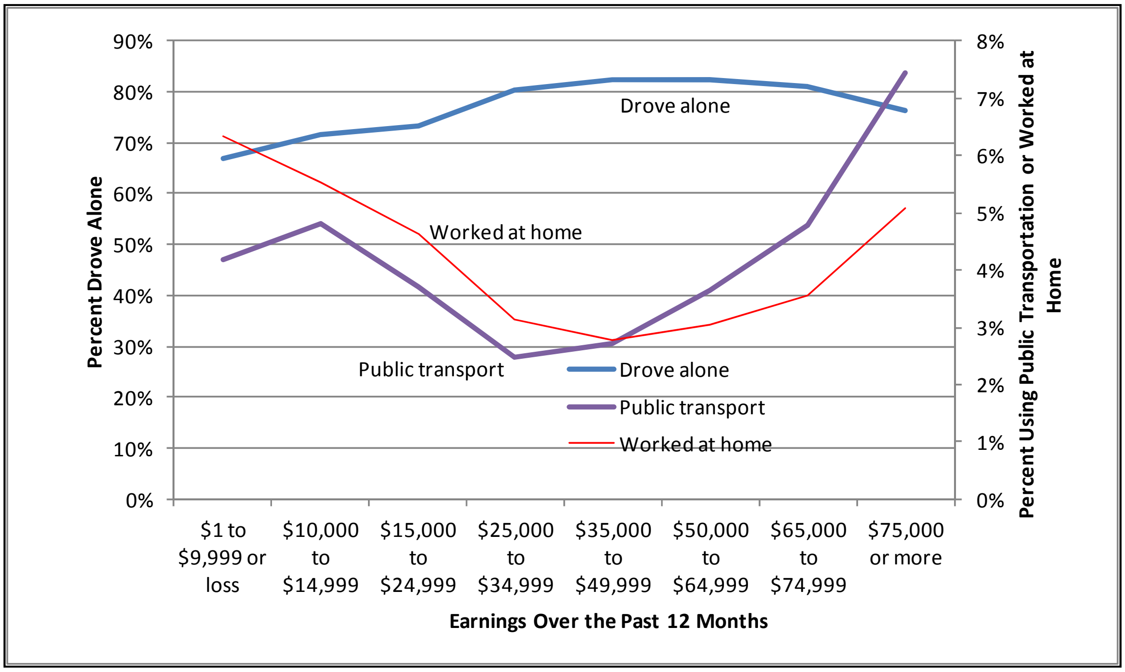

Figure 17. Percentages of Workers Who Drove Alone, Used Public Transportation, or Worked From Home by Workers' Earnings in Virginia. Data extracted from 2006-2010 American Community Survey 5-Year Estimates, Table B08119 (U.S. Census Bureau, 2011d). The "loss" noted in the category "$1 to $9,999 or loss" is the original language used in Table B08119 and is assumed by the author to reflect individuals who suffered a net loss in earnings. Dollar amounts are workers' earnings in the past 12 months in 2010 dollars.

Figure 18 suggests that the income for a commuter who chooses to use public transportation varies by region. The number of commuters who use public transportation is shown for four regions. For two of these—the Northern Virginia Regional Commission and the adjacent George Washington Regional Commission—the percentage of workers using public transportation *increased* with earnings. According to data extracted from Table B08119 of the 2006-2010 ACS (U.S. Census Bureau, 2011d), the Northern Virginia Regional Commission accounted for almost three-fourths (74%) of the workers using public transportation in Virginia. By contrast, the two other regions shown in Figure 18—the Richmond Regional PDC and the Hampton Roads PDC—generally showed a nominal trend of decreasing public transportation with income, with an exception being a nominal increase for the highest income category of $75,000 or more.

Low-Income Populations and Minority Populations: Those Protected Under Environmental Justice Regulations

Why Environmental Justice Is Relevant

In 1994, President Clinton issued Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. The order stated the following: **"**Each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations" (Executive Order 12898, 1994).

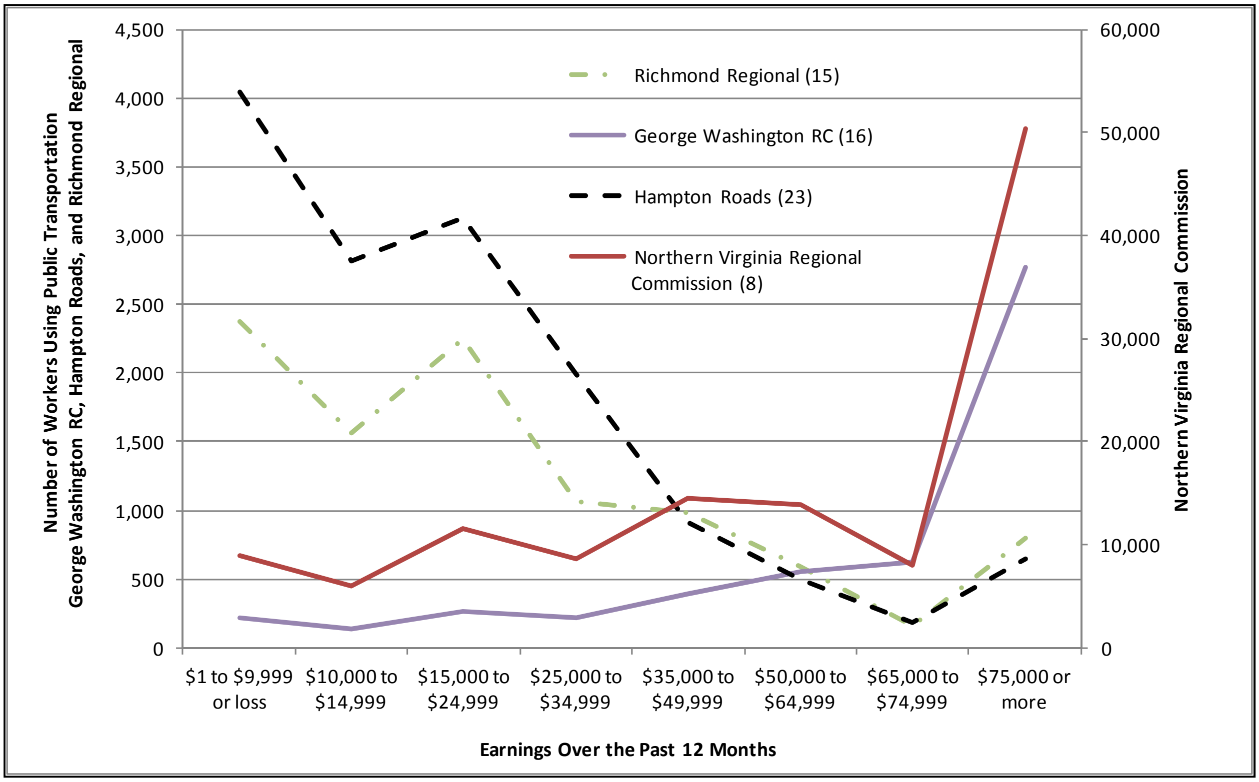

Figure 18. Number of Workers Using Public Transportation by Workers' Earnings in Four Virginia Regions. The regions include the Northern Virginia Regional Commission, the George Washington Regional Commission, the Richmond Regional PDC, and the Hampton Roads PDC. Numbers in parentheses indicate the number of the PDC. The "loss" noted in the category "$1 to $9,999 or loss" is the original language used in Table B08119 and is assumed by the author to reflect individuals who suffered a net loss in earnings. Data extracted from 2006-2010 American Community Survey 5-Year Estimates, Table B08119 (U.S. Census Bureau, 2011d). Dollar amounts are workers' earnings in the past 12 months in 2010 dollars.

The FHWA (2012a) provided an overview of the relevance of environmental justice for federal programs (such as surface transportation funding provided by the U.S. DOT): such programs are to be examined to determine whether they comply with the executive order. Although minority groups are also protected by the Civil Rights Act of 1964, low-income groups are not; as a consequence, achieving environmental justice is interpreted as protecting both of these groups such that in the transportation sector, *environmental justice* is defined as ensuring that "a disproportionate share of adverse effects will not fall upon low-income or minority (protected) populations" (Forkenbrock and Sheeley, 2004).

Since the issuance of Executive Order 12898 in 1994, environmental justice has received substantial attention in the planning process. A decade after its passage, Forkenbrock and Sheeley (2004) wrote that although there was not agreement as to how environmental justice assessments should be performed, there was agreement as to when they should be performed, namely, at several points during the planning process. Specifically, these points are as part of the statewide and MPO regional planning process (when budgetary resources are being allocated); as part of the project development process (when alternatives are being considered); and as part of the environmental review process (e.g., during preparation of an environmental impact statement). Kravetz and Noland (2012) suggested that environmental justice legislation has “proliferated” such that examination of highway safety investments must be considered; the authors illustrated how to assess the environmental justice impacts of “pedestrian-friendly” roadway investments.

A review of Prozzi et al. (2010) suggested that quantitative environmental justice impacts of toll facilities are typically limited to either the number of people displaced or noise impacts. For example, in the construction of the U.S. 36 Corridor in Colorado, the block groups where a majority of the residents were either low-income or minority populations were identified. Then, the percentage of persons displaced in these block groups were compared to the percentage of persons displaced in other block groups to ensure that displacements did not adversely affect minority or low-income individuals to a greater degree than the population as a whole. However, Prozzi et al. (2010) suggested that toll roads could generate a variety of environmental justice concerns other than displacements. Examples were as follows: (1) a facility might divide a particular neighborhood; (2) the facility might have a higher percentage of low-income or minority users; (3) there might not be a non-tolled option available; and (4) the toll facility might not serve poorer neighborhoods as well as wealthier neighborhoods. The authors’ recommendations focused on better outreach techniques to low-income and minority populations where such techniques concern obtaining opinions at residents’ homes rather than requiring such individuals to attend public meetings to offer opinions.

An example of a quantitative environmental justice analysis was offered by Hickey et al. (2010), who examined the impacts of fare increases in New York City’s transit system on low-income and minority populations. Using the location of a farecard’s first use as a surrogate for where a transit user lived, Hickey et al. (2010) determined the impact of a proposed fare increase on low-income versus high-income populations and minority versus non-minority populations. The farecard did not contain identifying information; the location of the first use of the farecard is tied to a specific census tract and data for that tract help determine the potential demographics of the user. Because where the same farecard is used can be tracked, the impacts of various types of fare increases can be determined. In this instance, the authors found that one particular proposal, which entailed raising the price of a single ride by 25%, raising the price of a 30-day pass by 27%, and additional changes in pricing) increased fares by 25.3% (for non-minority populations) compared to 25.2% (for minority populations); similar results were obtained for low-income versus high-income populations. Accordingly, the authors could show that low-income and minority populations were not adversely affected to a greater degree than other populations by the increase. Analyses are not restricted to fares; for example, Reddy et al. (2010) showed that a reduction in staffed transit booths (staff were eliminated in 25% of booths in low-income census tracts compared to 33% of booths in high-income census tracts) resulted in the high-income areas being adversely affected and the difference was statistically significant. This was compliant with Executive Order 12898 since low-income and minority areas were not disproportionately affected (Reddy et al., 2010).

The Minority Population

The VEC last produced population projections in 2007 (VEC, 2012) and the U.S. Census Bureau (undated, b) indicated that it does not have any plans to update state-level population projections. However, projections to year 2050 by the U.S. Census Bureau (2008a) indicated that in 2050, the minority population, which the U.S. Census Bureau defines as "everyone except for non-Hispanic, single-race whites," will be 53.7% of the U.S. total population; data for year 2035 suggest that for the United States as a whole, the minority population will be 46.9% of the U.S. population (U.S. Census Bureau, 2008b) up from 36.3% of the population in 2010 (U.S. Census Bureau, 2011g, Table QT-P4). Although Virginia-specific data are not available for year 2035, based on 2010 decennial census data, the minority population is 35.2% of Virginia's population, which was similar to the percentage in the U.S. population (36.3%). The population breakdown by race and Hispanic origin for the United States is shown in Figure 19.

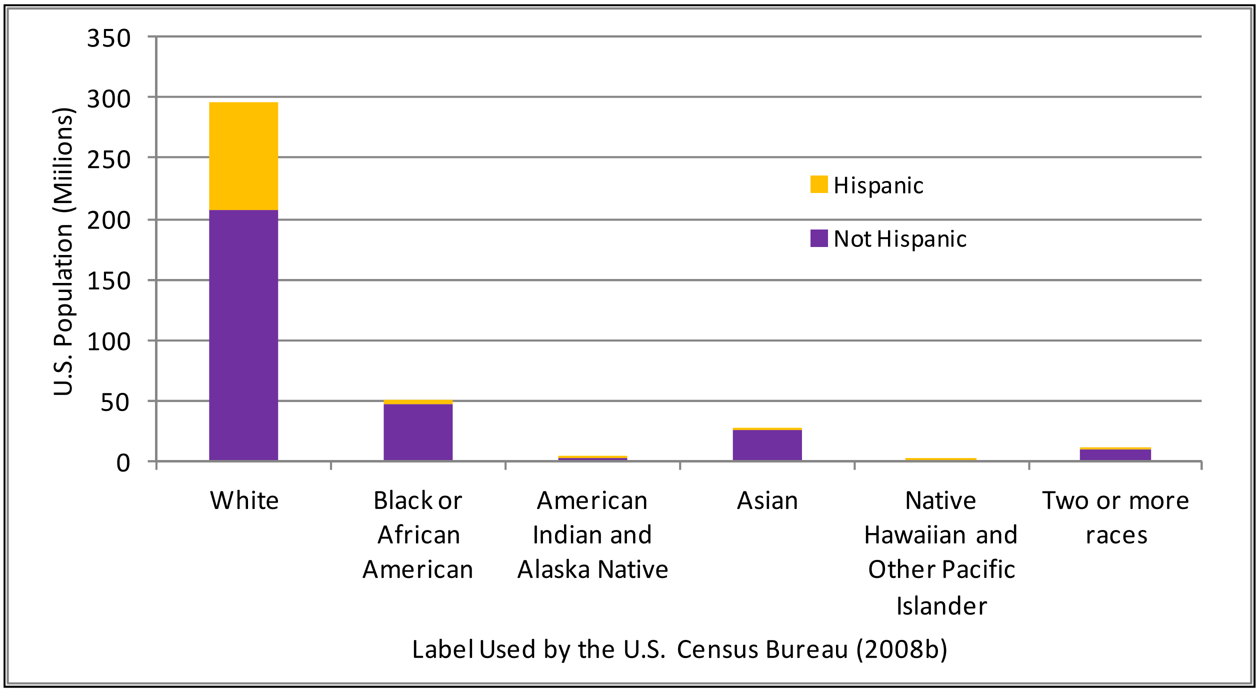

Figure 19. 2035 Projections of U.S. Population by Race and Hispanic Origin. Data extracted from the U.S. Census Bureau (2008b).

Low-Income Population

The U.S. Census Bureau (2011b) uses Office of Management and Budget Directive 14 to establish poverty thresholds based on the age and number of members in a family; for example, in 2010 the poverty level for a single adult (age 65+) living alone is $10,458; if that adult is younger than age 65 and cares for three children (under 18), the poverty level is $22,190. Such data show that based on Table S1701 of the 2006-2010 ACS (U.S. Census Bureau, 2011d), 10.3% of Virginians were below the poverty level. Cable and Tippett (2012) suggested that the poverty level has these deficiencies: it does not capture differences in cost of living by region, and it does not capture some important variations such as changes in cost of living by region and individuals who may exceed the poverty level but may still need some form of public assistance. Using a threshold of 150% of the poverty level for this latter group as suggested by Cable and Tippett (2012), Table S1701 of the 2006-2010 ACS (U.S. Census Bureau, 2011d) suggested that 17.3% of Virginians were below 150% of the poverty level.

Not surprisingly, the higher median incomes in the Northern Virginia Regional Commission led to a smaller percentage of persons being below the poverty level (or below 150% of the poverty level) than was the case in other regions (since the poverty level does not change based on cost of living). Figure 20 shows that a majority of Virginia's regions (12 of 21) had one-fifth or more of their populations at 150% or below the poverty level—meaning, based on Cable and Tippett (2012), that some form of public assistance is likely needed. In two regions (the Lenowisco PDC and the New River Valley PDC), more than one-fifth of the population was below the poverty level.

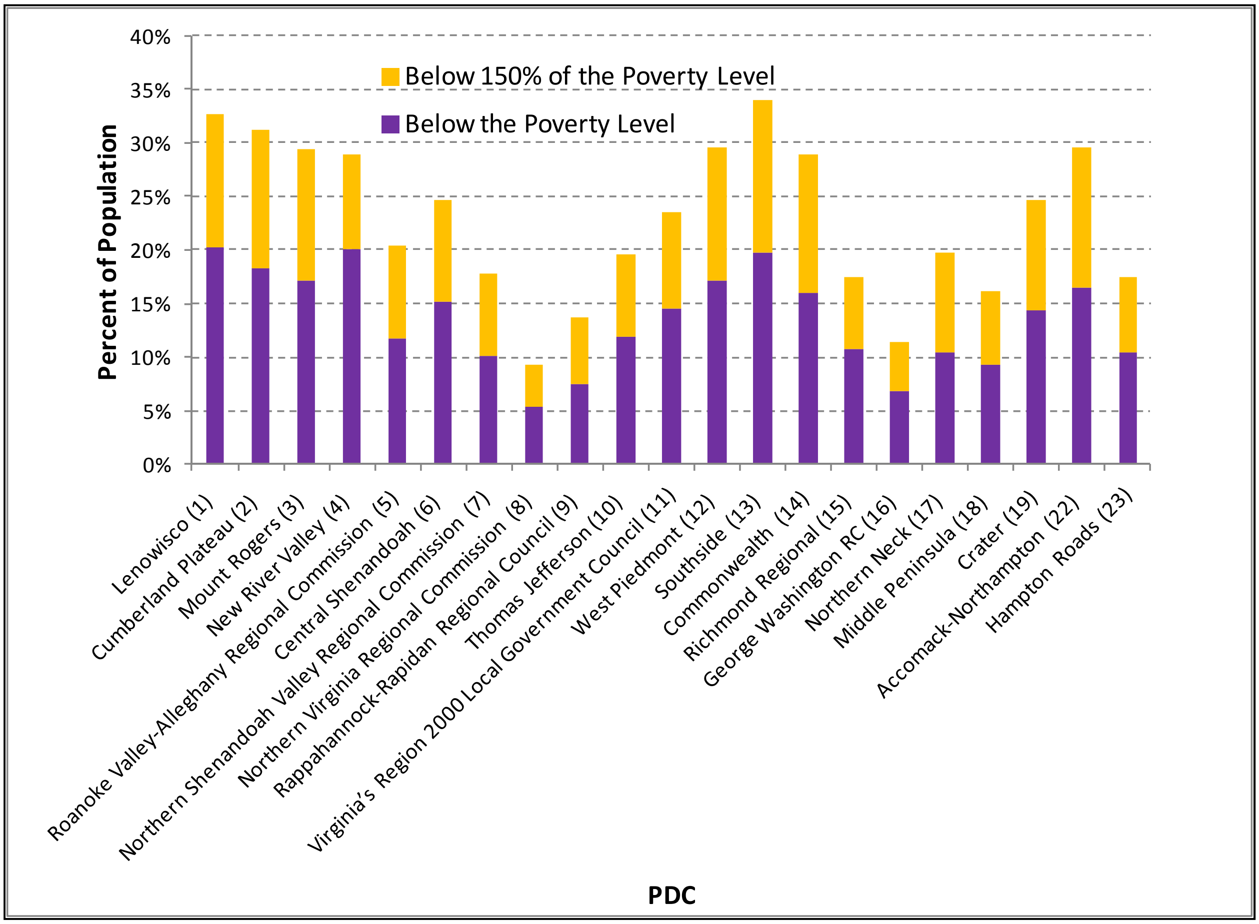

Figure 20. Percentage of Virginians Below 100% of Poverty Level and Below 150% of Poverty Level by PDC. Numbers in parentheses indicate the number of the PDC. *Poverty level* is defined based on family size, number of children, and income for a given year as defined by the U.S. Census Bureau (2011b). Based on data extracted from 2006-2010 American Community Survey 5-Year Estimates, Table S1701 (U.S. Census Bureau, 2011d). For example: The West Piedmont PDC had a population of 243,398, with 41,160 people (17.1%) below the poverty level. An additional 30, 301 people (12.4%) were above the poverty level but below 150% of the poverty level. Thus, a total of 71,911 people (almost 30%) were below 150% of the poverty level.

Virginians Who Speak English Less Than "Very Well"

At the state level, data from the ACS suggested that 5.7% of Virginians "[s]peak English less than 'very well'." This number did not change whether the 5-year ACS estimates for the period 2006-2010 (U.S. Census Bureau, 2011d), which encompass all Virginia counties, or the

1-year ACS estimates for 2010 (U.S. Census Bureau, 2011f), which provide estimates for counties of only 65,000 or more, were used. It is important to note that the classification of speaking English less than very well is based on the self-assessment of those responding to census questions, not on a test of language ability. At the county level, although the 2006-2010 ACS estimates indicated that the Northern Virginia Regional Commission had the largest percentage of persons indicating they speak English less than very well (13.4%), size alone was not a predictor of the percentage. For example, the region with the next largest percentage of persons indicating they do not speak English very well was the Accomack-Northampton PDC (with 4.8%) followed by Northern Shenandoah Valley Regional Commission (with 4.3%), as shown in Figure 21. There is variation within these regions; for example, within the Northern Shenandoah Valley Regional Commission with an average of 4.3%, the percentage is 13.1% for the City of Winchester.

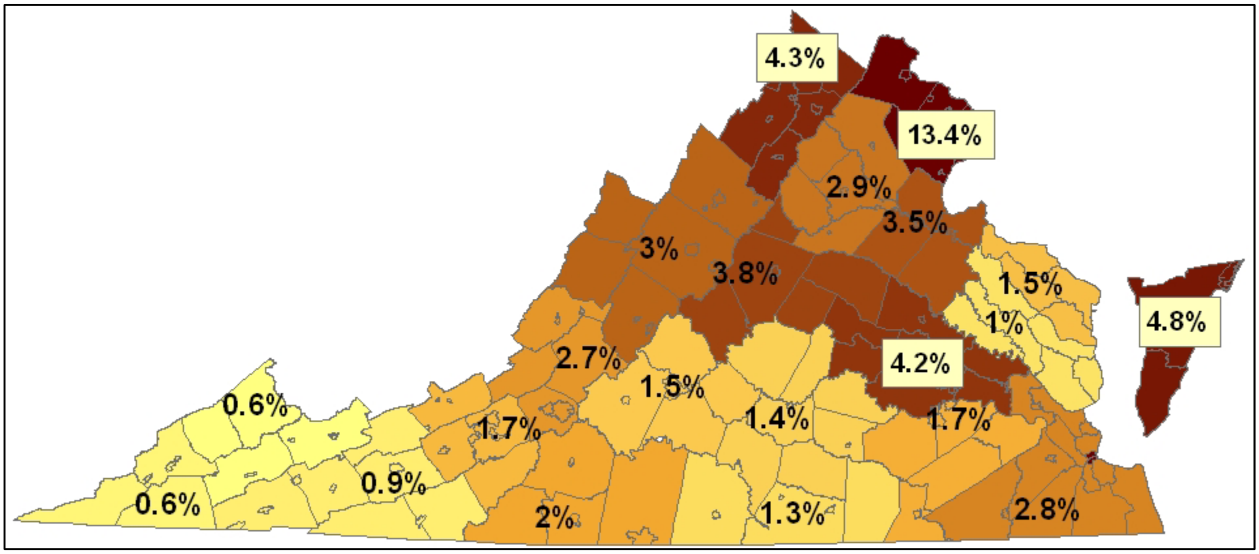

Figure 21. Current Percentages of Virginians Who "Speak English Less Than Very Well." Data extracted from 2006-2010 American Community Survey 5-Year Estimates, Table B06007 (U.S. Census Bureau, 2011d). The shading delineates the PDCs.

Licensed Drivers

Sivak and Schoettle (2011) reported a drop in the percentage of younger persons with a driver's license in the United States: from 1983 to 2008, this percentage of persons age 16, 17, 18, or 19 dropped by between 12 and 19 percentage points depending on the age. For example, in 1983, this percentage of persons age 18 was 80.4%; in 2008, this percentage was 65.4%. The authors reported decreases (although not as large) for other age groups under age 40: decreases were 10% for age 20-24; 9% for age 25-29; 6% for age 30-34; and 3% for age 35-39; increases were reported for age groups at age 50 and older (e.g., 3% for age 50-54 and 24% for age 70 and older. In a separate publication, Sivak and Schoettle (2012) reported that an empirical study of licensed drivers in 15 countries showed that a higher percentage of Internet users was a statistically significant predictor of lower percentages of younger persons with a driver's license. Further, the authors stated: "This finding is consistent with the hypothesis that access to virtual contact reduces the need for actual contact among young people."

In Virginia, the percentage of the population age 15 or older with a driver's license decreased from a high of 93% in 1991 to 83% in 2010, the most recent year for which data are available. These data were obtained from the U.S. Census Bureau (2000, 2011c) and the Federal Highway Administration, Office of Highway Policy Information (2012b). Figure 22 shows a decline in the percentage of persons age 15-19 with a license, from a high of 55% (in 1990) to 39% (in 2010). There have been declines in all other age groups under age 55 (although not as large) for the same period; for example, the percentage of persons age 20-24 with a driver's license decreased from 87% in 1990 to 76% in 2010. By contrast, the percentage of older Virginia drivers with a license increased; for example, in 1991, just 29% of drivers age 85 or older had a license and by 2010 more than 51% had a license. Increases, although not as large, were evident for the 80-85, 75-79, and 70-74 age groups, as shown in Figure 23 (with percentage point increases of 15, 11, and 4 for the period 1991-2010). Thus, the trends in Virginia are somewhat consistent with the national trends reported by Sivak and Schoettle (2012): over time, the percentage of the population in younger age groups with a driver's license has decreased and in older age groups has increased.

Figures 22 and 23 combined males and females. However, data from 1990, 2000, and 2010 (U.S. Census Bureau, 2000, 2011c; Federal Highway Administration, Office of Highway Policy Information, 2012b) suggested that whereas licensure rates for males and females under age 30 underwent similar changes, these changes differed for older drivers. For example, for age 20-24, the percentage of males with a driver's license dropped by 12 percentage points (84% to 72%), whereas the percentage of females dropped 10 percentage points (90% to 80%). Yet the

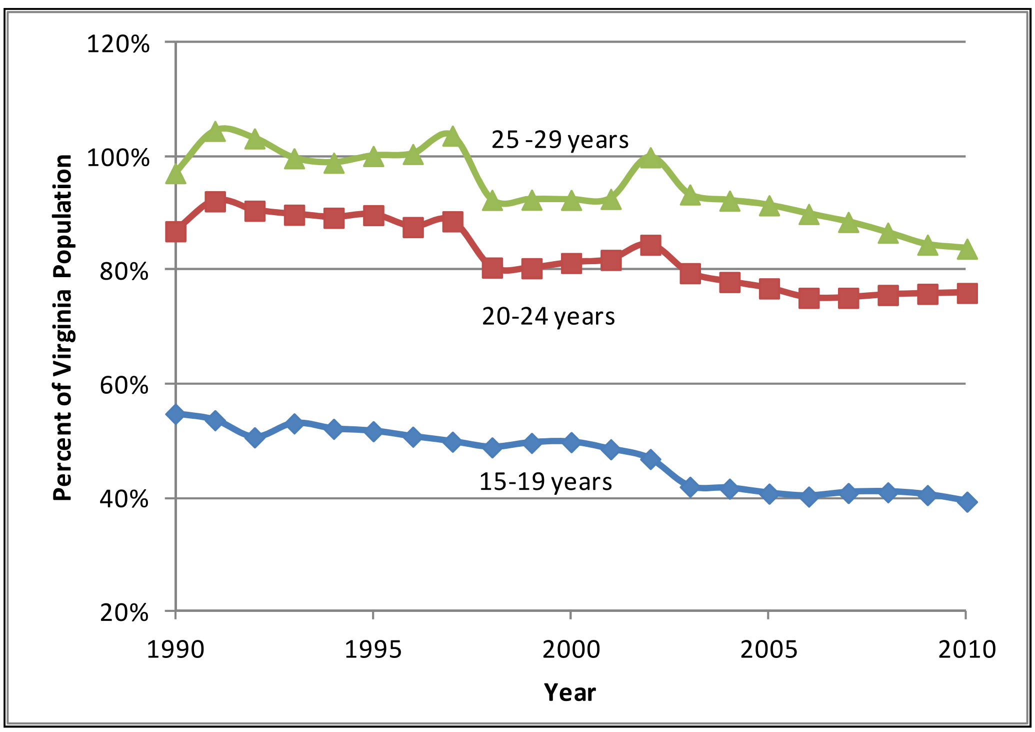

Figure 22. Percentage of Virginians Age 15-29 Years With a Driver's License, 1990-2010. Based on data extracted from the U.S. Census Bureau (2000, 2011c) and the Federal Highway Administration, Office of Highway Policy Information (2012b). Percentages may exceed 100% because of the manner in which licensed drivers are defined (Larson, 1992).

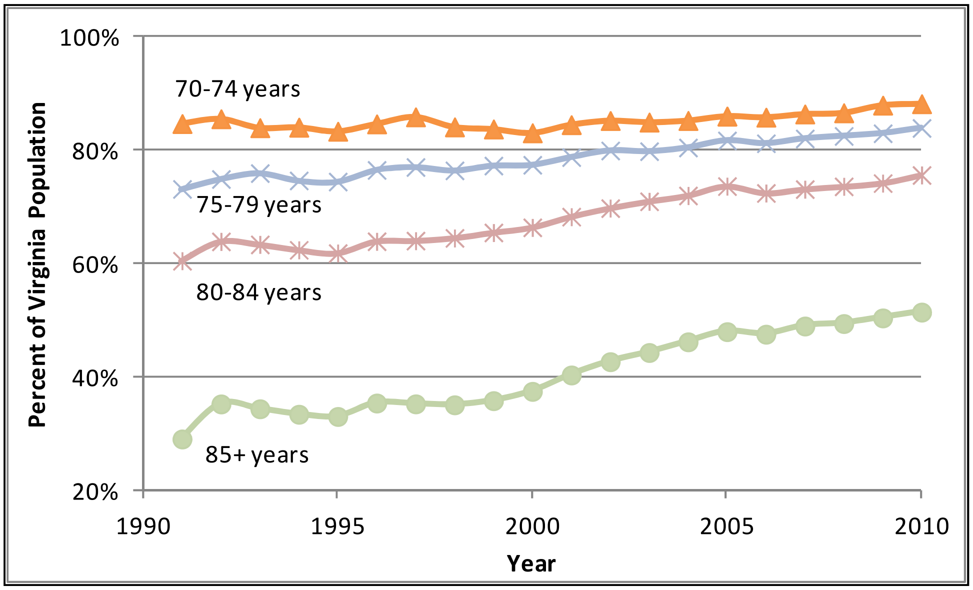

Figure 23. Percentage of Virginians Age 70+ With a Driver's License, 1990-2010. Based on data extracted from the U.S. Census Bureau (2000, 2011c) and the Federal Highway Administration, Office of Highway Policy Information (2012b).

percentage of males age 70+ with a driver's license dropped 2 percentage points (91% to 89%) whereas the percentage of females in the same age group increased 20 percentage points (50% to 70%). Further, for the 65-69 age group for the 1990 to 2010 period (not shown in Figure 23), the percentage of males with a driver's license dropped modestly (98% to 94%), yet the percentage of females had an increase (75% to 89%). Figure 24, in conjunction with Figure 23, suggests that most of the increase in the percentage of older drivers with a driver's license was attributable to increases in the percentage of females with a driver's license.

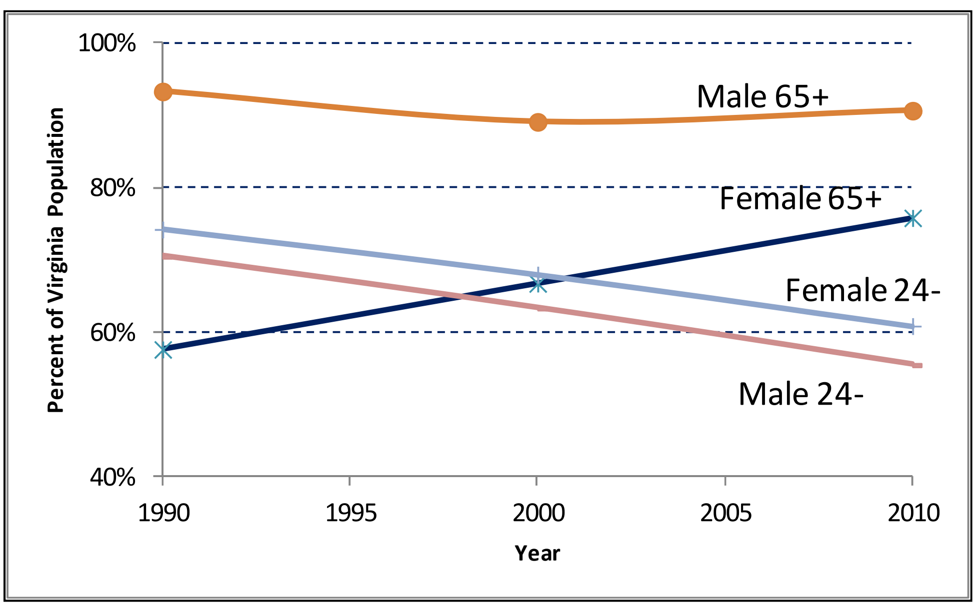

Figure 24. Percentages of Virginians Age 24 or Younger or Age 65+ With a Driver's License for Years 1990, 2000, and 2010. Based on data extracted from the U.S. Census Bureau (2000, 2011c) and the Federal Highway Administration, Office of Highway Policy Information (2012b).

Although one interpretation of Figures 23 and 24 is that the mobility needs of older women age 65+ are approaching those of men age 65+ to the extent that similar percentages will have a driver's license, Figure 24 clarifies that indeed a substantial portion of both sexes do not have a driver's license and thus are reliant on alternatives to driving alone. Rosenbloom and Winsten-Bartlett (2002) further noted that the mobility needs of older women (age 65+) may differ from those of older men (age 65+): whereas most older men have a spouse who can help when their health declines, this is not the case for most older women. Quoting a U.S. Census Bureau 1995 report, Rosenbloom and Winsten-Bartlett (2002) wrote that "while most elderly men have a spouse for assistance, especially when health fails, most elderly women do not." Although Rosenbloom and Winsten-Bartlett (2002) did not report how the word *most* was defined, they did note that more than one-half of all men age 85+ were married compared to 13% for all women age 85+ and a greater percentage of women age 65+ lived alone (41%) than men of the same age group (17%). Further, the percentage of women over age 65 living below the poverty line (14%) is larger than the percentage of men over age 65 living below the poverty line (7%).

With regard to 2035, the safety implications of continued changes in the composition of Virginians with a driver's license by age is not immediately clear. The Insurance Institute for Highway Safety (2012) indicated that the number of crashes per mile increases with an age over 69; however the same source cautioned that motorists age 70 or over drive fewer miles than motorists age 35-69 and that the higher crash rates for older motorists may be partly attributed to their greater use of city streets. The Insurance Institute for Highway Safety (2012) reported that motorists who drive more miles per year may use interstate or divided highways, which have lower crash rates than city streets. The National Highway Traffic Safety Administration (undated) reported that from 2000 to 2009, the population of persons age 65+ increased by 13%, with crash fatalities decreasing by 18% over the same period. Further, Cheung and McCartt (2011) reported that for the period 1997-2008, the fatal crash risk for drivers age 70+ in the United States had declined.

Telecommuters

In this report, *telecommuter* is defined as a person who works from home. This definition is useful because it is consistent with available data that define such a choice for the journey to work trip. It is limited because such a definition does not distinguish between persons who work from home because they have a home-based business and persons who replace the commute trip with working at home. The literature shows multiple definitions of *telecommuting* and *teleworking.* Jin and Wu (2011) noted that telecommuting may include workers with home-based businesses, self-employed individuals, and persons holding multiple jobs. Litman (2012a) used the term *telework* specifically to restrict this definition to "electronic communication that substitutes for physical travel"; however, Litman's definition encompasses non-work trips (e.g., banking that is done electronically). Rose (2010) defined the term *telework* as "working from another location (home, satellite office or Starbucks)."

Jin and Wu (2011) indicated that improvements in technology that facilitate telecommuting do not guarantee commensurate increases in the percentage of workers who choose to telecommute. For example, it is clear that Internet access has increased since 1995, when the 1995 National Personal Transportation Survey was conducted. However, in a re-analysis of data from the 1995 survey combined with data from the 2001 and 2009 National Household Travel Surveys, Jin and Wu (2011) found that from 1995 to 2009, *fewer* workers telecommuted at least once a week (11.7% in 1995 compared to 2.8% in 2009) and that more workers did not telecommute in the past 2 months (83.3% in 1995 compared to 89.9% in 2009). The authors' listing of multiple factors associated with increased telecommuting—(1) having more than one job; (2) being older (which was correlated with occupations conducive to telecommuting); (3) a higher level of education; (4) higher income; (5) households with no children; and (6) longer distance and travel time—suggests that the increase in technological feasibility competes with other factors that influence telecommuting. Complexities were also noted in terms of interpreting these factors; for example, although higher levels of education were associated with telecommuting, the authors noted that telecommuters who worked from home almost every day had less education than did telecommuters who worked from home less frequently (Jin and Wu, 2011).

The literature suggests ways to increase telecommuting. Rathbone (2006) identified one incentive to encourage telecommuting: a trip reduction (during the land development review process) for telecommuting trips. Although pointing out that an earlier (2005) survey had shown that only 5% of municipal respondents allowed such a reduction during the review process, Rathbone (2006) suggested telecommuting could enable both congestion reduction and emergency preparedness. A second type of incentive is tax credits for businesses to encourage telecommuting, one of which is the Telework! VA Program, which for the period 2001-2010, included the participation of 137 employers (ACT Telework Award, 2010). Wilton et al. (2011) explained that "workplace culture"—defined not as an employer's telecommuting policy per se but rather as the set of written and unwritten expectations about telecommuting—can influence its acceptance or rejection; a negative example would be a colleague who expressed concerns to a supervisor about telecommuting where the supervisor then concluded the practice was not productive.

Yet examination of eight strategic benefits of telecommuting for federal agencies (Steinhardt, 2007) raised the possibility that motivations for telecommuting may ultimately derive from interests unrelated, or only partially related, to congestion reduction. Although Steinhardt (2007) cited two travel-related benefits (reduction of congestion and emissions and mitigation of long commutes); six other benefits were also noted: (1) workforce retention; (2) decreased real estate needs; (3) continuity of services during an emergency; (4) accommodation of persons with disabilities; (5) increased productivity; and (6) reduction in sick leave. Further, Litman (2012a) cautioned that by itself, increased telecommuting may not necessarily reduce travel because of four potential behavioral changes: (1) a telecommuter may run errands that otherwise would be part of a chained work trip; (2) a telecommuter's vehicle may be used by another family member; (3) in the long-term the worker may choose to live further from his or her place of employment; and (4) the same technologies that support telecommuting may also facilitate other long distance relationships—and thus may result in greater travel.

In addition to how *telecommuting* is defined, the manner in which telecommuting is measured affects the interpretation of the results. For example, although Jin and Wu (2011) reported decreases from 1995 to 2009 in two telecommuting categories of "Almost every day" and "Once a week or more" and an increase in the telecommuting category of "Did not telecommute in past 2 months," the authors noted an increase in the categories of "Once a month or more" and "Less than once a month." Despite the wording, the five categories are mutually exclusive. Rose (2010) also suggested that at least infrequent telecommuting of once per month has been observed and stated that other research indicates that the number of once-per-month telecommuters has risen by 39% from 2002 to 2007.

Virginia data showed that the percentage of workers age 16 and older who worked from home increased from 3.2% to 4.2% between the 2000 census and the 2006-2010 ACS (U.S. Census Bureau, 2011d). Because the U.S. Census asks respondents who used more than one mode of transportation during the week to select the mode they used the most often, and because respondents who had more than one job are asked to indicate the mode for the job that entails the longest commute (U.S. Census Bureau, 2012), the percentage of Virginians working from home as shown here is most likely less than the number of Virginians who telecommuted at least a minority of the time.

Over that period (from 2000 to the 2006-2010 ACS), the percentage of workers working from home increased in 19 of Virginia's 21 regions and decreased only in the Mount Rogers PDC (from 2.7% to 2.5%) and the Central Shenandoah PDC (from 3.9% to 3.8%). From 2000 to the 2006-2010 data collection, the largest increases in the percentage of workers working from home were in the Northern Neck PDC (3%), the Crater PDC (2.3%), and the Southside PDC (1.9%). As shown in Figure 25, the most recent data suggest that the regions with the highest

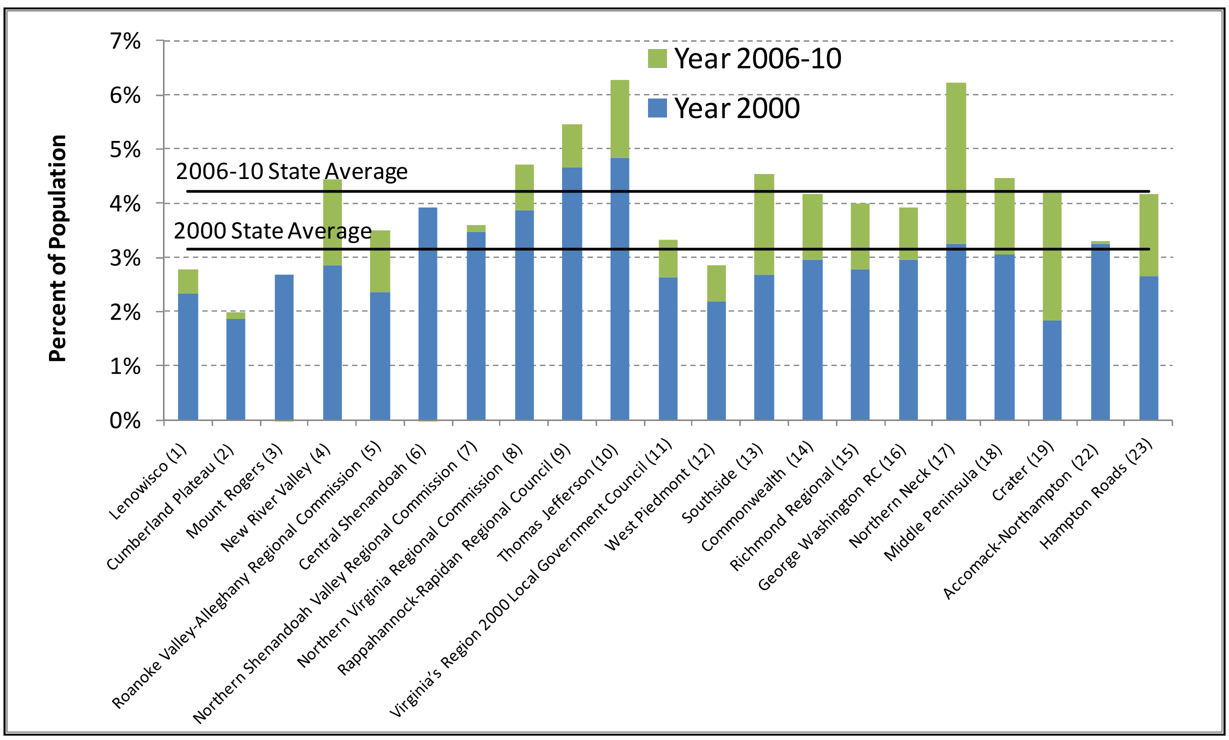

Figure 25. Percentage of Virginians Who Are Telecommuters by PDC. Numbers in parentheses indicate the number of the PDC. Based on data extracted from the U.S. Census Bureau (2003, 2011d [Table B08301]). *Telecommuters* are defined as persons for whom the American Community Survey data indicated "worked at home." Figure 25 likely underestimates the number of Virginians who telecommuted at least a minority of the time.

percentage of working from home are the Thomas Jefferson PDC (6.3%), the Northern Neck PDC (6.2%), the Rappahannock-Rapidan Regional Council (5.4%), the Northern Virginia Regional Commission (4.7%), and the Southside PDC (4.5%). For both the 2000 and 2006-2010 datasets, it was not the case that the most populous areas had the highest percentage of persons working from home. For example, in the 2000 census, the populous regions of the Hampton Roads PDC, the Richmond Regional PDC, the Roanoke Valley-Alleghany Regional Commission, and the George Washington Regional Commission all had percentages of persons working from home below the statewide average.

Importance of Travel Time Savings

Competing transportation investments, such as expanded transit service and enhanced traveler information, are typically evaluated using multiple criteria. Multiple criteria are evident in the VTrans 2035 goals such as safety, security, environmental stewardship, and coordination of transportation and land use (Office of Intermodal Planning and Investment, 2010). Multiple criteria are not unique to Virginia; for example, § 450.306 of Title 23 of the U.S. Code specifies eight planning factors that metropolitan regions must consider in their development of a transportation program that will receive federal funds, including safety, security, consistency of improvements with anticipated land use, and accessibility (e.g., an ability to reach key regional employment and social destinations).

The FHWA and the Federal Transit Administration (2007) argued that transportation investments influence social concerns such as equity across population segments, air quality, and consumption of environmental resources. Colman (2009) demonstrated how to monetize the impacts of potential transportation improvements using 23 criteria for the selection of projects in the Vancouver (Washington) transportation improvement program. Criteria included improved air quality (through reduction of carbon monoxide and volatile organic compounds); access to freight distribution centers; pedestrian and vehicular safety (separation of flows and better access management); and reduced single-occupant vehicles (e.g., transit expansion).

Cambridge Systematics, Inc. (2011) indicated that the societal costs of crashes exceeded those of congestion; for example, in the Richmond metropolitan area alone in 2009, whereas the cost of congestion had been $279 million, the cost of crashes (based on a valuation of $6 million for each fatality and $0.126 million for each injury as applied to Richmond’s 150 motor vehicle fatalities and 10,991 motor vehicle injuries) was $2.285 billion—about 8 times the cost of congestion. The authors suggested that nationally, the cost of crashes in urbanized areas was $299.5 billion—about 3 times greater than the 2009 congestion cost of $97.7 billion. Data for three urbanized areas that encompassed parts of Virginia—Richmond; Hampton Roads plus part of North Carolina; and Northern Virginia plus Washington, D.C., and parts of West Virginia and Maryland—showed that crashes exerted a monetized cost that was 2.42 times as great as the cost of congestion.

Clearly, expected travel time savings is only one of several rationales for making a transportation investment.

Relative Importance of Congestion

However, such savings is nonetheless a critical criterion: Litman (2012c) wrote that "travel time savings are often the primary justification for transportation infrastructure improvements." Garber and Hoel (2009) described such savings as "one of the most important reasons for making transportation improvements." Kato et al. (2011) showed the importance of monetizing travel time savings accurately in order to determine whether tolls users may be willing to pay for a facility. Although congestion is only one of eight performance elements in the National Capital Region Transportation Planning Board's (2010) long range transportation plan, the resultant congestion clearly affects several of the other metrics (e.g., one such metric, accessibility, is quantified as the number of jobs within 45 minutes of a resident by auto and transit).

HDR-HLB Decision Economics (2009) estimated that the cost of congestion in the United States was $85.4 billion, with most of this cost (70%) attributed to travel time (vehicle operating costs accounted for 13%; emissions accounted for 0.4%; and the remainder was attributed to a lack of reliability and reduced productivity). More recently, the Texas Transportation Institute's *Urban Mobility Report* (Schrank et al., 2011) now in its 20th year of publication, suggested that congestion, defined as monetized values of delay plus excess fuel consumption, cost the United States $101 billion annually in 2010 dollars, resulting in the need for specific operational and public transportation investments.

Role of Congestion in Three of Virginia's Urban Areas

Given an average per-gallon fuel price of $3.01 (diesel) and $2.75 (regular) in 2010, out-of-pocket costs attributable to excess fuel consumption alone are between $5.34 and $5.85 billion at the national level (depending on which fuel is purchased). An even larger cost is delay, which at 4.8 billion hours at the national level will be larger than the fuel cost (assuming an hourly value of delay exceeds about $1.20). Table 4 shows these costs in 2010 for three of Virginia's major metropolitan areas, where delay accounted for 90% to 96% of total costs. Table 4 also includes a societal cost of greenhouse gas emissions based on a value of $100 per metric ton for this excess fuel consumption. The methodology for performing this estimate was based on a review of the literature (Litman, 2012b; U.S. Department of Energy, 2011; U.S. Environmental Protection Agency [U.S. EPA], 2008; National Research Council, 2010); details of this review are given in the Appendix.

The Role of Fuel Prices Relative to Congestion

Forecasts from year 2010 to 2020 suggested a 60% increase in delay across the United States and a 68% increase in fuel consumption (Schrank et al., 2011). This increase is not uniform, however; it affects two specific segments of the population more than others. First, larger areas generally have more congestion than less populated areas—a trend reflected in Table 4, where the most populous areas have the largest delays. Second, heavy vehicles, which have a considerably higher value of time, carry a disproportionate share of the costs attributable to delay: at the national level, trucks accounted for 6% of vehicle travel in urban areas but reflected 26% of the congestion cost. For Virginia data, Schrank et al. (2011) used costs of $16.30 per

Table 4. Costs of Congestion for Three Virginia Metropolitan Areas in 2010[a]

Characteristic	D.C. Area (Maryland, D.C., and Virginia)	Hampton Roads Area	Richmond Area
Area population in 2010	4.536 million	1.551 million	0.967 million
Total delay (millions of hours)	188.65	36.54	13.80
Gallons of fuel consumed (millions)	95.37	9.30	3.11
Cost attributable to delay (billions)	\$3.56	\$0.67	\$0.25
Cost attributable to fuel (billions)[b]	\$0.28	\$0.03	\$0.01
Greenhouse gas costs (billions)[c]	\$0.092	\$0.003	\$0.009
Total congestion cost (billions)	\$3.87	\$0.70	\$0.26
Percent attributable to delay	90.45%	95.61%	95.06%

[a]Table created based on data provided by Schrank et al. (2011) except greenhouse gas emissions costs added by the author.
[b]The costs attributable to fuel consumption vary because the portion of excess gallons attributable to heavy trucks versus automobiles is not given; thus, a range of values was calculated as follows for fuel consumption costs assuming all vehicles are trucks and then assuming all vehicles are autos. These ranges were, in billions: \$0.273 to \$0.297 (D.C. area), \$0.008 to \$0.009 (Richmond), and \$0.024 to \$0.027 (Hampton Roads). Table 4 shows the midpoint values.
[c]The Transportation Research Board (2011) suggested the social costs of greenhouse gas emissions may be \$11 to \$110 per metric tons of CO_{2e}. Table 4 uses a value of \$100 per metric ton. For example, in the D.C. area, 71.117 million extra gallons of auto fuel were consumed, which at 9.27 kg of CO_{2e} per gallon (U.S. Environmental Protection Agency, 2008) yields 0.659 million metric tons of CO_{2e}; at \$100 per ton, this is \$66 million (autos only). The same approach for trucks yields (10.68 kg of CO_{2e})(24.248 million gallons)(\$100/ton)/1,000 kg/metric ton = \$26 million. This yields a total of \$92 million or \$0.092 billion in Table 4.

hour for personal travel and \$88.12 per hour for truck travel; such that trucks bore between 14% and 18% of total congestion costs for the areas of Richmond, Hampton Roads, and Northern Virginia. Thus looking to 2020, one can expect increased delay and costs in the urban areas plus an increase in the number of areas that are defined as congested.

Table 5 also suggests that although an increase in fuel prices can have a detrimental impact on total costs, this impact will not necessarily result in a large percentage change in such total costs provided the hourly value of time assumptions is valid. For example, if for year 2010 fuel prices increased from the Virginia values used in the analysis (\$2.63 to \$2.86 for Virginia autos, depending on the region, and \$2.88 to \$3.11 for trucks) to \$10 per gallon, although the cost attributable to out-of-pocket fuel purchases would have increased by 245%, Table 5 shows that the total congestion cost—fuel plus delay—would be a 16% increase. This increase assumes change in travel behavior.

In short, therefore, if fuel prices immediately rose from approximately \$3 per gallon to \$10 per gallon, the 2010 congestion costs in three Virginia urban areas (Richmond, Washington, D.C., and Hampton Roads) would increase from \$4.9 billion to \$5.7 billion (16%) because travel delay costs comprise such a large percentage of total congestion costs.

In practice, changing fuel costs would elicit a traveler response. There is extensive literature documenting the elasticity of motor vehicle travel with respect to fuel price. This literature shows a range of elasticity values that are influenced by the study methodology, the

Table 5. Impact of Increasing Fuel Prices on Total Virginia Congestion Costs[a]

Type of Congestion Costs[b]	Congestion Costs at 2010 Fuel Prices ($2.73 for autos, $3.00 for trucks)	Congestion Costs at Increased Fuel Prices ($10 for all vehicles)
Excess auto fuel (billions)	$0.224	$0.788
Excess truck fuel (billions)	$0.089	$0.289
Auto delay time (billions)	$3.760	$3.760
Truck delay time (billions)	$0.731	$0.731
Greenhouse gas costs (billions)	$0.104	$0.104
Total (billions)	$4.908	$5.673

[a]Congestion costs are the sum of costs attributable to (1) excess fuel and (2) delay. For 2010, Virginia fuel prices ranged from $2.63 to $2.86 (autos) and $2.88 to $3.11 (trucks), yielding the median values of $2.73 (autos) and $3.00 (trucks). No change in travel behavior is assumed.
[b]Data provided by Schrank et al. (2011) gave the following data for three Virginia urbanized areas (Northern Virginia, Richmond, and Hampton Roads): total gallons of fuel consumed (auto plus truck combined, not separated), total hours of delay (auto plus truck combined, not separated), the portion of total congestion costs attributable to truck, value of 1 hour of travel time (auto and truck separately), and price for 1 gallon of fuel (auto and truck separately). From these, one can solve for possible values shown in Table 5.
[c]The cost of greenhouse gas emissions is dependent on the market penetration rate of alternative-fueled vehicles. Based on a review of forecast in the literature (see the Appendix), one range of forecasts for year 2035 is 9% to 59%, suggesting the $0.104 billion shown in Table 5 could be reduced to between $0.043 and $0.095 billion.

nation where the study was performed, and the time period of the study. For example, Litman (2011) suggested that the reduced travel sensitivity to fuel price that occurred over roughly two decades (1990-2009) may have resulted from socioeconomic changes, such as increases in the number of women in the workforce; since then, Litman suggested elasticities have risen. Other elasticities include -0.2 to -0.4 (Burke and Nishitateno, 2011); -0.24 to -0.34 (Li et al. [2011] cited in Litman [2011]); and 0 to -0.5 (Sana et al., 2010). These elasticities will affect the interpretation of Table 5. For example, if an elasticity of -0.25 were chosen, the increase in fuel prices of $10 per gallon would yield about a 60% reduction in travel—meaning the congestion costs shown in Table 5 would drop by more than one-half their value.

Although the fuel price increase to $10 per gallon is hypothetical, the U.S. EIA (2012) has developed a "reference case" that forecasts future energy market behavior under a variety of assumptions pertaining to fuel availability, the continuation of current laws, and fuel demand. The U.S. EIA cautioned that a variety of factors can influence projections. With this caveat in mind, the U.S. EIA (2012) suggested that a price for a barrel of light sweet crude oil in 2035 will be $145 (in 2010 dollars), compared to a price of $85 to $110 per barrel from 2011; fuel prices are projected in the reference case to rise to $4.09 per gallon for autos and $4.49 per gallon for diesel from cited base prices of $2.76 and $3.00 per gallon for autos and trucks, respectively. With an elasticity of -0.25 (a rough midpoint value based on the studies cited by Litman [2011]), demand would drop by approximately 12% for autos and 12.4% for trucks based on these price increases and no other changes. When these changes are combined with an increase in vehicle-miles traveled (VMT) of 28.32% that is based on population growth (the lower end of the 2009 forecasts), a modified version of Table 5—shown as Table 6—suggests congestion costs approaching $5.7 billion.

Table 6. Possible Congestion Costs in 2035[a]

Type of Congestion Costs	Congestion Costs in 2010 (from Table 5)	Congestion Costs in 2035 (based on increased fuel prices and population)
Excess auto fuel (billions)[b]	$0.224	$0.364
Excess truck fuel (billions)[b]	$0.089	$0.146
Auto delay time (billions)[c]	$3.760	$4.244
Truck delay time (billions)[c]	$0.731	$0.822
Greenhouse gas costs (billions)	$0.104	$0.117
Total (billions)	$4.908	$5.693

[a]The methodology used to estimate the costs shown in Table 6 was the same at that used for those shown in Table 5 except as noted here.

[b]Fuel prices are estimated to rise to $4.09 (autos) and $4.49 (trucks) from baseline values of $2.76 and $3.00, respectively (U.S. Energy Information Administration. 2012). Based on an elasticity of -0.25, which is within a range of values cited in the literature (Burke and Nishitateno, 2011; Litman, 2011) and an increase in vehicle-miles traveled of 28.32% based on population growth from the 2009 report (Miller, 2009), there would be an increase of about 13% for autos and 12% for trucks.

[c]Assumes that delay increases linearly with demand. In some cases, an increase in demand may have no impact on delay; in other cases, an increase in demand may have a large impact on delay.

Impacts of Delay in Non-Urban Areas

Table 5 summarizes present congestion costs in three Virginia urban areas but does not address costs in locations outside these areas. Delays in the non-urbanized areas can result from congestion (e.g., unplanned incidents), but such delays can also result from detours, such as a temporary bridge closure. For example, in one central Virginia city, a 17-month bridge closure (VDOT, 2011) requires an estimated detour of 4 minutes and 1 mile per vehicle. This delay exerts a cost in terms of added travel time and vehicle expenses (as the detour requires 1 extra mile of travel). Based on the average annual daily traffic on the bridge (VDOT, 2010, 2011) and per-vehicle costs (Forkenbrock and Weisbrod, 2001), these costs are estimated to be approximately $8 million, as shown in Table 7.

Although the aforementioned example comprises an entire bridge closure, VDOT (2012) lists a variety of lane closures that will create additional delay for motorists. Examples are the 10-week bridge closure on U.S. 250 at Shadwell; the lane closure on Route 208 in Spotsylvania and Louisa counties that will result in two-way traffic using a single lane; and the use of one 14-foot travel lane in both directions for I-81 in Smyth County near Exit 45. Roughly 50 "major construction projects" are shown for the first 4 months for 2012 where such projects do not appear to be in the three urbanized areas of Washington, D.C., Richmond, and Hampton Roads.

Table 7. Costs of Delay for 17-Month Bridge Closure Requiring 1-Mile Detour

Type of Vehicle	Cost/hr	No. of Vehicles	Delay (hr)	Cost
Medium auto	$21.26	5,631,038	375,403	$7,979,893
4-Tire truck	$22.37	56,879	3,792	$84,825
Total				$8,064,718

These costs were updated to year 2011 dollars in accordance with a methodology published by the Federal Highway Administration (2005) and using the Bureau of Labor Statistics (2002,2011) employment cost index for all civilian workers. Most of the costs shown are based on labor savings.

If comparable projects were scheduled for the remaining 8 months of the year and if each project had an economic impact comparable to that shown in Table 7 ($8 million over a 17-month period or $5.6 million over 1 year), in the non-urbanized areas of Virginia the economic impacts could approach $285 million. This figure is speculative in the sense that (1) construction schedules vary throughout the year, and (2) the impacts of each project are variable. For example, in 2004, the Judith Stewart Dresser Memorial Bridge over the Chickahominy River closed for 44 days, causing a 63-mile detour (Sashin, 2004) for an estimated 3,500 motorists (VDOT, 2007). The hourly cost figures shown in Table 7 suggests that this closure—which covered less than a 2-month period—had an estimated cost of $3.3 million—less than one-half the impact of the $8 million closure based on Table 7.

As the figure of $285 million is an order of magnitude estimate, it cannot be used to make judgments about the value of delays. However, an implication is that continued needs for maintenance in 2035 will increase societal costs in the non-urban areas as well as the urban areas.

The Valuation of Travel Time

The assumptions made when monetizing travel time savings matter: the cost of an "hour of delay" differs as a function of trip purpose, income, criticality, stress, cargo value, and dollar year such that figures between $16 and $88 are found in the literature. Table 5 shows that the suggested hourly costs of delay account for much of the costs attributed to congestion. Because travel time savings is such an important component of the infrastructure investments, the assumptions therein merit attention.

Variation in Travel Time Values

A review of the literature (FHWA, 2005; Littman, 2011; Smalkoski and Levinson, 2005; Trottenberg, 2011) suggested at least six assumptions that should be considered when evaluating the value of time: (1) trip purpose; (2) base income level; (3) the criticality of the trip; (4) the value of the commodity being transported, if applicable; (5) trip comfort; and (6) the year in which the study was conducted.

1. *Trip purpose*. Work-based trips generally are valued more highly than non–work-based trips, and business trips (especially if made by commercial vehicle) are valued more highly then leisure trips. For example, Kato et al. (2011) surveyed users of Japanese expressways regarding the use of free and toll roads and found that users were willing to pay 33.9 yen per minute of reduced travel time for business travel, which is close to the average wage of 37.2 yen/minute—but the same users were willing to pay only 24.5 yen per minute for other trip purposes. In contrast with the $88.12 per hour figure (Schrank et al., 2011) in Table 5, Smalkoski and Levinson (2005) reported an average value of $49.42 per hour of commercial vehicle use and the U.S. DOT suggested a value of $22.90 per hour for "on-the-clock" business travel (Trottenberg, 2011). By contrast, for auto use, Schrank et al. (2011) employed values of $16.30 per hour of person travel time; Litman (2012c) reported that previous studies conducted in 2005 had found a range of $10 to $40 per hour; and the U.S. DOT suggested a value of $12 per hour for personal short distance travel, which was approximately one-half the median

household income (Trottenberg, 2011), where the values obtained were similar to those reported by the U.S. Census Bureau (2011d). As discussed in the Appendix (see Table A3), variation in regional median income can also affect how travel time is valued.

2. *Criticality*. Cirillo and Xu (2010) reported that a previous study of the use of toll lanes on S.R. 91 in Orange County yielded a value of $22.87 per hour in terms of travel time savings, whereas the hourly value of reliability was $15.12 and $31.91 for men and women, respectively. This difference in men and women's valuing of reliability matches a possibility suggested Koppelman and Bhat (2006), where the authors suggested that "one might argue that because women commonly take increased responsibility for home maintenance and child care, they are likely to evaluate increased travel time to work more negatively than men." Brownstone and Small (2005) also suggested child-care as a reason for the differential. Brownstone et al. (2003) reported a willingness to pay, for men and women (based on a congestion pricing effort on I-15 in San Diego) of $30 per hour, although the authors noted that perceived safety of the toll road may have inflated this estimate.

3. *Income*. Whereas Trottenberg (2011) suggested a value of $16.70 for personal intercity highway travel, a value of $31.90 per hour of such travel by air was suggested by Trottenberg (2011), owing to the higher incomes (in 2010 dollars) of such travelers. Koppelman and Bhat (2006) used a 1990 dataset to show how the value of time may range from $4.53/hour to $21.94/hour based on income levels ranging from $25,000 to $125,000.

4. *Commodity value*. Sinha and Labi (2007) noted that an inventory shipping cost may be determined for each hour of delay; for example, it can be shown that a $300,000 cargo that is delayed by 1 hour exerts a cost of $1.71 (see Eq. 1). Trottenberg (2011) pointed out, however, that accurately determining the value of such delays depends on a several factors such as whether the product is perishable and whether the product is needed for just-in-time delivery; indeed, there may be cases where delay is desirable if warehousing costs are a concern.

$$\text{Inventory costs} = \left(\frac{\$300{,}000}{\text{Truck cargo}}\right)\left(\frac{5\%\ \text{Interest}}{\text{Year}}\right)\left(\frac{1\ \text{Year}}{365\ \text{Days}}\right)\left(\frac{1\ \text{Day}}{24\ \text{Hours}}\right) = \$1.71\ \text{per hour} \qquad \text{[Eq.1]}$$

The value in Equation 1 ($1.71 per hour) is comparable to a vehicle inventory value of $1.78 per hour reported by Forkenbrock and Weisbrod (2001) for four-axle and five-axle vehicles.

5. *Comfort*. The pleasantness of the trip affects the value of travel time savings. Classically, comfort has been considered by making out-of-vehicle time (e.g., waiting for a bus, walking to a parking lot) have a higher value than in-vehicle time; for example, Martin and McGuckin (1998) suggested that out-of-vehicle time should count twice as much as in-vehicle travel time; Koppelman and Bhat (2006) suggested that out-of-vehicle time should be between 32% and 64% higher than in-vehicle travel time (with the higher increase accounting for shorter trips). Litman (2012c) pointed out that comfort is often not fully considered, citing studies that indicate that whereas personal travel by auto might be 50% of hourly wages (consistent with Koppelman and Bhat [2006] or Trottenberg, [2011]), the figure should be reduced to 25% of hourly wages if the transit trip is comfortable.

6. *Year of study*. The relative value of a dollar in year 2000 differs from the value of a dollar in year 2012. The FHWA (2005) explained that the value of time as used in the Highway Economic Requirements System (HERS) may be updated through the use of the Bureau of Labor Statistics (BLS) Employment Cost Index for total compensation of all civilian workers. For example, Forkenbrock and Weisbrod (2001) reported that the value of time for a driver of a small automobile for a business purpose trip was $30.22 (where this value was based on HERS). In 2011 dollars, using the appropriate indices from the BLS (2002, 2011), this value is $41.52.

Figure 26 portrays these hourly costs from the various studies cited therein. Costs were updated as appropriate using the employment cost index for total compensation of all civilian workers (BLS, 2002, 2011).

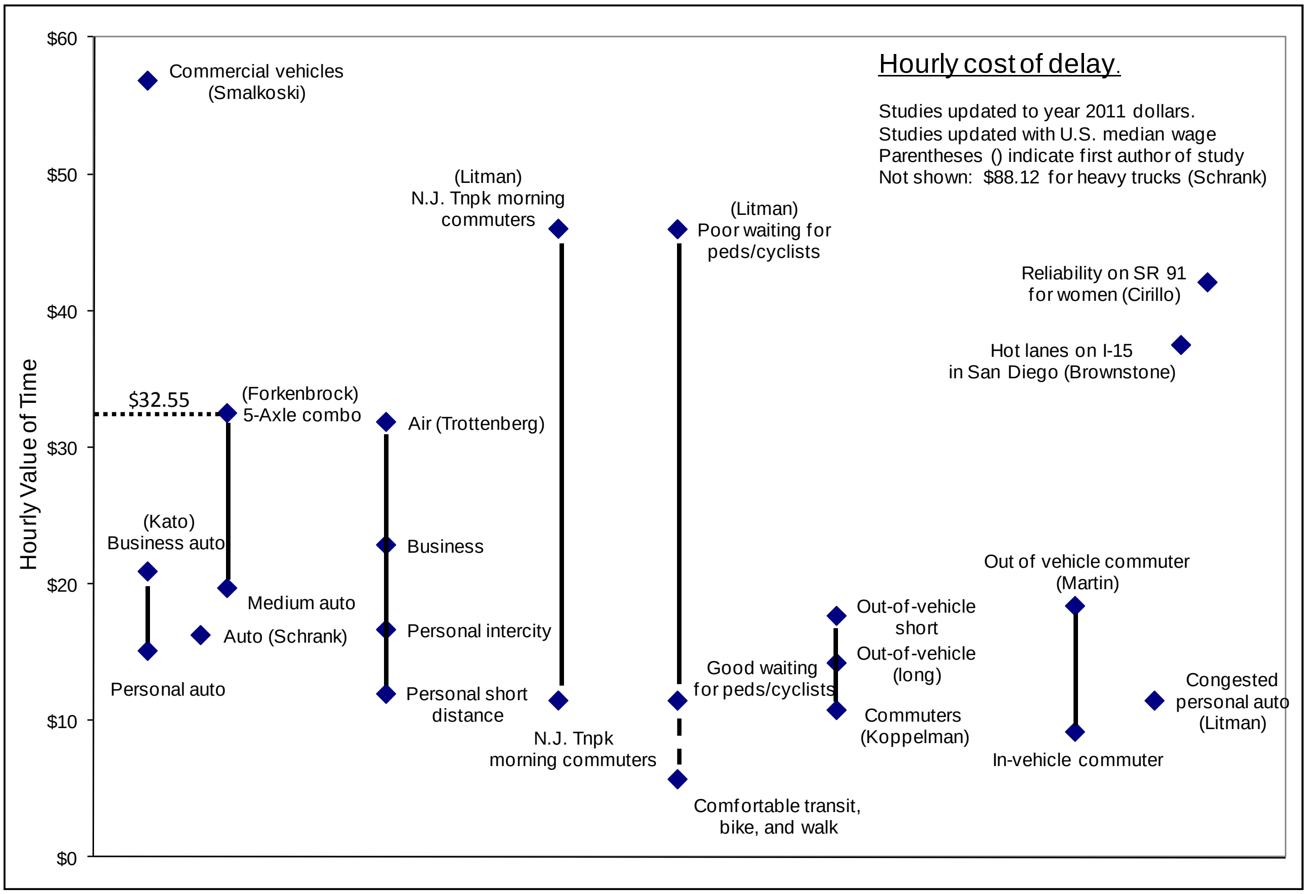

Figure 26. Hourly Values of Travel Time As a Function of Purpose, Comfort, and Criticality in the Literature. The values shown ($32.55 for a 5-axle combo vehicle and $88.12 for heavy trucks) are used in subsequent sensitivity analyses in this report. Air = travel by air; auto = travel by auto; out of vehicle = time not spent in a vehicle. The solid lines show contrasts between trip type characteristics. For example, results reported by Kato et al. (2011) suggested that 1 hour of personal auto time had a value of $15.15 whereas 1 hour of business auto travel had a value of $20.96. Brownstone = Brownstone et al., 2003; Cirillo = Cirillo and Xu, 2010; Forkenbrock = Forkenbrock and Weisbrod, 2001; Kato = Kato et al., 2011; Litman = Litman (2012c); Martin = Martin and McGuckin, 1998; Schrank = Schrank et al., 2011; Smalkoski = Smalkoski and Levinson, 2005.

How Changes in Valuation of Travel Time Affect Congestion Costs

When the respective hourly values for autos and trucks used in Table 5 ($16.30 and $88.12) are replaced with the labor hourly values that have been updated from Forkenbrock and Weisbrod (2001) (these are a slightly higher value for a medium auto of $19.74 and a lower value of $32.55 for a five-axle truck), the cost of congestion *increases* by 7%. Although this is initially surprising given the high $88.12 value of commercial vehicles used by Schrank et al. (2011), the fact that most of the delay is attributed to non-commercial vehicles explains why this total congestion cost rose.

The value of $19.74 per hour for an auto user is about 20% higher than the value used by Schrank et al. (2011). If one retains the $32.55 labor-only truck cost but reverts to the $16.30 auto cost (Table 4), the total cost of congestion *decreases* by 9%.

An inference is that the monetization of the travel time impacts for Virginia appears to be the correct order of magnitude. An implication is that congestion represents a substantial societal cost for Virginia. A second inference is that reductions in uncertainty, such as increased reliability for auto drivers or better knowledge of the bus arrival time for transit users, may make the mode more enjoyable and hence reduce the perceived cost of travel. A logical direction for further research is to quantify the extent to which reductions in uncertainty, as well as other changes in the travel comfort, reduce the perceived cost of travel.

SUMMARY OF FINDINGS

Population Growth

- *Four Virginia PDCs are expected to account for 76% of Virginia's 2010-2035 population growth, and eight PDCs are expected to account for 91% of the growth in the same period.* These percentages are consistent with previous trends from 2000 to 2010.

- *In terms of annual percentage population growth rates, most PDCs are expected to grow during 2010-2035 in the same manner they grew during 2000-2010*. Six PDCs had rates above 1% for 2010-2035. These and two other PDCs had rates above 1.0% for the 2000-2010 period during which the statewide average was 0.8%.

- *Virginians are growing older*. In 2010, the number of persons age 65+ outnumbered those age 0-19 in just one Virginia PDC; by 2035, this will be the case in eight PDCs. Statewide, the percentage of persons age 65+ will increase from 12.2% in 2010 to 18.5% in 2035; coupled with a general population increase, the number of Virginians may almost double (a 94% increase). Because less populous PDCs tend to have a greater percentage age 65+ than more populous PDCs, the distribution of persons age 65+ across Virginia is not uniform.

Specific Subpopulations and Transportation Modes

- *The percentage of Virginians with a disability may rise.* In 2010, slightly less than 11% of the non-institutionalized population had a disability. Because the percentage of population with a disability varies by age, the fact that the percentage of persons age 65+ will increase suggests the strong possibility that the percentage of persons with a disability will also increase. To be clear, however, the age group 35-54 has the greatest number of persons with a disability since this group has a large percentage of the population (41%).

- *Although a minority, there are households and workers without a vehicle throughout the urban and rural areas of Virginia*. A total of 186,322 households (6.3% of the statewide total) and approximately 333,000 workers (about 8.8% of the state's workforce) do not have a vehicle. Although the largest concentration of workers without a vehicle tends to be in more populous areas, there is no PDC where less than 5% of workers are without a vehicle.

- *Disparities in regional income levels exist at present and may continue.* If a CBO (2011) forecast of real income growth of 49.7% for 2011-2035 were to occur statewide, the disparity in incomes by PDC in 2010 would remain in 2035, with the six highest PDC per-capita incomes being the Northern Virginia Regional Commission, the Richmond Regional PDC, the Thomas Jefferson PDC, the Rappahannock-Rapidan Regional Council, the Hampton Roads PDC, and the George Washington Regional Commission. Because these PDCs also have relatively large populations, the incomes in these PDCs account for 78% of Virginia's total income; the incomes in the three largest PDCs account for 70% of Virginia's total income.

- *Disparities in cost of living and poverty exist throughout Virginia.* The income designated as the poverty level income does not account for differences in the cost of goods and services, which in Virginia is substantial. The regional price parity of the Northern Virginia Regional Commission is 41% higher than that for the Mount Rogers PDC. In 12 of Virginia's 21 regions, more than one-fifth of the population is below 150% of the poverty level. In two regions (the Lenowisco PDC and the New River Valley PDC), the income of more than one-fifth of the population is below the poverty level.

- *The decisions of the 2005 Defense Base Closure and Realignment Commission affect population, employment, and transportation operations at or in the vicinity of six military bases in or near Virginia*.

  — More than 50,000 jobs have been added to or near three bases in Virginia (Fort Belvoir, Fort Lee, and Quantico). An estimated $500 million has been added to the regional economy as a result of the Fort Lee expansion (City of Colonial Heights Virginia, undated).

  — The 75,500 population increase resulting from the expansions of the three Virginia bases plus three bases near the Northern Virginia Regional Commission (Aberdeen Proving Ground, National Naval Medical Center, and Fort Meade) is comparable to the ten year population growth for the Hampton Roads PDC (88,655) or the George Washington Regional Commission (86,729).

— Traffic impacts are expected, with more substantial impacts in the urban areas, such as some approaches of intersections in the vicinity of the Mark Center, which will be at Level of Service F without major capital investments (VDOT, 2010).

- *Low-income and minority populations (i.e., those protected under environmental justice regulations) are likely to increase.* Although Virginia-specific forecasts are not available, in 2010, the percentage of the minority population in Virginia (35.2%) was virtually the same as the national average (36.3%). By 2035, the minority population in the United States is forecast to rise to 46.9%. Although forecasts of the low-income population are not available, in 2010, the income of 10.3% of Virginians was below the poverty level and the income of 17.3% of Virginians was below 150% of the poverty level, a threshold below which some form of public assistance is thought to be necessary.

- *Environmental justice assessments continue to be necessary.* A review of the literature related to environmental justice suggested several instances where assessments of protected groups (low-income and minority populations) are required, including a statewide planning process. Recent literature suggests that environmental justice assessments may be needed for diverse types of investments, such as changes in transit fares or operations; toll road investments, and safety-related investments such as pedestrian treatments.

- *At present, 5.7% of Virginians speak English "less than very well."* The percentage varies by region but outside Northern Virginia is not necessarily correlated to the size of the area; for example, the region with the second largest percentage of such persons is the Accomack-Northampton PDC.

- *A smaller percentage of Virginians have a driver's license than in the past.* The percentage of those age 15+ with a driver's license decreased from 89% (in 1990) to 83% (in 2010). In particular, the percentage of Virginians age 15-24 with a driver's license dropped from 72% (in 1990) to 58% (in 2010).

- *The percentage of Virginians with a driver's license has not changed in the same manner for all age-sex groups.* Whereas the percentage of males age 65+ with a driver's license has not changed substantially (e.g., 93% in 1990 versus 91% in 2010), the percentage of females age 65+ with a driver's license has grown (e.g., 58% in 1990 to 76% in 2010).

- *The behavioral impacts of better electronic communications on telecommuting are not necessarily clear.* They may facilitate long distance connections and subsequent in-person travel, or they may instead reduce travel needs.

- *The percentage of Virginians who work from home has increased: from 3.2% in 2000 to 4.2% for the 2006-2010 period Explaining this increase is hindered by four complications:*

1. Telecommuting is measured and defined in several different ways.

2. The U.S. Census Bureau asks respondents to name just one mode (even though they may use multiple modes).

3. A variety of factors besides technology and congestion influence telecommuting.

4. The extent to which telecommuting reduces travel depends on other behaviors.

- *The smallest percentage of persons working at home (2.8% to 3.1%) is in the middle income groups ($25,000 to $64,999).* The percentage is 5.5% to 6.3% for the lower income groups ($24,999 and under) and 3.5% to 5.1% for the higher income groups ($65,000 and over).

- *The relationship between income and public transportation use differs by region.* For two regions--the Northern Virginia Regional Commission and the adjacent George Washington Regional Commission—the percentage of persons using public transportation increases with income such that persons earning $75,000+ annually are the largest group. By contrast, in the Richmond and Hampton Roads regions, the largest group comprises persons earning less than $10,000, with a generally inverse relationship between income and propensity to use transit.

Travel Time Costs Attributable to Delay

- *Travel time delays resulting from congestion exert a substantial cost in three of Virginia's urban areas: Hampton Roads; Richmond; and the Washington D.C., metropolitan area, which includes portions of Maryland and Virginia.*

— Excluding fuel costs and greenhouse gas emissions costs, delays in these three urban areas had an estimated cost of $4.5 billion, which was approximately 14 times the out-of-pocket cost of lost fuel.

— This cost can be increased (by 7%) or decreased (by 9%) if how an hour of delay is monetized is changed (e.g., using methods based on Forkenbrock and Weisbrod [2001]).

— Although a projected increase in fuel prices between 2010 and 2035 of 48% for autos and 50% for trucks (U.S. EIA, 2012) is expected to reduce highway travel, the expected increase in population may offset this decrease; with a variety of assumptions as reflected in Table 6, an expected congestion cost in urban areas approaches $5.7 billion.

— The $5.7 billion cost includes a societal cost of roughly $0.1 billion attributable to excess carbon dioxide equivalent emissions (CO2e) resulting from the excess fuel consumed. This estimate is sensitive to market penetration rates of alternative fueled vehicles (forecasts range from 9% to 59%) and monetization of emissions (valuations varied by at least three orders of magnitude as discussed in the Appendix).

- *Travel time delays exert costs in non-urban areas.* Table 7 shows that the travel time costs associated with one 17-month bridge closure is approximately $8 million. Continued needs for maintenance in 2035 are expected to increase societal costs of detours and temporary construction in the non-urban areas as well as the urban areas.

Travel Time Valuation

- *Travel time costs are sensitive to assumptions.* Six were noted herein: trip purpose, criticality, income level, commodity value, comfort level, and the year in which the study was conducted. Depending on the assumptions made, an hourly cost of delay ranges from $12 to $88. Not all users are impacted to the same degree: at the national level, heavy vehicles accounted for 6% of vehicle travel in urban areas but reflected 26% of the congestion cost (Schrank et al., 2011).

- *Travel time savings are not the only component of congestion costs.* For example, in urbanized areas, the cost of crashes has been estimated at about 3 times greater than the cost of congestion. Nationally, the cost of crashes in urbanized areas has been estimated at $299.5 billion—about 3 times greater than the 2009 congestion cost of $97.7 billion.

CONCLUSIONS

- *Statewide population trends may obscure divergent regional and group-specific trends*. For instance, although the percentage of Virginians holding a driver's license has decreased moderately (by six percentage points over two decades), the percentage of women age 65+ holding a driver's license increased by 18 percentage points over the same period. As another example, transit use rises or falls with an increase in income depending on which region of Virginia is being examined. It is not always the case that regions have different growth characteristics, however. For example, Virginians as a rule are generally growing older, with the portion of the population age 65+ increasing in all regions by year 2035.

- *Virginia remains diverse in terms of wealth and other socioeconomic characteristics.* The percentage of Virginians living below the poverty level ranges from 5.4% to 20.0% depending on the region, and almost 70% of total personal income is in 3 of Virginia's 21 PDCs. The percentage of persons who indicate they speak English "less than very well" ranged from 0.6% to 13.4% depending on region; only Northern Virginia exceeded the statewide average of 5.7% at present.

- *The aforementioned diversity reflects differences of degree because common themes nonetheless emerge*. As a whole, Virginians are growing older such that the population age 65+ will double between 2010 and 2035, and regardless or urban or rural composition, at least 5% of all workers in each PDC do not have a vehicle. Although congestion-related costs in three urbanized areas ($4.8 billion for Hampton Roads; Richmond; and the Washington, D.C., metropolitan area, which includes non-Virginia locations) at present dwarf detour-related costs outside those urbanized areas at present ($285 million), both costs are substantial in terms of their monetized value, especially in light of the fact that the population outside the congested areas is smaller than the urban population.

RECOMMENDATIONS

1. *The Office of Intermodal Policy and Investment should make the information presented in this report available to interested participants in the development of Virginia's statewide multimodal plan*. More updated information may become available in the future, such as updated 2035 population forecasts from the Weldon Cooper Center for Public Service (2012) in 2013.

2. *Stakeholders in the development of Virginia's multimodal transportation plan should consider explicitly identifying types of mobility needs that transcend regional boundaries.* Examples of such needs are ways to serve the population age 65+ (since this percentage is growing in all regions of Virginia); ways to accommodate persons with disabilities and workers without a vehicle (groups whose 2035 values are not forecast but that exist in all areas of Virginia); and ways to reduce travel time that results from congestion and detours (although the former is quantified only for three urban areas, the latter exists statewide). Identification of these consistent state mobility needs does not preclude region-specific initiatives; however, it may be a way to garner consensus on some initiatives that appear likely to have benefits throughout Virginia.

FUTURE RESEARCH NEED

A logical direction for further research is to quantify the extent to which reductions in uncertainty, as well as other changes in the travel comfort, reduce the perceived cost of travel. Although a reduction in travel time is desirable, the variation in hourly costs in Figure 26 suggests that other factors, such as improvements in reliability or reduction of travel stress, may reduce the perceived travel costs.

BENEFITS AND IMPLEMENTATION PROSPECTS

The primary purpose of this research is to provide socioeconomic information to developers of the updated Virginia 2035 statewide multimodal transportation plan. Members of the technical review panel suggested that the author provide, in addition to the report, a set of spreadsheets and GIS files that could be shared with participants who need access to these data, which is indeed feasible.

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REFERENCES

ACT Telework Award: Telework! VA. *TDM Review*, Vol. 17, No. 2, Spring 2010, pp. 33-34. http://data.memberclicks.com/site/asct/TDM_Review_Spring_2010_NEW.pdf. Accessed May 3, 2012.

Advameg, Inc. City-Data.com. Illinois. 2012. http://www.city-data.com/. Accessed April 16, 2012.

Association of American Railroads. *Rail Time Indicators: A Review of Key Economic Trends Shaping Demand for Rail Transportation.* Washington, DC, 2011. http://www.aar.org/~/media/aar/railtimeindicators/2011-12-rti.ashx. Accessed January 17, 2012.

Aten, B.H., and D'Souza, R.J. Research Spotlight: Regional Price Parities Comparing Price Level Differences Across Geographic Areas. *Survey of Current Business*, November 2008, pp. 64-74. http://www.bea.gov/scb/pdf/2008/11%20November/1108_spotlight_parities.pdf. Accessed June 25, 2012.

Aten, B.H., Figueroa, E.B., and Martin, T.M. Research Spotlight Regional Price Parities by Expenditure Class, 2005–2009. *Survey of Current Business*, May 2011, pp. 73-87. http://www.bea.gov/scb/pdf/2011/05%20May/0511_price_parities.pdf. Accessed April 13, 2012.

Bandivadekar, A., Bodek, K., Cheah, L., Evans, C., Groode, T., Heywood, J., Kasseris, E., Kromer, M., and Weiss, M. *On the Road in 2035: Reducing Transportation's Petroleum Consumption and GHG Emissions.* LFEE 2008-05 RP. MIT Laboratory for Energy and the Environment, Cambridge, MA, 2008. http://web.mit.edu/sloan-auto-lab/research/beforeh2/otr2035/. Accessed October 22, 2012.

Brady, J., and O'Mahony, M. *The Introduction of Electric Vehicles to Ireland: A Socioeconomic Analysis.* In *TRB 90th Annual Meeting Compendium of Papers DVD.* Transportation Research Board of the National Academies, Washington, DC, 2011.

Brownstone, D., and Small, K.A. Valuing Time and Reliability: Assessing the Evidence from Road Pricing Demonstrations. *Transportation Research Part A: Policy and Practice,* Vol. 39, No. 4, May 2005, pp. 279-293.

Brownstone, D., Ghosh, A., Golob, T.F., Kazimi, C., and Amelsfort, D.V. Drivers' Willingness-to-Pay to Reduce Travel Time: Evidence from the San Diego I-15 Congestion Pricing Project. *Transportation Research Part A: Policy and Practice,* Vol. 37, No. 4, May 2003, pp. 373-387.

Bureau of Economic Analysis. State Personal Income: Third Quarter 2011. BEA 11-61. Washington, DC, December 19, 2011a. http://www.bea.gov/newsreleases/regional/spi/2011/spi1211.htm. Accessed February 13, 2012.

Bureau of Economic Analysis. Quarterly State Personal Income. Personal Income (SQ1). Washington, DC, December 19, 2011b. http://www.bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=3. Accessed February 13, 2012.

Bureau of Economic Analysis. Local Area Personal Income and Employment: Personal Income, Per Capita Personal Income, and Population (CA1-3). Washington, DC, April 21, 2011c. http://www.bea.gov/iTable/iTable.cfm?ReqID=70&step=1&isuri=1&acrdn=5. Accessed February 2, 2012.

Bureau of Economic Analysis. Local Area Personal Income. BEA 12-15. Washington, DC, 2012. http://www.bea.gov/newsreleases/regional/lapi/lapi_newsrelease.htm. Accessed July 16, 2012.

Bureau of Labor Statistics. *Employment Cost Index—December 2001*. USDL 02-046. Washington, DC, 2002. http://www.bls.gov/news.release/archives/eci_01312002.pdf. Accessed January 4, 2012.

Bureau of Labor Statistics. *Employment Cost Index*. Washington, DC, 2011. http://data.bls.gov/pdq/querytool.jsp?survey=ci. Accessed January 4, 2012.

Bureau of Labor Statistics. Occupational Employment Statistics: May 2011 Metropolitan and Nonmetropolitan Area Definitions. Washington, DC, 2012a. http://www.bls.gov/oes/current/msa_def.htm#13980. Accessed June 27, 2012.

Bureau of Labor Statistics. May 2011 Metropolitan and Nonmetropolitan Area Occupational Employment and Wage Estimates, Washington, DC, 2012b. http://www.bls.gov/oes/current/oes_13980.htm. Accessed June 27, 2012.

Bureau of Labor Statistics. CPI Inflation Calculator, Washington, D.C., 2012c. http://www.bls.gov/data/inflation_calculator.htm. Accessed November 9, 2012.

Burke, P.J., and Nishitateno, S. *Gasoline Prices, Gasoline Consumption, and New-Vehicle Fuel Economy: Evidence for a Large Sample of Countries.* Crawford School of Economics & Government, Australian National University, Canberra, 2011. http://www.crawford.anu.edu.au/acde/publications/publish/papers/wp2011/wp_econ_2011_15.pdf. Accessed March 22, 2012.

Cable, D., and Tippett, R. Poverty and the Social Safety Net. Part 1: Who Are Virginia's Poor? Weldon Cooper Center for Public Service, Charlottesville, 2012. http://www.coopercenter.org/sites/default/files/node/13/NumbersCount_Poverty-and-the-Social-Safety-Net_%20Part%20I_02_28_12.pdf. Accessed May 16, 2012.

Cambridge Systematics, Inc. *Crashes vs. Congestion: What's the Cost to Society.* AAA, Washington, DC, 2011. http://newsroom.aaa.com/wp-content/uploads/2011/11/2011_AAA_CrashvCongUpd.pdf. Accessed January 18, 2012.

Cambridge Systematics, Inc., NuStats, McGuckin, N., and Ruiter, E. *A Guidebook for Using American Community Survey Data for Transportation Planning.* NCHRP Report 588. Transportation Research Board of the National Academies, Washington, DC, 2007.

Center for Regional Economic Competitiveness and the Center for Regional Analysis. *Assessing the Impact of BRAC in the Northern Virginia Workforce Investment Board Region*. SkillSource Group, Inc., Vienna, VA, 2007. http://www.myskillsource.org/home/documents/Executive_Summary.pdf. Accessed March 1, 2012.

Cheung, I., and McCartt, A.T. Declines in Fatal Crashes of Older Drivers: Changes in Crash Risk and Survivability. *Accident Analysis & Prevention*, Vol. 43, No. 3, 2011, pp. 666-674.

Cheung, S.Y., Coleri, S., Dundar, B., Ganesh, S., Tan, C.-W., and Varaiya, P. Traffic Measurement and Vehicle Classification with a Single Magnetic Sensor. Presented at the 84th Annual Meeting of the Transportation Research Board, Washington, DC, 2005. http://paleale.eecs.berkeley.edu/~varaiya/papers_ps.dir/sensors_trb_final4.pdf. Accessed March 1, 2012.

Chmura Economics & Analytics. *Economic and Social Indicators of Rural Virginia.* Center for Rural Virginia, Richmond, 2010. http://www.cfrv.org/RuralProsperityIndicators(ExecutiveSummary).pdf. Accessed April 13, 2012.

Cirillo, C., and Xu, R. The Acceptability and Drivers' Willingness to Pay and Departure Time Choice Model for HOT Lanes on I-495 in Maryland. Center for Integrated Transportation Systems Management, University of Maryland, College Park, 2010. http://www.citsm.umd.edu/documents/final-reports/Cirillo%20-%20HOT2010cc1.pdf. Accessed January 5, 2012.

City of Colonial Heights Virginia. Economy and Demographics. Undated. http://webcache.googleusercontent.com/search?q=cache:WCiogB6lDEQJ:www.colonial-heights.com/FactsFiguresEconomics.htm+city+of+colonial+heights+and+%24500+million+and+BRAC+and+Fort+Lee&cd=1&hl=en&ct=clnk&gl=us. Accessed March 22, 2012.

City of Petersburg Virginia. Draft Comprehensive Plan. 2011. http://www.petersburg-va.org/planning/compplan.asp. Accessed March 1, 2012.

Colman, S.B. Chapter 7: Evaluation and Prioritization Methods. In *Transportation Planning Handbook,* 3rd ed. Institute of Transportation Engineers, Washington, DC, 2009.

Congressional Budget Office. CBO's 2011 Long-Term Budget Outlook. Washington, DC, June 2011. http://www.cbo.gov/ftpdocs/122xx/doc12212/06-21-Long-Term_Budget_Outlook.pdf. Accessed February 13, 2012.

Coyle, J.J., Novack, R.A., Gibson, B.J., and Bardi, E.J. *Transportation: A Supply Chain Perspective*, 7th ed. South-Western Cengage Learning, Mason, OH, 2011.

Elgowainy, A., Zhou, Y., Vyas, A., Mahalik, M., Santini, D., and Wang, M. Impact of Plug-in Hybrid Electric Vehicle Charging Choices in 2030. In *TRB 91st Annual Meeting Compendium of Papers DVD.* Transportation Research Board of the National Academies, Washington, DC, 2012.

Executive Order 12898. Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. *Federal Register,* Vol. 59, No. 32, February 16, 1094.

Federal Highway Administration. *Highway Economic Requirements System—State Version: Technical Report, Chapter 5: Estimation of Impacts; Section 5.5 Travel Time Costs.* Washington, DC, 2005. http://www.fhwa.dot.gov/asset/hersst/pubs/tech/tech05.cfm#table527. Accessed October 22, 2012.

Federal Highway Administration and Federal Transit Administration. *The Transportation Planning Process: Key Issues: A Briefing Book for Transportation Decisionmakers, Officials, and Staff.* FHWA-HEP-07-039. Washington, DC, 2007. http://www.planning.dot.gov/documents/BriefingBook/BBook.htm. Accessed October 22, 2012.

Federal Highway Administration. Environmental Justice. 2012a. http://www.fhwa.dot.gov/environment/environmental_justice/. Accessed October 22, 2012.

Federal Highway Administration, Office of Highway Policy Information. Highway Statistics Series. 2012b. http://www.fhwa.dot.gov/policyinformation/statistics.cfm. Accessed April 27, 2012.

Forkenbrock, D.J. and Sheeley, J. *Effective Methods for Environmental Justice Assessment.* NCHRP Report 532. Transportation Research Board of the National Academies, Washington, DC, 2004.

Forkenbrock, D.J., and Weisbrod, G.E. *Guidebook for Assessing the Social and Economic Effects of Transportation.* NCHRP Report 456. Transportation Research Board of the National Academies, Washington, DC, 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_456-a.pdf.

Garber, N.J., and Hoel, L.A. *Traffic and Highway Engineering*, 4th ed. Cengage Learning, Toronto, Ontario, Canada, 2009.

HDR-HLB Decision Economics. *Assessing the Full Costs of Congestion on Surface Transportation Systems and Reducing them through Pricing*. U.S. Department of Transportation, Washington, DC, 2009. http://ostpxweb.dot.gov/policy/reports/Costs%20of%20Surface%20Transportation%20Congestion.pdf. Accessed February 15, 2012.

Hickey, R.L., Lu, A., and Reddy, A. Using Quantitative Methods in Equity and Demographic Analysis to Inform Transit Fare Restructuring Decisions. In *Transportation Research Record: Journal of the Transportation Research Board,* No. 2144. Transportation Research Board of the National Academies, Washington, DC, 2010, pp. 80-92.

Insurance Institute for Highway Safety. Q&A: Older Drivers, 2012 http://www.iihs.org/research/qanda/older_people.html. Accessed November 6, 2012.

Jin, X. , and Wu, J. Propensity to Telecommute: Exploring the National Household Travel Survey. In *Transportation Research Record: Journal of the Transportation Research Board,* No. 2231. Transportation Research Board of the National Academies, Washington, DC, 2011, pp. 110-119.

Kato, H., Sakashita, A., Tsuchiya, T., Oda, T., and Tanishita, M. Estimating Value of Travel Time Savings by Using Large-Scale Household Survey Data From Japan. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 2231. Transportation Research Board of the National Academies, Washington, DC, 2011, pp. 85-92.

Khan, K., and Kockelman, K. Predicting the Market Potential of Plug-In Electric Vehicles Using Multiday GPS Data. SWUTC/11/161123-1. University of Texas at Austin, 2011.

Koppelman, F.S., and Bhat, C. *A Self Instructing Course in Mode Choice Modeling: Multinomial and Nested Logit Models*. Federal Transit Administration, Washington, DC,

2006. http://www.ce.utexas.edu/prof/bhat/COURSES/LM_Draft_060131Final-060630.pdf. Accessed January 4, 2012.

Kravetz, D., and Noland, R.B. A Spatial Analysis of Income Disparities in Pedestrian Safety in Northern New Jersey: Is There an Environmental Justice Issue? In *TRB 91st Annual Meeting Compendium of Papers DVD.* Transportation Research Board of the National Academies, Washington, DC, 2012.

Larson, T.D. *Highway Statistics 1991.* FHWA-PL-92-095. Federal Highway Administration, Washington, DC, 1992. http://isddc.dot.gov/OLPFiles/FHWA/013340.pdf. Accessed November 2, 2012.

Litman, T. *Changing Vehicle Travel Price Sensitivities: The Rebounding Rebound Effect.* Victoria Transport Policy Institute, Victoria, BC, Canada, 2011. http://www.vtpi.org/VMT_Elasticities.pdf. Accessed March 22, 2012.

Litman, T. *The Future Isn't What It Used to Be: Changing Trends and Their Implications for Transport Planning.* Victoria Transport Policy Institute, Victoria, BC, Canada, 2012a. http://www.vtpi.org/future.pdf. Accessed May 1, 2012.

Litman, T. *Climate Change Emission Valuation for Transportation Economic Analysis.* Victoria Transport Policy Institute, Victoria, BC, Canada, 2012b. http://www.vtpi.org/ghg_valuation.pdf. Accessed June 11, 2012.

Litman, T.A. Transportation Cost and Benefit Analysis II—Travel Time Costs. Victoria Transport Policy Institute, Victoria, BC, Canada, 2012c. http://www.vtpi.org/tca/tca0502.pdf. Accessed November 6, 2012.

Lutsey, N. Comparison of Emissions, Energy, and Cost Impacts of Diesel and Hybrid Models in the United States in 2010. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 2252. Transportation Research Board of the National Academies, Washington, DC, 2011, pp. 40-48.

Martin, W.A., and McGuckin, N.A. *Travel Estimation Techniques for Urban Planning.* NCHRP Report 365. Transportation Research Board of the National Academies, Washington, DC, 1998. http://ntl.bts.gov/lib/21000/21500/21563/PB99126724.pdf. Accessed December 3, 2010.

Miller, J.S. *Socioeconomic and Travel Demand Forecasts for Virginia and Potential Policy Responses: A Report for VTrans2035: Virginia's Statewide Multimodal Transportation Plan.* VTRC 09-R16. Virginia Transportation Research Council, Charlottesville, 2009.

National Capital Region Transportation Planning Board. CLRP: Long Range Transportation Plan. Washington, DC, 2010. http://www.mwcog.org/clrp/performance/. Accessed November 6, 2012.

National Highway Traffic Safety Administration. *Traffic Safety Facts: 2009 Data.* DOT HS 811391. Washington, DC. http://www-nrd.nhtsa.dot.gov/Pubs/811391.pdf. Accessed July 17, 2012.

National Research Council. *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use.* National Academies Press, Washington, DC, 2010.

Office of Intermodal Planning and Investment. Virginia Surface Transportation Plan 2035. Richmond, 2010. http://www.vtrans.org/resources/VSTP_Entire_Report.pdf. Accessed January 6, 2012.

Office of the Secretary of the Army. *Report to Congress: Transportation Plan for BRAC Recommendation #133 Project Fort Belvoir-Mark Center, Virginia.* Department of the Army, Washington, DC, 2011. http://www.bracarlingtonva.us/default/index.cfm?LinkServID=E4555864-1D09-08FB-3BFD7C6F8EF44AAF&showMeta=0. Accessed February 17, 2012.

O'Leary, A.A. Email to J.S. Miller, July 12, 2012.

Paul, B.M., Kockelman, K.M., and Musti, S. Evolution of the Light-Duty Vehicle Fleet Anticipating Adoption of Plug-In Hybrid Electric Vehicles and Greenhouse Gas Emissions Across the U.S. Fleet. In *Transportation Research Record: Journal of the Transportation Research Board,* No. 2252. Transportation Research Board of the National Academies, Washington, DC, 2011, pp. 107-117.

Prozzi, J., Carroll, L., Loftus-Otway, L., Bhat, C., Paleti, R., and McCray, T. *Assessing the Environmental Justice Impacts of Toll Road Projects.* Center for Transportation Research, University of Texas at Austin, 2010. http://www.utexas.edu/research/ctr/pdf_reports/0_6544_1.pdf. Accessed May 4, 2012.

Rathbone, D.B. Editorial. *The Urban Transportation Monitor*, Vol. 20, No. 15, August 4, 2006, p. 11.

Reddy, A., Chennadu, T., and Lu, A. Safeguarding Minority Civil Rights and Environmental Justice in Service Delivery and Reductions: Case Study of New York City Transit Authority Title VI Program. In *Transportation Research Record: Journal of the Transportation Research Board,* No. 2163. Transportation Research Board of the National Academies, Washington, DC, 2010, pp. 45-56.

Rose, K. Flexible Work: Maximizing Transportation Opportunities in Where, When and How Work is Done. *TDM Review,* Spring 2010, pp. 8-11. http://data.memberclicks.com/site/asct/TDM_Review_Spring_2010_NEW.pdf. Accessed May 3, 2012.

Rosenbloom, S., and Winsten-Bartlett, C. Asking the Right Question: Understanding the Travel Needs of Older Women Who Do Not Drive. In *Transportation Research Record:*

Journal of the Transportation Research Board, No. 1818. Transportation Research Board of the National Academies, Washington, DC, 2002, pp. 78-82.

Sana, B., Konduri, K.C., and Pendyala, R.M. Quantitative Analysis of Impacts of Moving Toward a Vehicle Mileage-Based User Fee. In *Transportation Research Record: Journal of the Transportation Research Board,* No. 2187. Transportation Research Board of the National Academies, Washington, DC, 2010, pp. 29-35. http://trb.metapress.com/content/72h532k089771w7k/fulltext.pdf. Accessed March 23, 2012.

Sashin, D.A. Chickahominy Bridge to Reopen Today. *Daily Press,* August 6, 2004. http://articles.dailypress.com/2004-08-06/news/0408060100_1_bridge-s-weight-boat-traffic-bridge-post. Accessed March 20, 2012.

Schrank, D., Lomax, T., and Eisele, B. *2011 Urban Mobility Report*. Texas Transportation Institute, College Station, 2011. http://tti.tamu.edu/documents/mobility-report-2011.pdf. Accessed March 20, 2012.

Sinha, K.C., and Labi, S. *Transportation Decision Making: Principles of Project Evaluation and Programming.* John Wiley & Sons, Inc., Hoboken, NJ, 2007.

Sivak, M., and Schoettle, B. Recent Changes in the Age Composition of U.S. Drivers: Implications for the Extent, Safety, and Environmental Consequences of Personal Transportation. *Traffic Injury Prevention,* Vol. 12, 2011, pp. 588-592.

Sivak, M., and Schoettle, B. Recent Changes in the Age Composition of Drivers in 15 Countries. *Traffic Injury Prevention,* Vol. 13, 2012, pp. 126-132.

Smalkoski, B., and Levinson, D. Value of Time for Commercial Vehicle Operators in Minnesota. *Journal of the Transportation Research Forum*, Vol. 44, No. 1, 2005, pp. 89-102. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1091828. Accessed January 12, 2012.

Spraggins, H.B. The Case for Rail. *Journal of Management and Marketing Research*, Vol. 3, 2010. http://www.aabri.com/manuscripts/09224.pdf. Accessed January 17, 2012.

Steinhardt, B. *Human Capital: Telework Programs Need Clear Goals and Reliable Data.* Report GAO-08-261T. Government Accountability Office, Washington, DC, 2007. http://www.gao.gov/assets/120/118523.pdf. Accessed November 8, 2012.

Thiess, R. Addressing Price Parity Concerns. *The Economic Policy Institute Blog,* May 7, 2012. http://www.epi.org/blog/addressing-price-parity-concerns/. Accessed June 25, 2012.

TTX. The History of TTX. 2012. http://www.ttx.com/aboutttx/history.aspx/. Accessed November 6, 2012.

[Transportation Research Board] Committee on Federal Funding of Transportation Improvements in BRAC Cases. *Federal Funding of Transportation Improvements in BRAC Cases: Special Report 302*. The National Academies Press, Washington, DC, 2011.

Trottenberg, P. Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis. Memorandum to Secretarial Officers and Modal Administrations. U.S. Department of Transportation, Washington, DC, September 28, 2011. http://www.dot.gov/sites/dot.dev/files/docs/vot_guidance_092811c.pdf. Accessed November 2, 2012.

2005 Defense Base Closure and Realignment Commission. *2005 Defense Base Closure and Realignment Commission Report*. Arlington, VA, 2005. http://www.brac.gov/docs/final/Volume1BRACReport.pdf. Accessed March 22, 2012.

U.S. Census Bureau. (ST-99-8) Population Estimates for the U.S., Regions, Divisions, and States by 5-year Age Groups and Sex: Time Series Estimates, July 1, 1990 to July 1, 1999 and April 1, 1990 Census Population Counts. Washington, DC, 2000. http://www.census.gov/popest/data/state/asrh/1990s/tables/ST-99-08.txt. Accessed April 18, 2012.

U.S. Census Bureau. Table QT-P23, Journey to Work: 2000. 2003. http://factfinder2.census.gov. Accessed May 3, 2012.

U.S. Census Bureau. An Older and More Diverse Nation by Midcentury. August 14, 2008a. http://www.census.gov/newsroom/releases/archives/population/cb08-123.html. Accessed May 14, 2012.

U.S. Census Bureau. Projections of the Population by Sex, Race, and Hispanic Origin for the United States: 2010 to 2050 (NP2008-T4), National Population Projections. Washington, DC, 2008b. http://www.census.gov/population/www/projections/summarytables.html. Accessed May 14, 2012.

U.S. Census Bureau. Table QTP1, 2010 Census. 2011a. http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml. Accessed January 30, 2012.

U.S. Census Bureau. How the Census Bureau Measures Poverty. 2011b. http://www.census.gov/hhes/www/poverty/about/overview/measure.html. Accessed May 16, 2012.

U.S. Census Bureau. Table 2. Intercensal Estimates of the Resident Population by Sex and Age for Virginia: April 1, 2000 to July 1, 2010. ST-EST00INT-02-51. 2011c. http://www.census.gov/popest/data/intercensal/state/ST-EST00INT-02.html. Accessed April 19, 2012.

U.S. Census Bureau. 2006-2010 American Community Survey 5-Year Estimates. 2011d. http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t. Accessed July 13, 2012.

U.S. Census Bureau. 2008-2010 American Community Survey 3-Year Estimates. 2011e. http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t. Accessed March 2, 2012.

U.S. Census Bureau. 2010 American Community Survey 1-Year Estimates. 2011f. http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t. Accessed May 15, 2012.

U.S. Census Bureau. Table QT-P4, 2010 Census. 2011g. http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml. Accessed May 15, 2012.

U.S. Census Bureau. *American Community Survey: Puerto Rico Community Survey: 2010 Subject Definitions.* Washington, DC, 2012. http://www.census.gov/acs/www/Downloads/data_documentation/SubjectDefinitions/2010_ACSSubjectDefinitions.pdf. Accessed May 17, 2012.

U.S. Census Bureau. Age Data of the United States. Undated, a. http://www.census.gov/population/www/socdemo/age/general-age.html#older. Accessed April 11, 2012.

U.S. Census Bureau. State Population Projections. Undated, b. http://www.census.gov/population/www/projections/stproj.html. Accessed May 14, 2012.

U.S. Department of Energy. *Distribution Transformers Preliminary Technical Support Document.* Washington, DC, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/commercial/distribution_transformers_prelim_tsd.html. Accessed June 11, 2012.

U.S. Department of Health and Human Services. *Nondiscrimination on the Basis of Age in Programs or Activities Receiving Federal Financial Assistance From HHS.* 1979. http://www.hhs.gov/ocr/civilrights/resources/laws/ageregulation.html. Accessed April 16, 2012.

U.S. Energy Information Administration. Annual Energy Outlook Early Release Overview. Washington, DC, 2012. http://205.254.135.7/forecasts/aeo/er/pdf/0383er(2012).pdf. Accessed March 23, 2012.

U.S. Environmental Protection Agency. *Direct Emissions from Mobile Combustion Sources.* Washington, DC, 2008. http://www.epa.gov/climateleadership/documents/resources/mobilesource_guidance.pdf. Accessed June 1, 2012.

Vincent, G.K., and Velkoff, V.A. *The Next Four Decades: The Older Population in the United States: 2010 to 2050*. P25-1138. U.S. Census Bureau, Washington, DC, 2010.

Virginia Department of Transportation. Construction of New Route 5 Chickahominy River Bridge Underway. Richmond, February 27, 2007. http://www.virginiadot.org/newsroom/richmond/2007/construction_of_new_route15857.asp. Accessed March 20, 2012.

Virginia Department of Transportation. *Mark Center (BRAC) 133 Access Study*. Richmond, 2010. http://www.vamegaprojects.com/faqsdocuments/mark-center-documents/. Accessed November 2, 2012.

Virginia Department of Transportation. Under Construction: JPA Bridge, Charlottesville. 2011. http://www.virginiadot.org/projects/culpeper/jpa_bridge.asp. Accessed January 19, 2012.

Virginia Department of Transportation. Road Construction Ahead: January-April 2012. Richmond, 2012. http://www.virginiadot.org/travel/resources/rca-printable.pdf. Accessed January 26, 2012.

Virginia Employment Commission. LMI Data: Population Projections. 2007a. http://www.vawc.virginia.gov/gsipub/index.asp?docid=359. Accessed January 30, 2012.

Virginia Employment Commission. *An Economic Assessment of Fort Lee: 2006-2013: Viewing the Impacts of Expenditures in 2006, and the Ramifications of the 2005 Base Realignment and Closure Commission Actions on the Local Community*. Richmond, 2007b. http://forbes.house.gov/UploadedFiles/Fort%20Lee%20Impact.pdf. Accessed March 1, 2012.

Virginia Employment Commission. LMI Data: Population Projections. 2012. http://www.vawc.virginia.gov/gsipub/index.asp?docid=359. Accessed May 14, 2012.

Virginia Transportation Research Council. *Examining the Long-Term Viability of the Motor Fuels Tax and Possible Alternatives.* Office of Intermodal Planning and Investment, Richmond, 2008. http://www.vtrans.org/resources/Examining_the_Long-Term_Viability_of_the_Gas_Tax_FINAL.pdf. Accessed June 27, 2012.

Weldon Cooper Center for Public Service. Population Change and Components of Change, April 1, 2000 to April 1, 2010: Virginia Localities. February 3, 2011. http://www.coopercenter.org/demographics/interactive-map/citycounty. Accessed January 4, 2012.

Weldon Cooper Center for Public Service. Demographics and Workforce: Population Data. 2012. http://www.coopercenter.org/demographics/virginia-population-estimates. Accessed May 17, 2012.

Wilton, R.D., Páez, A., and Scott, D.M. Why Do You Care What Other People Think? A Qualitative Investigation of Social Influence and Telecommuting. *Transportation Research Part A*, Vol. 45, 2011, pp. 269-282.

APPENDIX

CALCULATIONS RELATED TO TABLES AND FIGURES

Change in Percentage of Population Age 65+ (Figure 5)

The values in Figure 5 were estimated as follows: for each age group, the difference in percentages for year 2010 according to the 2010 decennial census (U.S. Census Bureau, 2011a, Table QTP1) and the VEC projections for 2010 (VEC, 2007a) was added to the VEC projections for 2030 and then national changes in population were applied to these Virginia data. The Lenowisco PDC may be used as an example. VEC (2007a) projected that in the counties and cities that define the Lenowisco PDC, 16.14% of their population would be age 65+ in year 2010; actual census data showed this percentage to be 16.05%. Because the 2010 decennial census figure was slightly higher than the VEC 2010 figure, the difference—slightly more than 0.08%--was subtracted from the percentage VEC had estimated for 2030 (22.84%) to yield an adjusted 2030 forecast of 22.76%. Although the VEC projections (2007a) do not extend beyond 2030, national projections to year 2040 (Vincent and Velkoff, 2010) showed that much of the increase in persons age 65+ will occur between 2010 and 2030, with the percentage rising from 13.0% in 2010 to 19.3% in 2030,but leveling off at 20.0% (2040) and 20.2% (2050). This information yields a slightly adjusted forecast for year 2035 of (22.76% [{20.0 - 19.3}/2+19.3}/19.3 = 23.17%.) The intention of this approach was to retain the judgment made by the VEC (2007a) in developing the projections for 2030 except that newer information—in the form of the 2010 decennial census plus recent national forecasts, both of which became available after 2007—were used to update the VEC forecasts.

Change in Percentage of Persons With Disabilities (Figure 7)

For the 11% of persons with a disability who did not reside a jurisdiction of 20,000 or more an estimation process was used as follows. Alleghany County may be used as an example; it was not included in the 3-year ACS because it had a 2010 decennial census population of 16,250, which is under the 3-year ACS threshold of 20,000. According to the 2010 decennial census, counties such as Alleghany with fewer than 20,000 people represented 661,704 Virginians of the 8,001,024 statewide total. Alleghany represented 2.456% of this sub-20,000 person jurisdiction population (e.g., 16,250/661,704 = 2.456%). The ACS data (Table B18101 [(U.S. Census Bureau, 2011e]) showed that 121 persons under the age of 5 who reside in a jurisdiction of less than 20,000 had a disability. (These data give statewide total for persons with a disability and numbers for jurisdictions of 20,000 or more, so a statewide figure for jurisdictions under 20,000 may be determined via subtraction.) Accordingly, Alleghany County is estimated to have 2.456% of these 121 persons = 3 persons under age 5 with a disability. The same technique was applied for the remaining age categories.

Change in Auto Ownership (Figure 10)

There are two methods that can be used to estimate the number of workers without a vehicle.

1. *Method 1:* Match the number of workers at a statewide level only.
2. *Method 2:* Match the number of workers at each jurisdiction level.

Neither method necessarily gives perfect results.

Under Method 1, Table B08141 shows 3,790,952 Virginia workers, and Table B08203 shows the number of vehicles available (0, 1, 2, 3, or 4+) for four categories of households: zero-worker households, 1-worker households, 2-worker households, and 3+ worker households (U.S. Census Bureau, 2011d). Table B08203 does not indicate the average number of workers per 3+-worker household. One can calculate this number; assuming an average of 3.824 workers per household for this category causes the number of Virginia workers to be consistent with that in Table B08141. The weakness of Method 1 is that it assumes that in every jurisdiction the category of 3+ workers should be replaced with the same average of 3.824 whereas it may be the case that the average figure should be different by jurisdiction.

Under Method 2, the two tables can be aligned at a jurisdiction level so that the number of workers reported in Table B08141 matches the number of workers calculated from Table B08203 at both the state and jurisdiction level. In this manner, the average number of workers for the 3+-worker households may differ by jurisdiction, as shown in Table A1 for the counties of Accomack and Albemarle. The weakness of Method 2 is that for about one-sixth of Virginia's jurisdictions, the estimated number is below 3. For example, in order to align the total workers in Goochland County (reported as 7,312 in Table B08141) with the total calculated from Table B08203, one would have to assume the 3+ workers per household was replaced with an average of 0.50 worker per household. Based on a review of the U.S. Census Bureau's documentation (U.S. Census Bureau, 2012), it does not appear that the phenomenon of multiple jobs per worker or the existence of a prison population would explain the discrepancy.

The data from Table B08203 may then be used to estimate the number of workers without a vehicle. For example, for Accomack County, based on an assumption of 4.52 workers per household for the category of 3+ workers (computed from Table A1), there would be 1,378 workers without a vehicle, as shown in Table A2. If, however, the statewide average of 3.824 workers per household in the category of 3+ workers had been used, the method shown in Table A2 would have yielded 1,210 workers without a vehicle for Accomack County. Thus the two methods suggest between 1,210 (Method 1) and 1,378 (Method 2) workers without a vehicle for this single county.

Table A1. Worker and Household Data From Tables B08203 and B08141 of the 2006-2010 ACS

County	No. of 1-Worker Households	No. of 2-Worker Households	No. of 3+-Worker Households	Estimated Average No. of Workers per 3+-Worker Household	Total No. of Workers
Accomack	5,198	3,505	517	4.52[a]	14,547
Caroline	3,827	3,426	613	3.55	12,855
Goochland	2,191	2,478	330	0.50	7,312
Data source	Table B08203	Table B08203	Table B08203	Calculated	Table B08141

Data extracted from the U.S. Census Bureau (2011d).
[a]Example: If one assumes there are 4.52 workers for the 3+ workers category in Accomack County, the number of workers in the county is (5,198)(1) + (3,505)(2) + 517(4.52) = 14,547 workers, which matches the total reported in Table B08141.

Table A2. Data for Computing Number of Workers Without Vehicles for Accomack County

Household Size	No. of 0-Vehicle Households	No. of 1-Vehicle Households	No of 2-Vehicle Households	No of 3-Vehicle Households
1 worker	385			
2 workers	95[a]	302		
3+ workers	6	14[b]	89	131

Data extracted from the U.S. Census Bureau (2011d).
[a]Example: Since there are 95 households with 2 workers and 0 vehicles, this cell represents (2)(95) = 190 workers who do not have a vehicle.
[b]Example: Assuming 4.52 workers per 3+-worker household (Table A1), the 14 such households with 1 vehicle per household means this cell represents (4.52-1)(14) = 49 workers without a vehicle.

Regional Price Parities (Table 2)

Regional price parities are not directly available for all Virginia counties and cities. To estimate these values for the 21 Virginia regions (see Table 2), the following procedure was used.

- If a regional price parity was adopted for a location that was included in a modified PDC, then that regional price parity was adopted. For example, Aten et al. (2011) reported a regional price parity of 81.6 for the Kingsport-Bristol-Bristol, TN-VA area. This value was adopted for the Mount Rogers PDC (PDC 3) where Bristol is located.

- In rural areas, if a regional price parity was not available but another index was available, changes in the other index were related to changes in the regional price parity. For example, Chmura Economics & Analytics (2010) reported that rural areas of Virginia have a cost of living that is approximately 87% of the statewide average. For some regions that appeared to be composed largely of such rural areas, 87% of Virginia's regional price parity (which is 101.5) was applied.

- In particular, the three regions of the Rappahannock-Rapidan Regional Council (PDC 9), the George Washington Regional Commission (PDC 16), and the Crater PDC (PDC 19) were problematic because they did not have exclusively rural areas and no regional price parity was available. For these regions, the ratio of the cost of living was used to estimate the regional price parity. For example, Advameg, Inc. (2012) reported that Spotsylvania County (in PDC 16) had a cost of living of 112.5 and that Fairfax County (in PDC 8) had a cost of living of 134.7. Equation A1 may thus be used to estimate that regional price parity for PDC 16 as follows:

$$RPP_{16} = \left(\frac{COL_{16} - 100}{COL_{8} - 100}\right)\left(RPP_{8} - 100\right) + 100 \qquad \text{[Eq. A1]}$$

where

RPP is the regional price parity for a given PDC.
COL is the cost of living for the given PDC.

For example, since the regional price parity for PDC 16 is unknown, it may be estimated as follows given that PDC 8 has a regional price parity of 115.2:

$$RPP_{16} = \left(\frac{112.5 - 100}{134.7 - 100}\right)(115.2 - 100) + 100$$

Short-Term Transportation Impacts of BRAC (Figure 15)

Between 6,400 (TRB, 2011) and 7,000 (VDOT, 2010) employees are being added at the Mark Center. Immediate improvements are being made at the site although travel behavioral changes are desired. Because the nearest heavy rail (Metro) station is 4 miles away, it is expected that a substantial portion of immediate traffic will use single-occupant vehicles. VDOT (2010) reported that the developer (Duke Realty Corporation) will make improvements. These include the addition or extension of turn lanes at adjacent intersections (e.g., where North Beauregard Street intersects Seminary Drive and also Mark Center Drive, along with the addition of sidewalks [Office of the Secretary of the Army, 2011]), as well as the addition of a traffic signal or roundabout on the grounds of the Mark Center (VDOT, 2010).

Although a 40% vehicle trip reduction figure has been cited (VDOT, 2010), TRB (2011) stated: "The traffic management plan for the Mark Center assumes non-auto trips beyond what would be normal for its location." The Office of the Secretary of the Army (2011) explained that new measures to support such a reduction include (1) restrictions on Mark Center parking at 1,000 spaces below what would be permitted by the City of Alexandria; (2) a shuttle bus between the Mark Center, Virginia Railway Express (VRE) stations, and the Pentagon Metro station; and (3) the establishment of a "Transportation Management Office" that would coordinate with the City of Alexandria, Mark Center employees, and transit providers. These changes are expected to have both short-term and long-term impacts.

Between the present and 2015, these improvements proffered by Duke Realty Corporation (e.g., the aforementioned left-turn lanes, a physical barrier separating the I-395 ramp traffic from the roundabout, and sidewalk improvements) then of the six key intersections near the Mark Center, for the morning and evening peak periods, three will be Level of Service (LOS) F by 2015 with the remaining three intersections between LOS D and LOS E (Office of the Secretary of the Army, 2011). Without the additional Mark Center traffic, intersection LOS would range from A to D. If an additional $20 million in VDOT improvements are made, such as widening I-395 Northbound from two to three lanes; providing a pedestrian bridge across Seminary Road; and widening the intersections, the intersection LOS would improve: only one intersection would be at LOS F (and that would be for the evening peak only); a different intersection would be at LOS E (for the morning peak only); and all other periods and intersections would be between LOS B and D. Thus with the VDOT improvements and the proffered improvements, the LOS would not be as good as it would be without the Mark Center traffic but it would be better than with no improvements in place.

Percentage of Virginians with a Driver's License (Figure 22)

Population data for Virginia for years 1990-2010 were obtained from the U.S. Census Bureau (2000, 2011c). The number of Virginians with a driver's license was obtained from the FHWA Office of Highway Policy Information (2012b), which also noted for 2004 and later years, that the Virginia data included restricted drivers and graduated driver licenses. To avoid confusion for readers familiar with these data sources, it should be noted that the FHWA Office of Highway Policy Information (2012b) clarified that the standard for determining drivers under age 16 changed with the publication of the 1989 *Highway Statistics Series*, suggesting that data for persons age 15-19 are comparable for years 1989 and later.

For the 21 years of data (1990-2010 inclusive) and the 15 age groups (e.g., age 15-19, age 20-24, and so on except for year 1990 where there were 11 age groups only), a spreadsheet was developed showing 311 cells. For 17 of these 311 cells, there were more licensed drivers than population. Larson (1992) explained it is possible for this to occur either because some drivers may move from one state to another (but still be counted in the former state if their license has not expired) or because some drivers may obtain a license in a state different than the one that is their legal residence.

Telecommuters (Figure 25)

Data from the U.S. Census Bureau (2003, 2011) were used to tabulate the percentage of Virginia workers, age 16 and over, who worked from home for two time periods: 2000 (based on the decennial census) and the period 2006-2010 (based on the 5-year ACS for that period). Such persons are defined as *telecommuters*. No distinction is drawn between persons who work at home because they have no outside office and persons who work at home because they are telecommuters. Some literature defines *teleworking* as replacement of a work trip with working at home or working at an alternative location, such as a coffee shop or satellite office (Rose, 2010); other literature defines *teleworking* as using electronic communication to replace a physical trip, which includes not only work trips but also shopping (Litman, 2012a).

Societal Costs of Greenhouse Gases Attributable to Excess Fuel Use (Tables 4-6)

Tables 4, 5, and 6 indicate that the cost of excess fuel consumption includes not only the additional fuel that motorists must purchase but also the additional greenhouse gas emissions that result from the burning of this additional fuel. These greenhouse gas emissions are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_20). Estimation of the costs for these emissions requires assumptions, in terms of both the rate of emissions production and the cost to society.

The rate of emissions production depends largely, but not entirely, on fuel consumed. The U.S. EPA (2008) cited emissions rates as 8.81 kg of CO_2 per gallon (motor fuel) and 10.15 kg of CO_2 per gallon (diesel fuel). Litman (2012b) suggested similar rates (8.87 kg and 10.15 kg of CO_2 per gallon for motor fuel and diesel fuel, respectively). With the assumption that CH_4 and N_20 account for an additional 5% of emissions in terms of greenhouse gas equivalents (CO_{2e}) (U.S. EPA (2008), the rates increase to 9.27 and 10.68 kg of CO_{2e} per gallon for autos and trucks, respectively—recognizing that CH_4 and N_2O are dependent on assumptions regarding VMT and the use of catalytic converters.

To a greater extent than the quantity of greenhouse gas emissions estimated, the social cost of these emissions is highly variable. Litman (2012b) showed a range of figures from -$4.43 to $3,910 per metric ton (1,000 kg) of CO_{2e} (in 2007 dollars). Both Litman (2012b) and the U.S. Department of Energy (2011) showed that as the adverse impacts of greenhouse gas emissions may transpire in the future, the assumed discount rate influences these costs. For example, The U.S. Department of Energy (2011) showed that for year 2020, the costs per metric ton of CO_{2e} ranged from $6.80 to $41.70 (in 2007 dollars) depending on whether a discount rate of 2.5% or 5% is assumed. The National Research Council (2010) also noted the variability in costs, indicating that costs may range from $10 to $100 (in 2007 dollars) per ton (e.g., 2,000 pounds rather than the metric tonne of 1,000 kg, which would be 2,205 pounds). Thus the National Research Council (2010) suggested a cost range between $11.03 and $110.25 per metric ton.

A value of $100 per metric ton of greenhouse gas equivalents (CO_{2e}) places the cost of the extra fuel consumed at $31 million, which is about 2% of the total congestion costs shown in Table 4. This value is toward the upper end of a $11.03-to-$110.25 per metric ton equivalent suggested by the National Research Council (2010). However, the National Research Council (2010) acknowledged that such a monetization "does not adequately capture the small probability of catastrophic climate changes and impacts." For example, Litman (2012b) identified recommended or "central" (e.g., from a range) costs from published studies that showed published estimates of $12, $78, $178, $326, and $917 per metric ton of CO_{2e}. Had the highest figure of $917 per metric ton of CO_{2e} been used in Table 4, instead of the cost of $100 per metric ton, the greenhouse gas costs would have been $954 million, which would thus be about 16.6% of the total congestion costs.

In Table 4, the greenhouse gas emissions costs are for only the *excess* fuel consumed. A different perspective would be to compute emissions costs for *all* fuel consumed. A simplified approach for such a calculation is to multiply the societal cost of a metric ton of CO_{2e} (e.g., assume $100 per metric tonne) by the number of kilograms of CO_{2e} per gallon (roughly 10) and to divide by 1,000 (see Eq. A2) to find that greenhouse gas emissions costs would add approximately $1 per gallon of fuel, which is roughly a 25% increase in expected 2035 fuel costs. As noted by Litman (2012b), the National Research Council (2010), and the U.S. Department of Energy (2011), the challenge in such a calculation is determining the societal cost of a metric ton of CO_{2e}.

$$\left(\frac{\$100}{\text{metric ton CO}_{2e}}\right)\left(\frac{10\text{kg CO}_{2e}}{\text{gallon fuel}}\right)\left(\frac{\text{metric ton CO}_{2e}}{1{,}000\text{ kg CO}_{2e}}\right)=\$1 \text{ per gallon fuel} \qquad \text{[Eq. A2]}$$

Other impacts that may be monetized are the various types of emissions (e.g., nitrogen oxides and volatile organic compounds) that produce ground level ozone in the presence of sunlight).

Penetration Rate of Hybrid Vehicles (Table 5)

The Uncertainty of Hybrid Vehicle Forecasts

The costs attributable to greenhouse gas emissions shown in Tables 4 through 6 are dependent on the extent to which alternative-fueled vehicles (AFVs) are used in lieu of the current vehicle fleet. As is the case with forecasting fuel prices, the literature noted that a variety of factors, not necessarily predictable, influences fleet composition. Brady and O'Mahony (2011) stated that in a review of market penetration rates, "the range of conceivable market penetration scenarios varies widely." Paul et al. (2011) noted that several factors will influence market penetration rates, notably technological advances, changes in fuel price, and changes in government policies; not only do these affect individual ownership decisions but they also affect the range of vehicle choices provided by the market. An example of a difficult-to-predict attribute is the reduction in the incremental cost in new technology, which must be compared to reductions in incremental costs for conventional technologies. Lutsey (2012) reported that at present, such incremental costs for hybrid vehicles are between $2,800 and $3,500, with most of the cost attributable to the battery, motor, and other power electronics (e.g., the inverter). Lutsey (2012) suggested that these could be reduced by about one-half within the next decade and contrasted this with diesel-engine emission control standards that would increase the incremental cost of diesel engines. As a consequence, the literature examined alternative scenarios; e.g., Bandivadekar et al. (2008) developed forecasts for electric vehicle sales rates for a scenario favoring a future turbocharged gasoline-powered engine (that reduced fuel consumption) and for a scenario where hybrid electric vehicles (HEVs) were favored; the rate of sales ranged from 15% to 55% of new vehicles in year 2035 depending on the scenario.

Whereas year 2035 may be considered a long-range prediction, some have noted that even short-range predictions cannot be made because of rapid fluctuations in underlying conditions. The Virginia Transportation Research Council (2008) concluded that with respect to AFVs and HEVs, even short-range predictions were infeasible, stating:

> The data on HEV sales lead therefore to a conclusion similar to the conclusion regarding AFVs: without additional information on which to base a forecast of the market share at which HEVs will level off, it is hard to know what growth rate to expect for them over the next few years.

The authors noted that this condition arose because the sudden increase in fuel prices at the time of the report's creation (in 2008) led to the demand for hybrid vehicles exceeding production capacity.

Range of Forecasts for Hybrid Vehicles

Thus the literature offers a range of forecasts for the percentage of the vehicle fleet that will be hybrid vehicles. For example, Paul et al. (2011) suggested that in year 2035, *plug-in* HEVs (a subset of all electric vehicles) could represent 2.2% to 4.0% of the vehicle fleet, whereas Elgowainy et al. (2012) suggested that such plug-in HEVs would be 10% of the fleet in 2030. Lutsey (2012) reported that forecasts for *sales* of hybrid vehicles generally for year 2025 (not 2035) ranged between 20% and 68% up from 3% of sales in 2009. As pointed out by Brady and O'Mahony (2011), the percentage of hybrid vehicle sales would be expected to be higher than the percentage of on-road hybrid vehicles given the average vehicle lifespan of 15 years (Paul et al., 2011). Khan and Kockelman (2011) noted work conducted in 2009 had suggested hybrid vehicles (including but not limited to the plug-in variety) could represent 19% of the vehicle fleet (in 2035), leading the authors to write: “In reality, no one knows what the future will hold, due to uncertainty in innovations, fuel prices, government regulation, and consumer motivation.” Bandivadekar et al. (2008) suggested a market share of hybrid vehicles (including plug-in vehicles) could be 55% of new vehicle sales in 2035 (under a scenario where conditions favored hybrid vehicles) compared to 22.5% of new vehicle sales if there were no clear winner between hybrids and advances in other technologies such as turbocharged vehicles.

Paul et al. (2011) modeled household data in Austin (Texas) to forecast the 2035 percentage of the vehicle fleet that could be replaced by three alternatives to the internal combustion engine: plug-in HEVs, hybrid vehicles without the plug-in feature, and the smart car (using the Mercedes smart car as an example). The authors forecast that such vehicles would increase to 8.91% of the vehicle fleet in year 2035 under the continuation of present trends. Such trends reflect a 63% increase in VMT and an 80% increase in greenhouse gas emissions. Relative to the trend scenario, the authors found that the percentage of such vehicles in the fleet could increase depending on a variety of policy scenarios. The increases were as follows: 9.42% if the price of the plug-in HEV was lowered by $4,100 such that it was only $3,900 more than a conventional auto; 10.66% if a fee or rebate of $200 was charged for each mile per gallon that a vehicle’s fuel economy was below or exceeded 30 mpg; 12.38% if the aforementioned fee or rebate was raised from $200 to $400; 15.26% to 17.21% if the $200 or $400 aforementioned fee or rebate was combined with a $5 per gallon fuel price; 10.63% if job and household densities quadrupled; and 17.53% for a fuel price of $7 per gallon.

In particular, Paul et al. (2011) showed that although the resultant emissions are influenced by vehicle technology, the effect of technology cannot be fully assessed without considering market forces and government policies. The effect of fuel prices may be used as an example. Relative to the trend scenario, a fuel price of $7 per gallon was shown to reduce emissions by 37.20%; although part of the decrease was attributable to the use of AFVs, the decrease also results because of an overall reduction in VMT. Yet a scenario studied by Paul et al. (2011) also showed some surprises: relative to the trend scenario, a rebate for plug-in HEVs resulted in a slight *increase* in emissions (presumably because the better fuel economy reduced the cost of driving). Because the increase in VMT (0.96%) was more than the increase in emissions (0.08%), it appears the use of AFVs was helpful given that VMT increased; however, the results suggest that some policies—such as the price reduction for such low-emitting vehicles—could have an unintended consequence, which in this case was an increase in travel.

Summary of Forecasts for Hybrid Vehicles

For 2035, based on the work by Khan and Kockelman (2011) and Paul et al. (2011), a range of forecasts for fleet composition in 2035 for HEVs is 9% to 19%. A higher forecast may be derived from the assumption that hybrid vehicles would represent 68% of new vehicle sales in year 2035 (Lutsey, 2012); this forecast is 59% of the fleet assuming a 15-year vehicle life and a constant sales growth from 2010. Accordingly, assuming idling does not increase emissions, the greenhouse gas costs shown in Tables 5 and 6 attributable to delay may be reduced from $104 million assuming no change in emissions rates to between $43 million and $95 million depending on the market penetration of AFVs. This assumption is dependent on several factors as reported by others (e.g., Paul et al. [2011]) in terms of technological changes, pricing, and vehicle use.

Regional Variation in Value of Travel Time (Figure 12, Figure 26, and Table 2)

As shown in Figure 26, the value of 1 hour of time depends on the trip purpose. For some trip purposes, such as long distance commercial truck trips, it is not necessarily the case that the location of the trip should influence the value of time. However, for some trip purposes, such as personal short-distance travel, an individual's relative wealth or earning potential would be expected to influence the value of time. Because wealth varies by location, there is reason to believe that the median value of time should also vary. For personal short-distance travel, Trottenberg (2011) suggested using a value of time that was approximately one-half the median *household* income; household income is used because travel budgets are based on total income rather than just wages and because all family members (not just the wage earner) are affected by travel delays. Accordingly, Table A3 shows the hourly value of personal travel based on dividing household income by 2,080 and then using one-half the value, where median household income for the region is estimated by the author from Table S1903 and Table B08201 of the 2006-2010 ACS (U.S. Census Bureau, 2011d). The use of one-half the hourly income is itself comprises an assumption; a review of Martin and McGuckin (1998) suggested that the relationship between hourly income and value of travel time (e.g., 50% in the case of Table A3) matters as much as the income level itself.

Trottenberg (2011) suggested that the hourly value of *business travel* can be based on the gross *wage*, which is also shown in Table A3. For comparison, with this value, Table A3 also shows the values that would have been obtained had the regional price parity been used. A review of work by Thiess (2012) suggested that it may be possible to use regional price parities to derive an hourly value of time. In her application, Thiess converted a national poverty wage ($10.73) to state-level poverty wages by multiplying the national wage by the state's regional price parity relative to 100 (the national average). For instance, for years 2005 and 2006, Aten and D'Souza (2008) had reported that New York's regional price parties were, respectively, 131.0 and 131.8, for an average of 131.4. Accordingly, the $10.73 multiplied by the ratio (131.4/100) yields $14.10, which, as reported by Thiess, is the poverty level for New York State.

A caution in deriving Table A3 is that there are differences in how *income* is defined. For example, the BEA (2012a) reported that the 2009 per-capita personal income for the United States as a whole was $38,846; with an average household size of 2.59 persons, a U.S. household income would be roughly $100,611. By contrast, the U.S. Census Bureau (2011d), based on the 2006-2010 ACS (see Table S1903), reported a median household income of $51,914, which is considerably closer to the median value used by Trottenberg (2011) of $49,777. For this reason, Table A3 used household incomes from the U.S. Census Bureau rather than from the BEA. It appears the difference may be attributable to definitions; the BEA (2012) included "employer-provided health insurance, dividends and interest income, social security benefits, and other types of income" along with wages and salaries, whereas the U.S. Census Bureau (2012) reported certain exclusions from income, such as "medical care, employer contributions for

Table A3. Hourly Values of Travel Time Based on Median Income

Region	Personal Travel (2010$)	Business Travel (2011$) Based on Regional Median Wage	Business Travel (2011$) Based on State Median Wage and Regional Price Parity
Lenowisco PDC (1)[a]	$7.98[a]	$12.89[a]	$14.03[a]
Cumberland Plateau PDC (2)	$7.82	$12.89	$14.03
Mount Rogers PDC (3)	$8.75	$14.12	$14.03
New River Valley PDC (4)	$9.93	$15.13	$14.44
Roanoke Valley-Alleghany Regional Commission (5)	$11.75	$14.65	$15.16
Central Shenandoah PDC (6)	$11.02	$14.27	$14.89
Northern Shenandoah Valley Regional Commission (7)	$13.40	$15.25	$15.15
Northern Virginia Regional Commission (8)	$24.16	$23.87	$19.81
Rappahannock-Rapidan Regional Council (9)	$16.61	$14.41	$18.26
Thomas Jefferson PDC (10)	$13.78	$16.13	$16.64
Virginia's Regional 2000 Local Government Council (11)	$10.77	$14.00	$14.77
West Piedmont PDC (12)	$8.94	$13.37	$14.46
Southside PDC (13)	$8.52	$13.12	$15.18
Commonwealth PDC(14)	$9.26	$13.12	$15.18
Richmond Regional PDC (15)	$14.64	$17.19	$16.19
George Washington Regional Commission (16)	$18.77	$20.65	$18.13
Northern Neck PDC (17)	$11.82	$14.44	$15.18
Middle Peninsula PDC (18)	$13.23	$15.82	$15.18
Crater PDC (19)	$11.14	$16.14	$15.00
Accomack-Northampton PDC (22)	$9.59	$14.44	$15.18
Hampton Roads PDC (23)	$14.03	$15.84	$16.54
Average	$15.86	$17.45	$17.45

[a]Example: For the Lenowisco PDC, the estimated annual median household income derived from Table S1903 and Table B08201 of the 2006-2010 American Community Survey (U.S. Census Bureau, (2011d) was $33,191, which, when divided by 2,080 hours per year, yields $15.96 per hour. Based on the assumption that personal travel is one-half this value (Trottenberg, 2011), the value of time for personal travel in this region is $7.98. Based on a review of data from the Bureau of Labor Statistics (2012a,b), the median wage for all occupations in this region is $12.89, which is the value of time for business travel. A value of time based on regional price parities (RPP) would be estimated as the RPP for the Lenowisco PDC (81.1) divided by the statewide average Virginia RPP (101.5) and then multiplied by the median wage of $17.45 to yield $14.03.

individuals." Further, the per-capita values calculated from the BEA (2011c) and adjusted for inflation from the BLS (2012c) are mean values whereas the U.S. Census Bureau (2011d) used median values. Despite these differences, common trends in terms of income distribution are evident in Table A4. For example, whether median household income (based on the census) or per-capita income (based on BEA data) is used, the Southside PDC has between slightly more than one-half (54%) and almost two-thirds (65%) of the statewide income value.

Table A4. Per-Capita Incomes and Median Household Incomes for Virginia Regions

PDC	Per-Capita Income Based on Bureau of Economic Analysis (2011a,c) in 2011 Dollars		Median Household Income Based on U.S. Census Bureau (2011d) in 2010 Dollars	
	Per-Capita Income	Percent of Statewide Value	Median Income	Percent of Statewide Value
Lenowisco PDC (1)	$30,010	66%	$33,191	50%
Cumberland Plateau PDC (2)	$31,223	68%	$32,517	49%
Mount Rogers PDC (3)	$30,262	66%	$36,412	55%
New River Valley PDC (4)	$29,516	65%	$41,290	63%
Roanoke Valley-Alleghany Regional Commission (5)	$39,680	87%	$48,874	74%
Central Shenandoah PDC (6)	$32,845	72%	$45,836	69%
Northern Shenandoah Valley Regional Commission (7)	$36,154	79%	$55,730	84%
Northern Virginia Regional Commission (8)	$63,702	140%	$100,487	152%
Rappahannock-Rapidan Regional Council (9)	$42,733	94%	$69,114	105%
Thomas Jefferson PDC (10)	$43,532	95%	$57,318	87%
Virginia’s Regional 2000 Local Government Council (11)	$33,184	73%	$44,789	68%
West Piedmont PDC (12)	$31,032	68%	$37,178	56%
Southside PDC (13)	$29,618	65%	$35,445	54%
Commonwealth PDC(14)	$27,663	61%	$38,527	58%
Richmond Regional PDC (15)	$44,029	97%	$60,919	92%
George Washington Regional Commission (16)	$40,645	89%	$78,063	118%
Northern Neck PDC (17)	$38,608	85%	$49,168	75%
Middle Peninsula PDC (18)	$39,074	86%	$55,041	83%
Crater PDC (19)	$35,038	77%	$46,338	70%
Accomack-Northampton PDC (22)	$34,991	77%	$39,883	60%
Hampton Roads (23)	$41,354	91%	$58,356	88%
Statewide	$45,595	100%	$65,975	100%