Making the Case for Transit:
WMATA Regional Benefits of Transit

Technical Report

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Acknowledgements

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Introduction

Purpose

This purpose of this Technical Report is to assess the benefits associated with the transit services currently provided by the Washington Metropolitan Area Transit Authority (WMATA/Metro) and all transit agencies within the Washington, D.C. metropolitan area. These benefits include avoidance of additional road capacity and parking costs, travel time savings, travel cost savings, accident reduction savings, emissions reduction savings, and land value premium impacts. The study was designed to answer Metro's question, "What are all the types of benefits generated by WMATA's operation in the region, and how can we measure them?"

In response, this report was developed to identify, and where possible estimate, the value of Metro and all transit services in the region in a number of different ways—from avoided auto parking, to property value impacts—to appeal to a range of stakeholders. The report is not a cost-benefit analysis on the existence of Metro, nor should its results be construed as such. Instead, it is designed to give multiple audiences a sense of transit's role in the region using a variety of metrics by simply describing the variety of ways Metro and all transit services have impacted the metropolitan region.

One primary way this report measures the value of public transportation is by predicting the effects of removing all transit services for the region. One of the best ways to understand the value of something is to take it away. This is, of course, a hypothetical situation. Without transit, the Washington region probably would look very different than it does today, and land use patterns would be substantially altered. However, that is exactly the effect that this report tries to measure. By imagining the region without transit, it is possible to understand the role and value in the economy of the Washington metropolitan area.

Background

Public transportation in the Washington D.C. metropolitan region has grown successfully in recent decades. The Washington Metropolitan Area Transit Authority (WMATA) Compact was established in 1967. The heavy rail network now stretches 106 miles, and the bus and paratransit systems have been expanded to cover over 1,500 square miles. Around 1.2 million riders board the WMATA system each day, and many more board other regional transit services.

The success of public transit in Washington has required substantial monetary resources from local, regional, and federal funding partners, and the transit system continues to need capital and operating investment. The 2010 Capital Needs Inventory (CNI) identified $11 billion of capital investment needs over the next ten years (year-of-expenditure dollars) to maintain existing infrastructure and meet customer demand. In addition, the region is actively planning to expand transit services, including surface transit and heavy rail extensions.

Given the magnitude of the Washington region's usage and investment in transit, it is worth contemplating transit's broader impacts on the regional economy and transportation network. The funding needs to maintain and expand the transit system are substantial, and should be viewed in the context of the benefits they provide. Against a backdrop of funding needs, a crucial unanswered question is, "how is the region impacted from continued funding of Metro and the public transit system?"

Metro wished to take a comprehensive measurement of the economic, mobility, and other impacts of its transit services, and create a "business case" for transit funding. In doing so, Metro wanted to quantify its benefits using metrics and measures consistent with a variety of internal, regional, and federal initiatives.

- Internally, Metro is analyzing different scenarios of expansion in its Regional Transit System Plan. Additionally, the Authority's CNI identifies over $11 billion in investment need by 2020 to replace rail cars, rebuild infrastructure, and reinvest to maintain a state of good repair and meet customer demand. The benefits of transit will help put results and recommendations from both of these efforts into context, so decision makers can make informed choices.
- Regionally, the Region Forward plan, prepared by the Greater Washington 2050 Coalition, outlines desires to create a more sustainable community through transit investment. It forms a planning guide to help measure regional progress toward a more livable future and outlines specific goals, targets and indicators that should be directly correlated to the efforts of this study.
- On the federal side, the partnership on livability between HUD, DOT and EPA has created a guiding set of livability principles that identify specific goals for strengthening federal efforts to ensure that infrastructure investments will protect the environment and develop livable communities. Many federal grant programs use livability and economic impacts in their grant award criteria, and Metro sought enhanced understanding of the different ways to measure the benefits of current and future transit services.

Steering Committee

Metro convened a group of outside experts and stakeholders to oversee and guide the study. The Committee held three meetings over the course of the study to suggest benefits metrics and methodologies, define and select benefits metrics, review and provide feedback to the study, and disseminate the results. The Steering Committee reviewed the work of the study but did not formally approve it. The Committee was comprised of regional stakeholders, federal liaisons, and outside experts, including the following organizations:

- Federal Transit Administration (U.S. Department of Transportation)
- Greater Washington Board of Trade
- Maryland Department of Transportation
- Northern Virginia Transportation Commission
- District of Columbia Office of Planning
- Center for Clean Air Policy
- Brookings Institution
- Urban Land Institute
- Downtown D.C. Business Improvement District
- D.C. Business Improvement District Council
- Restaurant Association of Metropolitan Washington

Literature Review and Background Research

To help establish a wide range of different indicators of benefits, Metro reviewed existing nationwide literature on economic and other metrics. The review focused both on traditional economic benefits analyses, as well as newer literature and methodologies. Metro reviewed a number of Authority, regional and federal initiatives for a policy-level understanding of how national and regional policy is viewing transit investments. The review highlighted the following sources as a summary of current thinking on the economic and other benefits of transit:

- Federal HUD-DOT-EPA Partnership for Sustainable Communities, and FTA Livable and Sustainable Communities program
- Inventory of Commercial Space Proximate to Metro Stations, WMATA, 2005
- 30 Years of Smart Growth: Arlington County's Experience with Transit Oriented Development in the Rosslyn-Ballston Metro Corridor, Arlington County, 2008
- Fiscal Impact of Metrorail On The Commonwealth of Virginia, NVTC 1994
- The Economic Impact of Transit Investment: A National Survey, Canadian Urban Transportation, 2010
- Traffic *Impact Analysis: Effects Of The Absence Of Bart Service On Major East Bay Corridors*, Jorge Laval, Michael Cassidy and Juan-Carlos Herrera, Institute of Transportation Studies, UC Berkeley, 2004

These sources helped establish a range of benefit metrics, from which Metro and the Steering Committee narrowed down to a smaller subset of metrics to quantify. The full literature review can be found in the Appendix of this report.

Initial Economic Benefits Metrics

At the midpoint of the study, the initial list of economic benefits metrics included the following:

	Lane miles of additional road infrastructure averted due to current Metro bus and rail service, and corresponding capital and maintenance costs saved
	Number of parking spaces avoided and corresponding acres of land available for other uses in the Washington region due to the Metro bus and rail system
	Commercial and residential property value differentials with proximity to Metrorail stations. Total value of development near stations, and the differential near/not-near stations.
	Average per-acre *property tax* revenues generated within ½ mile of Metrorail station and ¼ mile of Metrobus compared to jurisdictional per-acre average, and compared to within X proximity to highways
	Direct and indirect jobs created by Metro (number, wages, job types: opportunities for low-income workers, manufacturing, construction, and construction suppliers, etc.)
	Overall number and variety of businesses (or sf of retail) within 1/2 mile of Metrorail stations and ¼ mile of bus corridors.
	Average per-acre *sales tax* revenues generated within a 1/2 mile of a Metrorail stations compared to jurisdictional per-acre average
	Job Accessibility. Effect of transit on employer access to labor or employee access to jobs. Amount of land where employers can locate and reach XX employees by transit.
	Annual passenger miles/trips taken on Metro and avoided annual VMT.
	Additional annual hours that *would be lost* to higher levels of traffic congestion if Metro service were discontinued and corresponding dollar value
	Same as (12), for truck congestion cost, based on delay and commodity value (combine with # 12)
	Number of *transit-dependent riders* in the region relying on Metro – elderly, disabled, lower-income (includes Metro rail and bus riders and paratransit riders)
	Number of annual work and non-work trips taken on Metro bus and rail, and break down of what those trips are for (e.g., work commute, shopping, errands, school, entertainment, etc.)

	Gallons of gasoline/barrels of oil saved from X% of mode shift from SOV to Metro, and corresponding dollar value (oil per $GDP)
	Tons of greenhouse gases saved by X% mode shift to Metro and/or by X% reduction in traffic congestion, and corresponding dollar value (if possible)
	Net tons of air pollutants saved (PM, CO, NO_x, SO_2), and dollar value of the savings
	Water runoff measured as the net acreage of impermeable surfaces from parking lots and roads that would be needed to accommodate uptick without Metro service
	Death, injury, and accident risk for a driver versus a Metro rider in the Washington region. Number of deaths, injuries, and accidents averted due to Metro (from reduced cars traffic) and corresponding dollar value.
	Public Safety and emergency preparedness, transit's role in evacuation
	Annual household savings from lower car ownership and operation costs to families living near Metro service (housing + transport HH costs; tax reduction for infrastructure)
	Annual Metro bus and rail trips taken by the following groups: senior citizens, low-income households, non-drivers, and persons with disabilities. Projected number of transit-dependent seniors in the Washington region by 20*XX*. Number/percent of seniors and non-drivers confined to the home due to lack of transportation options.
	Number of music/cultural venues, restaurants, cafes, bars, parks, etc. near Metro (hipness factor; also as a percentage of X% of venues, Y% of land near Metro)
	Numbers of people served by Metro bus and rail service (living within ½ mile of rail stations and bus corridors
	Number of people moved annually for special regional events (e.g., sporting events, marathons, festivals, major concerts, national rallies, etc.)
	Number and percentage of federal employees who use Metro (enrolled in SmarTrip)
	Annual number of tourists using Metro rail and bus to visit the region

Report Organization

The Technical Report is organized as follows. The Executive Summary provides an overview of the Regional Benefits of Transit Study. Section 1 summarizes the travel scenarios used to develop the study. It is followed by a discussion in Section 2 of the technical approach developed and travel demand modeling tool employed to estimate and quantify the mobility benefits of transit in the region. The results of this modeling approach are summarized in Section 3 with operating statistics, such as travel time saved, vehicle miles traveled (VMT) reduced, and construction of additional roadway capacity avoided. Section 4 describes the methodology used to monetize the transportation mobility benefits offered by Washington, D.C.'s transit services, and Section 5 summarizes the capital expenditures that would be required to provide the additional roadway lane miles needed to keep the level of service the same in the absence of transit. Section 6 addresses the land value premium analysis data, estimation, and results. Section 7 provides a summary table of the monetized transportation and mobility benefits offered by transit in the Washington, D.C. metropolitan area. Lastly, Section 8 provides a list of benefit outcomes by type that were identified during the Regional Benefits of Transit Study. A literature review is provided in the Appendix.

Executive Summary

With Metro, the region works. Without Metro, the region would be less wealthy, harder to get around, and have less economic activity. Families would spend more getting around.

Without Metro, the Capital Region could not easily serve constituents from across the country, and would not function as the world-class capital that the United States needs and deserves. Metro provides local, regional, and national benefits that extend beyond traditional measures of mobility.

This report details Metro's critical role in the Capital Region: the benefits Metro brings to the region's economy and to its ability to function smoothly as the capital of the United States. This report details the benefits that Metro delivers to the Capital Region. This Executive Summary summarizes the findings. The body of the report details the methodologies used and discusses the results in more detail.

I. Metro is an outstanding investment of public funds and is vital to the Capital region's economy

1. Metro boosts property values—adding 6.8% more value to residential, 9.4% to multi-family, and 8.9% to commercial office properties within a half-mile of a rail station. [1] *Property becomes significantly more valuable as a property gets closer to Metrorail stations.*

2. The demand for locations near Metrorail stations produces approximately $133M (¼ mile) to $224M (½ mile) in additional revenues from property taxes due to the premium associated with properties located near rail stations. [2]

The real estate located within ½ mile and ¼ mile of Metrorail stations generated approximately $3.1B and $1.8B in property tax revenues for the Compact area[3] in 2010, respectively.[4]

Within a ½ mile of Metrorail stations: D.C. collected $2.26B, Virginia collected $470M, and Maryland collected $355M. While within a ¼ mile of Metrorail stations, D.C. collected $1.37B, Virginia collected $290M, and Maryland collected $124M.

[1] Based on a series of hedonic regressions of data compiled from GIS shapefiles obtained from either the real estate assessor's office or department of tax administration.
[2] Estimate based on premium analysis of parcel assessment data from Compact area jurisdictions, property tax rates for the local jurisdictions, Business Improvement Districts, and federal government payments to the District for courts, defender services, and offender supervision. Additionally, the ½ mile revenues include the ¼ mile revenues.
[3] The WMATA Compact area includes the District of Columbia, the cities of Alexandria, Falls Church, and Fairfax and the counties of Arlington, Fairfax, and Loudoun and political subdivisions of the Commonwealth of Virginia located within those counties, and the counties of Montgomery and Prince George's in the State of Maryland and political subdivisions of the State of Maryland located in these counties.
[4] Estimate based on GIS analysis of parcel assessment data from Compact area jurisdictions, property tax rates for the local jurisdictions, Business Improvement Districts, and federal government payments to the District for courts, defender services, and offender supervision. The ½ mile revenues include the ¼ mile revenues.

The value of real estate located within a ½ mile of Metrorail stations represents 27.9% of the Compact area's tax base on 4% of its land, including 68.1% for D.C., 15.3% for Virginia, and 9.9% for Maryland. [5]

New Metro(rail) station produces new jobs and private investment

"Prior to the addition of the New York Avenue Metro(rail) Station, the Washington, D.C., Metro system bypassed an urban, economically underdeveloped neighborhood known as NoMa, for its location north of Massachusetts Avenue. NoMa enjoyed good regional location and road access, but lacked good rail access. The opening of the Metro(rail) station dramatically changed the area.

Assessed valuation of the 35-block area increased from $535 million in 2001 to $2.3 billion in 2007. Over 15,000 jobs have been created since 1998 with $1.1 billion in private investment. This increase in property values (300 percent between 2001 and 2007) has attracted further real estate development and residents."

– National Council on Public Private Partnerships (NCPPP), Case Study: New York Avenue Metro(rail) Station, Washington, D.C.[6]

3. Metro supports businesses, so businesses locate near Metro.

Economic activity tied to Metro's presence is critical to the economic success of the region. Businesses locate near Metrorail stations because it expands their pool of employees and their pool of customers.

Metro knits the region into a whole, enabling employment, shopping, and entertainment across communities, which would be impossible with roads alone.

"We have come a long, long way from the bad old days of a deserted, dilapidated and dangerous downtown during the evening hours and few destination retail and entertainment neighborhoods. The establishment and growth of vibrant areas such as Penn Quarter, Ballston, U/14th Street Corridors are directly attributable to transportation access for patrons, visitors and employees."

– Claude Andersen, Metropolitan Washington Restaurant Association[7]

4. Metro saves families $342 million per year in car operating expenses.

Even as property values increase near Metro, Metro reduces total household expenses by reducing transportation costs. Annual savings from lower car operation costs to families living near Metrorail stations and/or bus corridors is $342 million ($2010) annually. [8]

[5] GIS analysis of parcel assessment data and total jurisdiction assessment values
[6] NCPPP, "New York Avenue Metro Station, Washington, D.C.", www.ncppp.org/cases/nystation.shtml.
[7] Letter to WMATA Board, April 2, 2010
[8] Based on estimated VMT avoided from the MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use and variable per mile costs of auto use from AAA's Your Driving Costs, 2010. These savings do not include vehicles that would have to be purchased by zero-car households.

II. Metro serves people from across the country and is vital to a Capital Region that works

Metro carries millions visiting their representatives, their government, and their history. Thanks to Metro, Americans from around the country can easily visit Congressional offices, visit the Monumental Core, and move in and out of town without a car.

Metro benefits the nation by supporting a Capital Region that works. The region's remarkable density of public and private offices, close to Congress and the White House, is made possible by Metro. In the absence of Metro, the parking necessary to accommodate federal workers alone would cover downtown.

Similarly, the roads necessary to accommodate those who use Metro would have fundamentally changed the character and look of the region.

Without additional roads, congestion in the region would be significantly higher, discouraging investment, sapping budgets, and interfering with the efficient functioning of all parts of the government.

One in 10 Metrorail trips begins or ends at a station adjacent to the U.S. Capitol or the Pentagon.[9]

5. Metro serves people from across the country

Every year, Metro transports more than 8 million Americans visiting the nation's capital.[10]

Metro's highest ridership days are days on which special events occur on the National Mall. Rail ridership on the day of President Reagan's memorial service in 2004 was over 850,000.[11] On Inauguration Day 2009, Metro provided 1,120,000 rail trips, 423,000 bus trips, and 1,721 MetroAccess trips for a total of 1,544,721 trips.[12]

Special events in the area relied on Metrorail alone for over 3.5 million passenger trips during 2010. A few of the major events relying on Metrorail in 2010:[13]

- Annual Cherry Blossom Festival, drawing visitors from around the world: 300,000 to 500,000 trips
- July 4th celebration: over 580,000 trips
- October Marine Corps Marathon: over 60,000 trips
- Sporting events all year for the Nationals, Redskins, Capitals, Wizards, Mystics, and D.C. United: almost 1.5 million trips.

[9] WMATA, 2004 WMATA Strategic Alliances and Risk Assessment Program
[10] Calculation based on the 2007 WMATA Rail Survey
[11] 2004 WMATA Strategic Alliances and Risk Assessment Program
[12] Metro, "Metrorail sets new record for highest ridership day of all time", press release, January 20, 2009. http://www.wmata.com/about_metro/news/PressReleaseDetail.cfm?ReleaseID=2439
[13] WMATA estimation of ridership from special events.

2010 was typical; however, Metro also enables a wide variety of events that would otherwise be difficult or impossible to serve. Further, Metro enables the region to host more than one large event at a time, as befits its role as a world-class city. For example, on July 11, 2008, Metrorail carried 854,638 people, the day of the Women of Faith Conference and a Nationals baseball game.

6. Metro moves federal workers

35% of the weekday trips on Metrorail are made by federal employees: 249,087 trips.[14] Building parking to accommodate those employees would cost the taxpayers approximately $2.4 billion for below ground parking ($2010).[15]

The federal government is the largest employer in the region. Almost one half of peak period riders are commuting to or from federal jobs, and, at other times of the day, federal employees use Metro to take care of government business.[16]

Metro is a critical recruitment and retention tool for federal employers. Approximately 170,000 federal employees use the SmartBenefits federal transit benefit program[17]; this is 45% of the region's 375,000 federal workers.

7. Metro makes room for the historic and productive parts of the region

Without regional transit (not just Metro), the region would need to add over 1,000 lane-miles of arterials and highways to maintain current travel speeds, assuming people kept choosing the same destinations—this length is equivalent to adding more than 15 lanes to the entire circumference of the Capital Beltway. [18] Many bridges would require 2 or 3 additional lanes in each direction.

710 of those miles would be necessary to directly replace Metro service. Estimated capital cost of those new lanes: $4.7 billion ($2010).[19] The other 300 miles of new highway would be needed to replace other regional transit—transit whose ridership would almost certainly drop significantly without Metro. For example, MARC service to Union Station would lose substantial ridership without Metro, so that even if MARC existed without Metro, many current MARC riders would be on the road.

Those new cars would require parking spaces: roughly double the number of current spaces in the D.C. and Arlington cores. [20] Capital cost of additional parking is $2.9 billion for below-ground parking ($2010).[21]

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[14] 2007 Metrorail Passenger Survey
[15] Assumes 327 SF per parking space (the average for all WMATA parking facilities, including parking, curves, ramps, etc. and uses average SF construction costs for underground parking garages from RS Means (2007). In addition, it is important to note that not all spaces would have to be built because some portion could be accommodated by excess capacity at existing garages or lots. However, the occupancy rates of current parking facilities in the D.C. and Arlington Cores is unknown.
[16] WMATA, "2004 WMATA Strategic Alliances and Risk Assessment Program"
[17] WMATA, "2004 WMATA Strategic Alliances and Risk Assessment Program"
[18] Estimated by the MWCOG Version 2.3.17 Regional Travel Demand Model with 8.0 Land Use
[19] Uses average road and bridge construction costs per mile for the region. These costs do not include right-of-way purchases or the purchase of vehicles that would be required for some zero-car households.
[20] Estimated by the MWCOG Version 2.3.17 Regional Travel Demand Model with 8.0 Land Use

Since the core is essentially built out, new parking would require razing buildings—removing tax base and employment.

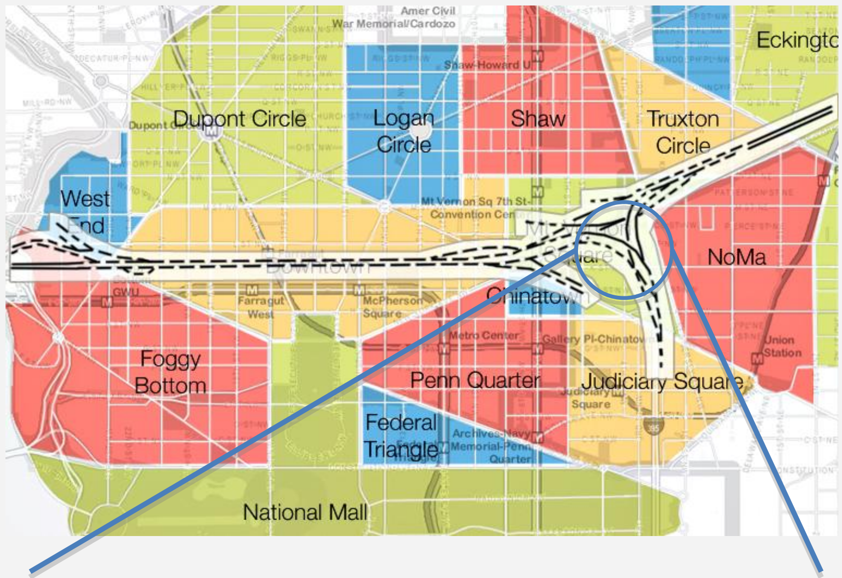
The region's economic and population growth potential is constrained by its ability to move people and goods. As the area has limited space available in which to expand roads, future growth will depend on continued capacity growth in the Metro system.

[21] Assumes 327 SF per parking space (the average for all WMATA parking facilities, including parking, curves, ramps, etc. and uses average SF construction costs for underground parking garages from RS Means (2007). This cost of additional parking includes the parking costs associated with federal employees reported earlier. It is not in addition to the federal parking costs. In addition, it is important to note that not all spaces would have to be built because some portion could be accommodated by excess capacity at existing garages or lots. However, the occupancy rates of current parking facilities in the D.C. and Arlington Cores is unknown.

Building Metro allowed and produced economic development

Plans in the 1970s to improve access to the core included building interstates directly through the city. The region chose to use Metro to provide that access rather than take land for highways. Where there would have been highways, thriving neighborhoods now exist.

Without Metro: access with highways puts an interchange in Mount Vernon Square.



With Metro: Live, work, play.

In particular, much of the Mount Vernon Square neighborhood would have been lost to a large interchange. At the time, the interchange would have displaced 845 dwelling units and 97 commercial and industrial firms employing 980 people.

As the area has developed, north of New York Avenue, we now have a neighborhood of row houses, small apartment buildings, and churches. The sidewalks are brick and shadowed by tall trees. On New York Avenue, we have several restaurants, bars, and a car mechanic.

The City Vista block (east of 5th, between L and M) would have been parking above the freeway. Thanks to Metro, we instead have a vibrant development: apartments, condominiums, a large Safeway, a mobile phone store, a bank, a hardware store, a variety of restaurants (some with outdoor seating), a gym, and a Starbucks. A farmer's market has opened up a block away. It is a half to three-quarters of a mile to three subway stations, and only a mile to a fourth: Union Station where you can also connect to the Amtrak lines going all up the east coast.

In short, this is a great neighborhood with lots of variety and everything its residents need. Had the region chosen the freeway instead of Metro, we would have lost this neighborhood and its contributions to employment, taxes, and quality of life.

Sources: Map and description of displacement adapted from "District of Columbia Interstate System 1971," November 1971, De Leuw, Cather Associates and Harry Weese & Associates, Ltd. City Vista photo: Sean Robertson.

8. Transit saves the Capital region almost 148,000 hours/day from being lost to traffic congestion.[22]

If the more than 1 million daily regional transit trips switched to driving, and roadways were not expanded, the region would initially experience at least a 25% increase in congestion during rush hours.

Over time, people would respond to the congestion by shifting to destinations closer to home. Individuals would make fewer trips from town to town as households selected different locations in which to work, live, and play.

The regional economy would fragment, losing some of the benefits of its size. Opportunities for each resident, and each employer, would shrink, damaging residents' opportunities and employers' labor pools. The region overall would become far less competitive with other regions; in effect, rather than the entire region competing with, say, Boston, Fairfax would compete with Boston.

III. Metro provides numerous other benefits

- *Public safety and emergency preparedness*

  Metro provides an indispensable part of the Capital Region's emergency preparedness. On September 11, 2001, Metro facilitated the safe evacuation of hundreds of thousands of people; moving such numbers of people would not be possible without Metro.

[22] Estimated by the MWCOG Version 2.3.17 Regional Travel Demand Model with 8.0 Land Use

- *Jobs and access to jobs*
  - 14,900 direct and indirect jobs supported by Metro operations. [23]

> "All of my 30 staff members depend on the Metro system to get to and from work." "During snow storms, when Metro was closed, both guests and especially staff had a problem getting to the restaurants. My staff counts on Metro to get to work and to get home at the end of the night." – Restaurant Association Metropolitan Washington (RAMW) Member survey

  - 2.0 million jobs (or 54% of all regional jobs) are accessible within a ½ mile of Metrorail stations and Metrobus stops. 300,000 more jobs are accessible within 1 mile of Metrorail stations and Metrobus stops.[24]

- *Mobility*
  - Metrorail carried 217 million trips in 2010, and Metrobus, 123 million trips.[25]
  - About 20% of Metrorail riders and 53% of Metrobus riders are from zero-car households.[26]
  - Metrobus serves a diverse population

    4% of riders are Asian; 59%, Black/African American; 10%, Hispanic; 1%, Native American; 19%, White; and 2%, multi-racial.[27]

    Household incomes vary widely: 19% of riders have an annual household income under $10,000; 11%, $10-20,000; 23%, $20-40,000; 14%, $40-60,000; 12%, $60-100,000, and 9% over $100,000.[28]
  - Metro carries people for many purposes.

    For Metrorail passengers, 83% of trips are to work/home, 4% are job-related, 5% are personal, 2% are school, 3% are shopping/meals, and 2% are sightseeing or recreational trips.[29]

    For Metrobus, 73% of trips are to work/home, 3% are job-related, 12% are personal, 5% are school, 4% are shopping/meals, and 3% are sightseeing or recreational trips.[30]

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[23] Direct jobs reported in WMATA's Proposed Fiscal 2012 Annual Budget, total jobs (direct+indirect+induced) estimated using RIMS II direct effect multipliers for the Transit and ground passenger transportation industry in the Washington, D.C. MSA (2002/2007)

[24] Employment data is based on Round 8.0 co-operative forecasts for 2007 and WMATA service based on MWCOG version 2.3 model for 2007.

[25] WMATA 2010 Metro Facts, http://www.wmata.com/about_metro/docs/metrofacts.pdf

[26] 2007 Metrorail Passenger Survey

[27] 2008 Regional Bus Survey.

[28] 2008 Regional Bus Survey.

[29] Trip purpose from 2007 Metrorail Passenger Survey

[30] Trip purpose from 2008 Regional Bus Survey, for WMATA Routes only

- *Fuel Savings*

  Travel by Metro instead of auto saves 40.5 million gallons of fuel annually.

- *Cleaner air*

  About 260 tons VOC, 22 tons PM, and 0.5 million tons of CO2 are avoided in the region due to reduced auto use associated with all transit services in the region.[31] Taking into account the emissions associated with WMATA's services, the estimated monetary value of environmental savings is $9.5 million ($2010) annually.[32]

[31] Estimate based on estimated VMT avoided from the MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use and emissions rates from WMCOG Air Quality Conformity Determination of the 2010 Constrained Long Range Plan and the FY 2011-2016 Transportation Improvement Program and the Sightline Institute.
[32] Calculation based on the 2007 WMATA Metrorail Passenger Survey

1.0 Study Scenarios

The following scenarios were developed in order to measure WMATA's contribution to the Washington regional economy. Two scenarios were developed. The first scenario estimates the volume of roadway capacity that would be required to maintain current levels of service if WMATA and other regional transit services were unavailable. The second scenario is constructed to examine how mobility in the region would change if WMATA and other regional transit services were not available to the region's travelers. A key difference between Scenarios 1 and 2 is the treatment of travel patterns. They are fixed in Scenario 1 in order to generate an estimate of road costs. By contrast, travel patterns are allowed to adjust in Scenario 2 as travelers adapt to rising congestion. The outcomes of Scenarios 1 and 2 are not additive.

- **Base Case**:
  - Basis for comparing conditions in the absence of transit
  - Represents current travel patterns and level of service on highway and transit

- **Scenario 1**: Lane miles of additional road infrastructure averted due to transit
  - Removes all transit service from the Base Case
  - Maintains the Base Case travel patterns
  - Adds highway capacity to return to the Base Case level of service

- **Scenario 2**: No additional investment in infrastructure
  - Removes all transit service from the Base Case
  - Regional travel patterns allowed to change

The three scenarios described above are modeled for current conditions (year 2007) using the latest release of the MWCOG Version 2.3.17 travel demand model. The Version 2.3 model is calibrated to the most recent household travel survey and transit on-board surveys (2007/2008). This version of the model also utilizes the most current (Round 8.0) land use information and features a detailed mode choice model which permitted the stratification of transit trips by WMATA and non-WMATA riders.

2.0 Travel Demand Technical Approach and Methodology

2.1 Base Case

The Base Case scenario serves as the basis for comparing Scenarios 1 and 2. The Base Case scenario model run is done with off-the-shelf transit and highway inputs, for year 2007, provided by MWCOG and is run with a full speed feedback loop. The person trip tables, mode choice results, highway and transit assignment results obtained at the end of fourth and final iteration speed feedback loop are considered the final outputs, representing the current travel patterns and level of service on highway and transit. The loaded highway networks output at the end of the fourth iteration speed feedback loop prior to the speed-volume averaging step are used as the basis for comparing the highway performance of Scenarios 1 and 2 (described below).

For Scenarios 1 and 2 specified above, the transit network input files are modified to remove all existing transit service from the region. The initial attempt at removing just the WMATA operated rail and bus service resulted in over-utilization of remaining transit service as the model is not transit capacity constrained, e.g. over 200,000 trips were assigned to Commuter rail. In order to keep the modeling part relatively simple, it was decided to remove all transit service from the region. To apportion the benefits related to WMATA service, factors were developed based on the WMATA share of the total transit passenger miles traveled on an average weekday.

2.2 Scenario 1

The objective of this scenario is to quantify the total lane miles of additional roadway infrastructure avoided throughout the region due to the use of transit. In order to determine this, it is assumed that the total person trips and their distribution remain unchanged——the same as the Base Case. The mode choice model is run with no transit paths to develop a set of auto person trip tables. Additional capacity is added to the highway segments to absorb the additional vehicles (relative to the Base Case) such that the level of service (volume over capacity – v/c ratio and loaded speeds) are returned to the Base Case conditions. This is achieved by using the final trip distribution output of the Base Case and iteratively running the model steps from mode choice to highway assignment (iteration 4's Mode_Choice.bat, Auto_Driver.bat, Time-of-Day.bat, and Highway_Assignment.bat).

Additional lanes (1, 2, or 3) are added to the segments of the base highway system (Freeways, Expressway and Major Arterials) that are already above v/c ratio of 1.0 in the Base Case. It is assumed that minor arterials and collectors have sufficient reserve capacity to handle the additional traffic volumes added to the system due to absence of transit. For freeways, the decision to add a lane for a segment is made if the additional volume requires at least half (0.5) a lane; two lanes are added if additional volume requires at least 1.5 lanes and three lanes are added if additional volume requires at least 2.5 lanes. For arterials, the decision to add additional 1, 2, or 3 lanes is triggered if additional volumes require at least 0.75, or 1.75, or 2.75 lanes respectively.

The analysis is done for both AM and PM peak period assignments. The total number of lanes added to each direction is computed by taking the maximum of AM and PM peak period assignment results. At the end of each iteration of converged highway assignment (AM and PM peak), the volume to capacity ratio is computed and compared to the Base Case to determine if the level of service is similar to the Base Case or not. The v/c ratio is compared before the speed volume averaging step is applied. This is necessary as the scenario assumes a fixed trip table between the Base Case and the scenario.

Finally, manual adjustments are applied to the additional lanes (plus or minus) requirement to avoid abrupt increase or decrease in number of lanes along the facility so that each segment/corridor is treated like a project.

Figures 1a and 1b show the segments of highway that require additional lanes to absorb the increase in auto traffic demand in the absence of transit. The width of the color line represents the number of lanes and the color of line distinguishes between freeway and arterials.

Figure 1a: Additional lanes required to handle traffic volumes diverted by transit

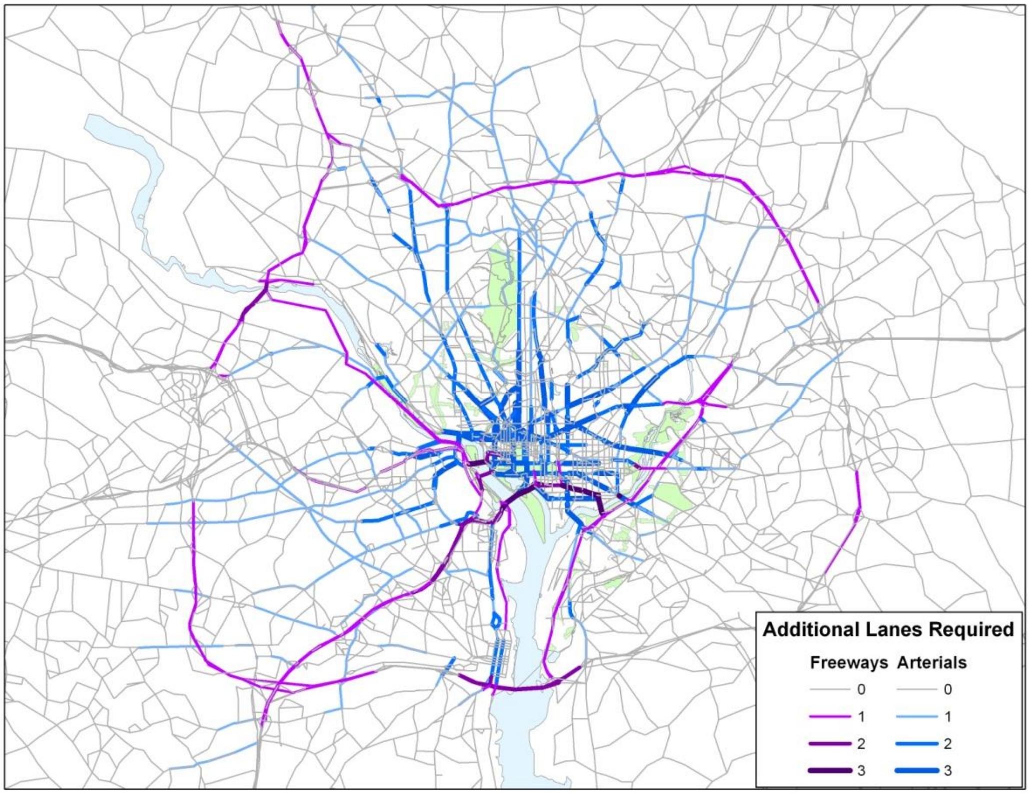
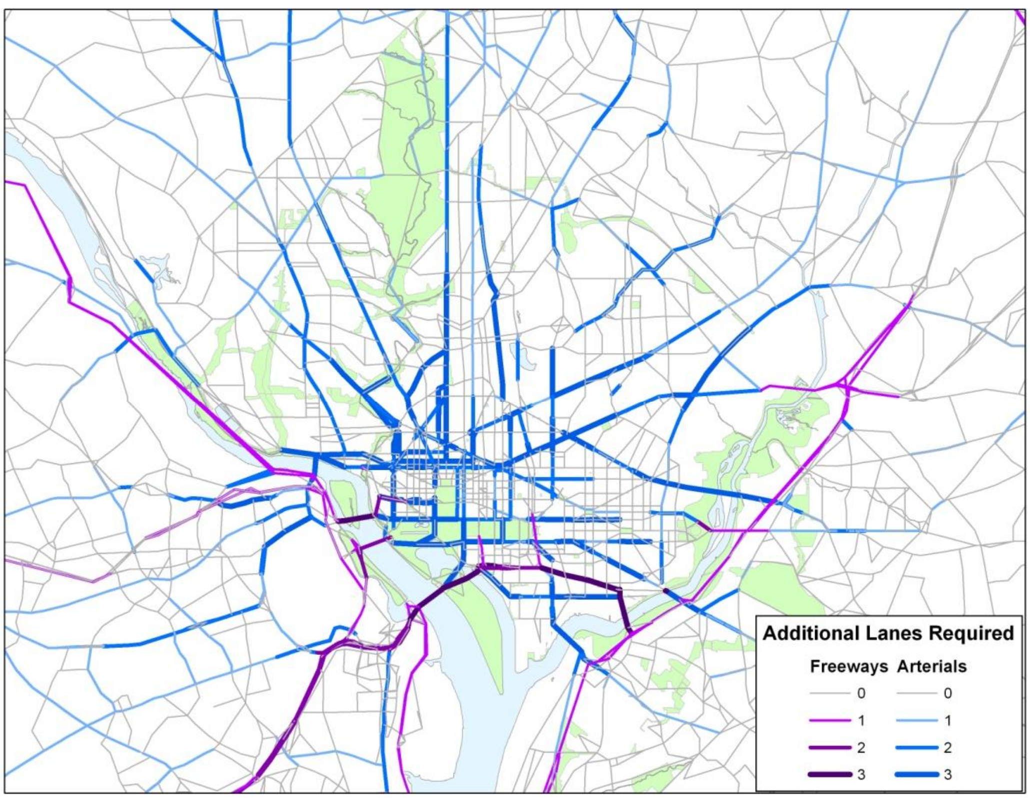


Figure 1b: Additional lanes required to handle traffic volumes diverted by transit



2.3 Scenario 2

The objective of this scenario is to measure the increase in travel time experienced by travelers if no additional improvements are made to the highway system and all transit service is removed from the region. Without any additional investment in infrastructure, it is expected that the travel patterns in the region will change. In order to model this scenario, the input transit networks are modified to remove all transit service from the region and a full run of the MWCOG model with four speed feedback loops is done. Since the trip distribution model uses composite impedance (includes transit and highway time), the gravity model is informed with a new set of impedances which affects the regional trip distribution. The output person trip tables are different from the Base Case.

The total motorized person trips at the end of final speed feedback loop are slightly higher than the Base Case even though the land use and trip-rates are kept un-changed. This difference is most likely due to the difference in non-motorized person trips between the two scenarios. It is our understanding that the non-motorized trip making uses transit accessibility as a measure of walking/biking and in the absence of transit, this measure makes it harder to walk/bike. Although this result is counter-intuitive, the difference in total peak trips is small enough to not affect the current analysis.

3.0 Travel Demand Results

Table 1 summarizes the key model statistics for the Base Case and two transit free scenarios described above. These results are for base year 2007 conditions. The preliminary key initial findings are summarized below for each scenario.

Please note that the two scenarios modeled are not complementary scenarios. The outcomes of these scenarios cannot be mixed and matched; instead the two scenarios help with measuring benefits of transit using different metrics. Also note that the land use assumptions are identical for all scenarios.

3.1 Scenario 1

Initial analysis shows that in order to maintain existing conditions in the absence of transit, that is existing travel patterns and travel speeds, significant improvements will be required to the freeways, expressway and arterials throughout the WMATA Compact region.

- Over 925,000 additional weekday one-way auto trips
- Over 1,000 lane miles of additional highway required to accommodate additional auto trips
- Various river crossings require 2 to 3 additional lanes per direction

3.2 Scenario 2

Initial analysis shows that average travel time increases by one quarter during the peak travel. It is also observed that increased congestion forces households to change travel patterns and choose different work and activity locations resulting in a more fragmented region. The travel patterns show that fewer inter-jurisdiction trips are made and an increase in intra-jurisdictional travel activity is observed (refer to Table 2).

Table 1: Year 2007 Average Weekday Statistics-Benefits of Transit Service in Washington Metro

		2007 Base Case	Scenario 1 (Additional highway infrastructure added to sustain current level of service) - 2007	Scenario 2 (No additional investment in infrastructure) - 2007		% Different w.r.t. Base Case: Scenario 1 (Additional highway infrastructure added to sustain current level of service) - 2007	% Different w.r.t. Base Case: Scenario 2 (No additional investment in infrastructure) - 2007
Mode Choice	Total Person Trips	17,296,062	17,296,062	17,480,869		0%	1%
	Total Transit Trips	1,085,060	0	0		-100%	-100%
	Total Auto Trips	16,211,003	17,296,062	17,480,869		7%	8%
	Total Vehicle Trips	15,318,021	16,244,215	16,380,181		6%	7%
Peak Vehicle Miles Traveled	D.C.	4,151,871	5,566,808	5,097,270		34%	23%
	MD Compact	20,244,453	22,024,936	21,660,599		9%	7%
	VA Compact	15,367,585	16,912,336	16,334,957		10%	6%
	Compact Total	*39,763,909*	*44,504,081*	*43,092,826*		12%	8%
Total Vehicle Miles Traveled	D.C.	8,785,253	11,339,887	10,542,166		29%	20%
	MD Compact	43,092,942	46,066,603	45,473,936		7%	6%
	VA Compact	32,564,111	35,231,537	34,217,286		8%	5%
	Compact Total	*84,442,307*	*92,638,028*	*90,233,387*		10%	7%
Peak Vehicle Hours Traveled	D.C.	231,159	272,842	524,643		18%	127%
	MD Compact	778,625	858,711	993,917		10%	28%
	VA Compact	645,307	699,731	856,461		8%	33%
	Compact Total	*1,655,092*	*1,831,283*	*2,375,021*		11%	43%
Total Vehicle Hours Traveled	D.C.	391,156	454,829	760,591		16%	94%
	MD Compact	1,387,164	1,492,221	1,661,086		8%	20%
	VA Compact	1,107,836	1,178,224	1,362,724		6%	23%
	Compact Total	*2,886,156*	*3,125,274*	*3,784,401*		8%	31%
Avg. Trip Length (Mi)	Peak	11.3	11.2	11.0		-1%	-3%
	Off-Peak	9.5	9.5	9.3		0%	-2%
	Daily	**10.3**	**10.3**	**10.1**		**-1%**	**-2%**
Avg. Speed (MPH) - Compact Jur.	Peak	24	24	18		1%	-24%
	Off-Peak	36	37	33		2%	-8%
	Daily	**29**	**30**	**24**		**1%**	**-19%**
Added Lane Miles (Freeway)	D.C.		51				
	MD Compact		71				
	VA Compact		107				
	Region wide		**230**				
Added Lane Miles (Arterial)	D.C.		390				
	MD Compact		202				
	VA Compact		189				
	Region wide		**781**				
Added Lane Miles (Total)	D.C.		441				
	MD Compact		274				
	VA Compact		296				
	Region wide		**1,011**				

Source: Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use

Table 2: District to District Person trip flows (Base Case vs. No Additional Infrastructure Scenario)

2007 Base Case: Total Motorized Person Trips

	D.C.	MD Compact	VA Compact	Rest of MD	Rest of VA	Total
D.C.	874,463	256,857	165,071	16,893	6,284	1,319,568
MD Compact	657,606	3,733,611	213,594	190,729	11,647	4,807,187
VA Compact	391,472	127,166	3,404,949	11,495	172,720	4,107,802
Rest of MD	132,978	296,811	90,233	3,663,626	25,760	4,209,408
Rest of VA	68,698	42,491	415,119	22,675	2,303,114	2,852,097
Total	2,125,217	4,456,936	4,288,966	3,905,418	2,519,525	17,296,062

2007 Scenario 2 (No additional investment in infrastructure): Total Motorized Person Trips*

	D.C.	MD Compact	VA Compact	Rest of MD	Rest of VA	Total
D.C.	926,696	254,033	161,374	17,433	6,559	1,366,095
MD Compact	624,463	3,791,541	187,821	208,831	11,116	4,823,772
VA Compact	347,466	103,058	3,460,675	10,437	178,699	4,100,336
Rest of MD	151,596	276,614	75,893	3,651,274	24,537	4,179,915
Rest of VA	74,035	33,654	400,622	20,548	2,297,084	2,825,944
Total	2,124,256	4,458,900	4,286,386	3,908,524	2,517,995	17,296,062

Difference: Total Motorized Person Trips (Scenario 2 minus Base Case)

	D.C.	MD Compact	VA Compact	Rest of MD	Rest of VA	Total
D.C.	52,233	-2,824	-3,697	540	275	46,527
MD Compact	-33,143	57,930	-25,773	18,102	-531	16,585
VA Compact	-44,006	-24,108	55,726	-1,058	5,979	-7,466
Rest of MD	18,618	-20,197	-14,340	-12,352	-1,223	-29,493
Rest of VA	5,337	-8,837	-14,497	-2,127	-6,030	-26,153
Total	-961	1,964	-2,580	3,106	-1,530	0

% Difference: Total Motorized Person Trips (Scenario 2 vs. Base Case)

	D.C.	MD Compact	VA Compact	Rest of MD	Rest of VA	Total
D.C.	6%	-1%	-2%	3%	4%	4%
MD Compact	-5%	2%	-12%	9%	-5%	0%
VA Compact	-11%	-19%	2%	-9%	3%	0%
Rest of MD	14%	-7%	-16%	0%	-5%	-1%
Rest of VA	8%	-21%	-3%	-9%	0%	-1%
Total	0%	0%	0%	0%	0%	0%

* Scenario 2 Person Trip Tables Normalized to Match Base Case Total
Source: Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use

4.0 Monetization of Operational Benefits

Transit in the Washington, D.C. metropolitan area provides transportation benefits to users in terms of travel time, travel cost, accident reduction, and emissions reduction savings that result from increases in mobility and reduced congestion and VMT in the region. These benefits are monetized using outputs from the MWCOG travel demand model, values of time, operating costs associated with auto and transit travel, and economic values of accidents and emissions.

The benefits in this section are estimated for Scenario 2 because this scenario represents a more accurate picture of transit's impacts today. If transit were not available, travelers would have to switch to auto travel, and the additional infrastructure needed to support this increase in demand would take decades to arrive. As a result, people would face severe congestion and gridlock that would force many to alter their trip origins or destinations in order to reduce their trips lengths and travel times.

4.1 Travel Time Savings

With Scenario 2 current transit users would be forced to switch to auto trips. As a result there would be a significant increase in travel time for all travelers because there is no additional highway infrastructure available to meet this increase in demand. This translates into a degradation in the network's level of service that affects where people choose to work and make trips. As a result, in Scenario 2 people choose work and activity locations closer to their homes, resulting in fewer inter-jurisdiction trips. While travel times are likely to increase in this scenario, the amount of the increase is tempered by the reduction in inter-jurisdiction trips.

The travel demand model estimates the changes in auto (vehicle travel time multiplied by average auto occupancy to get *auto person hours*) and transit travel time (*transit person hours*) separately, and therefore, the auto and transit travel time savings must be monetized separately. For example, the changes in auto travel time for Scenario 2 do not account for any previous time spent traveling on transit under the Base Case. However, for an estimate of total travel time saved with transit, the analysis should only consider the additional time spent traveling by auto (i.e. the time over and above the previous transit trips). Therefore, the previous time spent in transit travel must be netted out from the auto travel time analysis. Additionally, transit travel times from the travel demand model include out-of-vehicle time (i.e. wait times, transfer times, etc.), while the auto travel time only accounts for in-vehicle time. As a result, an out of vehicle auto time of 5 minutes per person-trip was added to the auto person hour estimates provided by the travel demand model results.

The travel demand model results indicate that the average weekday travel time savings associated with all regional transit service in 2007 is 56,587 hours for home-based work trips and 91,259 hours for non-work trips for Scenario 2. Of the total regional savings, 70 percent is associated with WMATA transit services, based on the percentage of regional transit passenger miles on WMATA. These time savings estimates represent a sum of auto and transit time savings. Auto time savings are based on the conversion of vehicle hours traveled to person hours using average auto occupancy for each scenario. Transit time savings are reported in person hours.

Both auto and transit time savings are further allocated to work and non-work trips based on the percentage of peak and off-peak trips that are home-based work. The travel demand model indicates that 35 percent of peak trips are home-based work and 16 percent of off-peak trips are home-based work.[33] The average weekday travel time savings are then annualized using a factor of 300[34] and

[33] The percentages come from the travel demand model for auto trips. The transit portion of the model is a 24-hour period model that assumes all work related trips occur in the peak and all non-work trips occur in the off-peak. This assumption is a simplification of the model that over states the amount of work trips that occur in the peak. As a result, the analysis applies the auto work trips percentages that occur in the peak and non-peak to the transit trips to better reflect the number of work trips occurring in the peak and off-peak.
[34] Annualization factor is from NTD.

monetized using the average hourly wage for the Washington, D.C. Metropolitan Statistical Area (MSA).[35] Using US DOT guidance, work based trips are valued at the full average hourly wage, while leisure (non-work based) trips are valued at 50 percent of the average hourly wage.[36]

Table 3 summarizes the annual travel time savings associated with Baseline in comparison to Scenario 2 for all regional transit services as well as for WMATA transit services in 2007. Scenario 2 yields a decline in roadway level of service—indicating there is an additional travel time cost or penalty (as opposed to savings) for the region that is associated with Scenario 2 compared to the Baseline.

Table 3: Travel Time Savings Associated with Regional Transit Service in 2007 (millions of 2010$)

	Auto				Transit				Annual Value of Total Travel Time Savings Assoc. with All Transit	Annual Value of Total Travel Time Savings Assoc. with WMATA (millions)
	Additional Travel Time Savings Per Person (millions of hours)	Average Annual Wage per Hour	Value of Time	Annual Value of Time Saved (millions)	Annual Time Savings Per Person (millions of hours)	Average Annual Wage per Hour	Value of Time	Annual Value of Time Saved (millions)		
Scenario 2										
Work - Compact Area	98.771	$ 32.86	100%	$ 3,245.2	(81.795)	$ 32.86	100%	$ (2,687)	$ 557.8	$ 390.4
Peak	87.008	$ 32.86	100%	$ 2,858.7	(68.809)	$ 32.86	100%	$ (2,261)		
Off Peak	11.764	$ 32.86	100%	$ 386.5	(12.987)	$ 32.86	100%	$ (427)		
Non-Work Compact Area	223.346	$ 32.86	50%	$ 3,669.1	(195.968)	$ 32.86	50%	$ (3,219)	$ 449.8	$ 314.8
Peak	161.585	$ 32.86	50%	$ 2,654.5	(127.787)	$ 32.86	50%	$ (2,099)		
Off Peak	61.761	$ 32.86	50%	$ 1,014.6	(68.181)	$ 32.86	50%	$ (1,120)		
Total for the Compact Area				$ 6,914.3				$(5,906.8)	$ 1,007.5	$ 705.3

Notes:
(1) Travel Time Saved for peak and off-peak travel is from Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use.
(2) Additional out of vehicle travel time of 5 minutes per person trip was added to auto travel to better reflect total auto travel time. Transit times already include out of vehicle travel time.
(3) 35 percent of peak trips are work trips and 16 percent of off-peak trips are work trips. All other trips in the peak and off-peak are classified as non-work trips.
(4) Average annual wage is escalated to 2010 dollars based on the CPI increase for Washington, D.C. MSA between 2009 and 2010.
(5) Average annual wage per hour assumes that the wage reflects 2,000 hours worked.
(6) Value of time is base on US DOT, OST guidance.

Source: AECOM

4.2 Travel Cost Savings

Under Scenario 2 current transit users would have to switch to auto trips, which would increase the VMT traveled in the Washington, D.C. metropolitan area and vehicle operating costs for travelers. In 2007, there were just over 1.08 million average weekday transit trips in the region. Scenario 2 would increase average weekday VMT by 5.79 million, which translates into a significant decline in the level of service because it assumes that no additional highway capacity is added. With this decline in the highway network's level of service, travelers choose work and activity locations closer to their homes, resulting in fewer inter-jurisdictional trips and a lower average trip length than is experienced today; however, these

[35] The average hourly wage for the Washington, D.C. MSA was estimated by dividing the average annual wage for the MSA (provided by the Bureau of Economic Analysis, Summary Table CA34) by 2000 hours (typical hours worked in one year).
[36] US DOT guidance, *Revised Departmental Guidance: Valuation of Travel Time in Economic Analysis,* Table 1, 2011. Accessed at: http://ostpxweb.dot.gov/policy/reports/vot_guidance_092811.pdf

travel pattern changes are not significant enough to offset the increase in VMT due to the absence of transit. Consequently, the VMT for Scenario 2 increases as there would be more users of the highway network.

Similar to the travel time savings analysis, the travel demand model estimates the changes in *auto VMT* and *transit trips* separately, and therefore, the auto and transit travel cost savings are monetized separately. For example, the changes in auto costs for Scenario 2 do not account for any previous money spent on transit trips under the Base Case. However, for an estimate of total travel cost saved for the scenarios, the analysis should only consider the additional money spent traveling by auto (i.e. the cost over and above the previous transit trips). Therefore, the previous transit costs must be netted out from the auto travel cost analysis.

The increase in daily VMT associated with each scenario is annualized using a factor of 300.[37] The increase in personal vehicle trips in the region adds 1.74 billion VMT annually for Scenario 2.[38] Of the total regional increase in VMT, 70 percent is associated with the loss of WMATA transit services, based on the percentage of regional transit passenger miles on WMATA. For these new drivers, this translates into a reduced transit trip cost (both parking and fare)[39], but an increase in parking costs, tolls, and personal variable vehicle operating costs in terms of fuel, maintenance, tires, and a portion of the depreciation.[40] These vehicle operating costs vary by the size of the vehicle; however, the average auto operating cost per mile for these components is 28.5 cents (for all sedans), according to AAA's 2010 Edition of "Your Driving Costs."[41] This vehicle operating cost assumption is conservative because at least some portion of these miles will be made in cars that would have to be purchased due to the removal of transit from the transportation network. However, the travel demand model does not provide an estimate of the number of additional cars required in the region to accommodate the Scenario 2 travel needs.

In addition to vehicle operating costs, new drivers will also have an increase in auto parking and toll expenses, which were estimated by the travel demand model. Scenario 2 parking expenses would increase by $2.8 million daily[42], and toll expenses[43] would increase by $13,364 daily in comparison to the Base Case Scenario. The increases in parking expenses associated with these scenarios are for the entire region (not just the WMATA Compact area). However, since parking generally is free or significantly less expensive in the counties not located within the WMATA Compact area, it is assumed that most of these parking expenses do in fact occur within the Compact area. Additionally, it is also important to note that the average parking cost assumptions do not change in the model for Scenario 2. This assumption likely understates the additional parking costs associated with Scenario 2 in comparison to the Base Case because the sharp increase in demand and limited change in supply would likely drive up the average daily peak parking costs in the region.

[37] Annualization factor is from NTD.
[38] Annual change in VMT and transit riders is from Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use.
[39] Reduced transit trips costs are estimated by the Year 2007 MWCOG Version 2.3.17 Regional travel Demand Model with Round 8.0 Land Use.
[40] This analysis assumes that half of the depreciation impacts are due to mileage or wear and tear on the vehicle.
[41] The AAA per mile operating cost is the composite average for small, medium, and large sedans. This average is conservative because it excludes higher cost vehicles (e.g. SUVs and minivans); however, it also does not include other lower cost vehicles (e.g. motorcycles). http://www.aaaexchange.com/Assets/Files/201048935480.Driving%20Costs%202010.pdf
[42] This translates into an average peak parking cost per day of $9.04 for D.C. and $6.11 for Arlington (in 2007$).
[43] The toll revenues are for all toll roads in the region.

The increase in daily auto parking and toll expenses associated with Scenario 2 is annualized using a factor of 300.[44] The increase in parking and toll expenses in the region adds $836.2 million annually for Scenario 2.[45] Of the total regional increase in auto parking and toll expenses, 70 percent is associated with the loss of WMATA transit services, based on the percentage of regional transit passenger miles on WMATA.

The travel cost savings is monetized by multiplying the annual change in VMT by the average auto operating cost per mile, adding the additional toll and parking expenses, and subtracting the average cost (including parking and fare expenses) of the transit trips multiplied by the annual reduction in transit trips.[46] Table 4 below summarizes the annual travel cost savings associated with all regional transit services as well as for WMATA transit services in comparison to Scenario 2.

Table 4: Travel Cost Savings Associated with Regional Transit Service in 2007 (millions of 2010$)

	Auto					Transit			Annual Value of Total Travel Cost Savings Assoc. with All Transit (millions)	Annual Value of Total Travel Cost Savings Assoc. with WMATA (millions)
	Annual VMT Saved (millions)	Auto Operating Cost per Mile	Annual Value of Auto Travel Cost Savings (millions)	Annual Value of Auto Parking Cost Savings (millions)	Annual Value of Toll Cost Savings (millions)	Annual Change in Transit Riders (millions)	Average Transit & Parking Fare Per Trip	Annual Value of Transit Travel Cost Savings (millions)		
Scenario 2	1,737.324	$ 0.285	$ 495.8	$ 831.3	$ 4.9	(325.5)	$ (2.6)	$ (843.5)	$ 488.5	$ 342.0

Notes:
(1) Annual change in VMT and transit riders from Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use.
(2) Average fare and parking costs for transit trips provided by 2007 MWCOG travel demand model in 2007$. Escalated to 2010 using Washington, D.C. MSA CPI for all items.
(3) Average auto operating cost is from AAA's "Your Driving Costs" 2010 for variable operating costs only.
(4) Auto parking cost and toll savings includes parking and toll costs for the entire region, not just the WMATA Compact area

Source: AECOM

4.3 Auto Accidents Avoided Savings

Scenario 2 would increase the VMT traveled in the Washington, D.C. metropolitan area by diverting annual transit trips to the highway network. This increase in personal vehicle trips in the region adds 1.74 billion VMT annually for Scenario 2—as described in Section 4.2: Travel Cost Savings.[47] This increase in VMT escalates the likelihood of vehicle crash occurrences involving fatalities, injuries, and property damage as the crash rate for autos is higher than the crash rate for transit vehicles. From 2003 to 2008 transit bus travel resulted in 0.05 deaths per 100 million passenger miles, compared to 1.42 deaths for motor vehicles. The fatality rate for rail transit was even lower, 0.02, over the same period according to data from APTA's 2011 Public Transportation Fact Book.[48] Data are not available for accidents of lesser

[44] Annualization factor is from NTD.
[45] Annual change in parking and toll expenses are modeled using the Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use.
[46] The transit average fare and parking assumptions were provided by the Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model. The costs were provided in 2007 dollars and escalated to 2010 dollars: $2.33.
[47] Annual change in VMT and transit riders is from Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use.
[48] APTA's 2011 Public Transportation Fact Book, p.20, http://www.apta.com/resources/statistics/Documents/FactBook/APTA_2011_Fact_Book.pdf

severity; the working assumption here is that the same trend prevails. Because data for transit accidents is not available for all types of accidents, and recognizing that the propensity for transit accidents is very low—nearly zero in the case of fatalities, the value of accidents avoided through the use of transit is estimated on the VMT avoided and auto accident rates only. The value of transit accidents is not netted against the auto value. While this overstates the safety benefit, the data are not available to remedy this. Moreover, the APTA data cited above suggest that the overstatement is slight.

To estimate the increase in these accidents by severity, the VMT saved with transit services is multiplied by fatal, injury, and property damage only crash rates developed by the US DOT Bureau of Transportation Statistics (BTS).[49] These accident types are further disaggregated into Maximum Abbreviated Injury Scale (MAIS) using the NHTSA KABCO-AIS Conversion Table for Injury – Severity Unknown and No Injury accidents.[50] The auto accidents avoided savings is estimated by applying the value of a statistical life as published by the US DOT Office of the Secretary.[51] This methodology is consistent with the benefit-cost analysis guidance provided by the US DOT in the TIGER III Final Notice of Funding Availability.[52] Table 5 summarizes the annual accidents avoided savings associated with the each scenario for all regional transit services as well as for WMATA transit services in 2007.

Table 5: Auto Accidents Avoided Savings Associated with Regional Transit Service in 2007 (millions of 2010$)

		# of Accidents							Annual Value of Total Accident Savings Assoc. with All Transit	Annual Value of Total Accident Savings Assoc. with WMATA
	Annual VMT Saved (millions)	Annual Fatalities	Annual MAIS 5 Critical Injuries	Annual MAIS 4 Severe Injuries	Annual MAIS 3 Serious Injuries	Annual MAIS 2 Moderate Injuries	Annual MAIS 1 Minor Injuries	Annual MAIS 0 No Injuries		
Scenario 2	1,737.3	23.5	14.9	6.3	55.4	155.4	1,146.7	3,504.0	$ 321.0	$ 224.7

Notes:
(1) Annual change in VMT and transit riders from Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use.
(2) Accident rates from 2011 BTS Motor Vehicle Safety Data Table 2-17, Preliminary data for 2009 http://www.bts.gov/publications/national_transportation_statistics/#chapter_2
(3) Value of accidents from USDOT Value of a Statistical Life (http://ostpxweb.dot.gov/policy/reports/vsl_guidance_072911.pdf) Values updated to 2010 using GDP Deflator.

Source: AECOM

49 2011 BTS Motor Vehicle Safety Data Table 2-17, Preliminary data for 2009, http://www.bts.gov/publications/national_transportation_statistics/#chapter_2

50 USDOT, TIGER III Final Notice of Funding Availability, Federal Register, Vol 76, No 156, p. 50308, http://edocket.access.gpo.gov/2011/pdf/2011-20577.pdf

51 USDOT Office of the Secretary, "Treatment of the Economic Value of a Statistical Life in Departmental Analyses – 2011 Interim Adjustment," July 29, 2011 Memorandum: http://ostpxweb.dot.gov/policy/reports/vsl_guidance_072911.pdf

52 USDOT, TIGER III Final Notice of Funding Availability, Federal Register, Vol 76, No 156, p. 50308, http://edocket.access.gpo.gov/2011/pdf/2011-20577.pdf

4.4 Emissions Savings

Scenario 2 would increase the VMT traveled in the Washington, D.C. metropolitan area by diverting annual transit trips to the highway network. This increase in personal vehicle trips in the region adds 1.74 billion VMT annually for Scenario 2—as described in Section 4.2: Travel Time Savings.[53] This additional VMT in turn increases the amount of Nitrogen Oxide (NOx), Volatile Organic Compounds (VOC), and Particulate Matter (PM) emissions from autos in the region. The emissions rates for the Washington, D.C. metropolitan area were taken from Appendix G of MWCOG's *Air Quality Conformity Determination of the 2010 Constrained Long Range Plan and the FY 2011-2016 Transportation Improvement Program*.[54] The rates used are for running vehicles only and conservatively exclude the impacts from cold starts and hot soaks. It also is important to note that this report did not include emissions rates for Carbon Monoxide (CO); therefore, these emissions potentially represent an additional impact that could not be quantified at this time.

For transit's existing VOC and NOx emissions, Appendix H of the *MWCOG Air Quality Conformity Determination of the 2010 Constrained Long Range Plan and the FY 2011-2016 Transportation Improvement Program* was used. This report modeled the annual tons of VOC and NOx associated with bus transit in the entire Washington, D.C. metro area based on fleet composition and the MOBILE v6.2 model.

To estimate Greenhouse Gases (GHG or Carbon Dioxide) from auto, bus, and rail travel, passenger miles are used based on the emissions factors from the Sightline Institute. Therefore, for auto travel, the VMT avoided must be multiplied by the average auto occupancy for each scenario. For transit (both bus and rail), passenger miles for 2007 were collected from the National Transit Database profiles for the transit providers in the region, including:

- WMATA
- Maryland Transit Administration (including 10 percent of bus passenger miles and 70 percent of commuter rail passenger miles since the data reflects all services throughout Maryland)
- Howard Transit
- Ride-On Montgomery County Transit
- City of Fairfax CUE Bus
- Fairfax Connector Bus System
- Potomac and Rappahannock Transportation Commission
- City of Alexandria - Alexandria Transit Company
- Transit Services of Frederick County
- Loudoun County Commuter Bus Service
- Prince George's County Transit
- Arlington Transit - Arlington County (NTD data only available for 2009)
- Martz Group, National Coach Works of Virginia (NTD data only available for 2009)
- VRE

[53] Annual change in VMT and transit riders is from Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use.

[54] http://www.mwcog.org/store/item.asp?PUBLICATION_ID=395 The rate used were for Running-Arterials as these emissions rates tended to be the lowest. As a result, they provide a conservative estimate of the potential emissions associated with each scenario.

All transit services in the region (not just the Compact area) were used to estimate GHG impacts because the service providers that reside outside the Compact area primarily are destined for the Compact area. The passenger miles for each mode are then multiplied by the appropriate CO2 emissions factors from the Sightline Institute, including 0.5 pounds per passenger mile for bus (between ½ and ¾ full), 0.225 for rail with 50 passengers per car, and 0.9 for auto (between Prius/carpool and single rider).[55]

The emissions savings is estimated by applying the economic cost of air emissions, specified by the National Highway Traffic Safety Administration (NHTSA), to the changes in NOx, VOC, PM, and CO2 associated with auto, bus, and rail travel in each scenario.[56] Table 6 summarizes the annual emissions savings associated with Scenario 2 for all regional transit services as well as for WMATA transit services in 2007. While, Table 7 summarizes the Greenhouse Gas annual emissions savings for all regional transit services as well as for WMATA transit services in 2007.

Table 6: Emissions Savings Associated with Regional Transit Service in 2007 (millions of 2010$)

		Tons of Auto Emissions			Tons of Bus Emissions		Tons of Rail Emissions	Value of Emissions Savings			Annual Value of Total Emissions Savings Assoc. with All Transit (millions)	Annual Value of Total Emissions Savings Assoc. with WMATA (millions)
	Annual Auto VMT Saved (millions)	Annual VOC (tons)	Annual NOx (tons)	Annual PM (tons)	Annual NOx (tons)	Annual VOC (tons)	Annual NOx (tons)	Annual VOC (millions)	Annual NOx (millions)	Annual PM (millions)		
Scenario 2	1,737.324	317.5	649.2	21.8	(1,119.2)	(56.6)	(306.0)	$ 0.4	$ (4.3)	$ 6.6	$ 2.7	$ 1.9

Notes:
(1) Annual change in VMT from Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use.
(2) Emissions rates (grams per mile) from MWCOG, Air Quality Conformity Determination of the 2010 Constrained Long Range Plan and the FY 2011-2016 Transportation Improvement Program for the Washington Metropolitan Region, Appendix G (Nov 2010)
(3) Emissions for bus come from MWCOG, Air Quality Conformity Determination of the 2010 Constrained Long Range Plan and the FY 2011-2016 Transportation Improvement Program for the Washington Metropolitan Region, Appendix H (Nov 2010).
(4) Value of emissions per ton from, "Final Regulatory Impact Analysis, Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks
http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/CAFE_2012-2016_FRIA_04012010.pdf

Source: AECOM

Table 7: GHG Savings Associated with Regional Transit Service in 2007 (millions of 2010$)

	Auto			Bus			Rail			Annual Value GHG Emissions Savings Assoc. with All Transit (millions)	Annual Value of GHG Emissions Savings Assoc. with WMATA
	Annual Passenger Miles Saved (millions)	CO2 Pounds per Auto Pax Mile	Value of CO2 (per metric ton)	Annual Passenger Miles Saved (millions)	CO2 Pounds per Bus Pax Mile	Value of CO2 (per metric ton)	Annual Passenger Miles Saved (millions)	CO2 Pounds per Rail Pax Mile	Value of CO2 (per metric ton)		
Scenario 2	2,079.5	0.9	$ 21.93	(717.2)	0.5	$ 21.93	(1,853.4)	0.225	$ 21.93	$ 10.9	$ 7.6

Notes:
(1) Annual change in auto passenger miles from Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use. Auto VMT is multiplied by Average Auto Occupancy to get Auto Passenger Miles.
(2) Annual transit passenger miles from NTD 2007 transit profile for regional transit agencies.

[55] http://www.sightline.org/maps/charts/climate-CO2byMode
[56] The economic costs of air emissions are taken from the Final Regulatory Impact Analysis of the National Highway Traffic Safety Administration's rulemaking on Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks. http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/CAFE_2012-2016_FRIA_04012010.pdf

(3) Emissions rates per passenger mile from Sightline Institute.
(4) Value of emissions per ton from, "Final Regulatory Impact Analysis, Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks
http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/CAFE_2012-2016_FRIA_04012010.pdf

Source: AECOM

5.0 Monetization of Capital Benefits

If transit service were not available in the Washington, D.C. region, (as assumed in Scenario 1 and 2), additional infrastructure costs would be required in order to support the additional cars on the roadways and the resulting increase in demand for parking in the D.C. and Arlington Cores—the central business districts of the Washington, D.C. region. For Scenario 1, these additional costs would include the additional road and bridge infrastructure required to maintain the 2007 roadway network's level of service as well as additional parking garages/spaces. For Scenario 2, which assumes no additional roadway and bridge infrastructure is built, these additional costs would only include the additional parking infrastructure to accommodate the increased number of cars parking in the D.C. and Arlington Cores.

Similarly, for both Scenarios 1 and 2, the costs associated with the transit system in the Base Case would not be present. As a result, the capital investment required to support the transit system would not be necessary, resulting in a savings for the region in comparison to the Base Case.

5.1 Highway Investment

Scenario 1 assumes that additional road infrastructure would be built in order to accommodate the 2007 transit users and keep the same level of service on the highway network as in the Base Case. This additional infrastructure would include roadway lanes miles as well as bridge lane miles for both freeways and arterials. The additional lane miles by roadway types required (road/bridge and freeway/arterial) for Scenario 1 were estimated by the travel demand model. The capital costs associated with this new roadway investment represent a benefit of transit in the Washington, D.C. MSA because these investments would be required only if the transit system did not exist. In other words, with transit these roadway and bridge investments would not be needed and represent a savings for the region. This section summarizes the methodology used to estimate the capital cost savings associated with the additional lane miles.

5.1.1 Methodology

Using engineering cost standards and professional experience estimating highway and bridge project costs in the Washington, D.C. metropolitan area, an AECOM highway cost engineer developed average per lane mile costs for highway and bridge projects in the region (excluding right-of-way expenses). These average costs represent industry starting points for capital projects in the region, and would go up or down depending on the nature of the project, including factors such as number of interchanges, wetlands, drainage, mitigation costs, and other similar factors. The estimates for highway/road and bridge per lane mile costs were developed as described below:

- Highway/Road costs (excluding ROW):
  - General cost per SF: $70
  - Incidental cost per SF (35%): $25
  - Total per SF: $95
  - Cost per lane mile: $6.1 million (2011 dollars)
    $6.02 million (2010 dollars, deflated using GDP deflator for Direct Capital Non-Defense outlays from the US 2012 Budget[57])

- Bridge costs (excluding ROW):
  - General cost per SF: $250
  - Incidental cost per SF (30%): $75
  - Total per SF: $325
  - Cost per lane mile: $20.5 million
    $20.23 million (2010 dollars, deflated using GDP deflators for Direct Capital Non-Defense outlays from the US 2012 Budget[58])

These per lane mile costs are similar to those provided by the Maryland State Highway Administration's (SHA) *2009 Capital Cost Manual* for Maryland's roadway construction ($6 million per lane mile) and bridges over water ($280 per SF, or approximately $18 million per lane mile).

5.1.2 Reasonableness of Methodology

In order to further verify the reasonableness of the construction costs per lane mile for both bridge and road capacity projects in the Washington, D.C. MSA, websites for the Federal Highway Administration (FHWA) and Departments of Transportation (DOTs) of the District, Virginia, and Maryland were searched to identify recent construction projects involving entire bridge replacements or increasing lane capacity. These projects provide a range of costs for the new construction of roadway and bridge lane miles in the region. The VDOT, DDOT, and MDOT websites include details on completed and current projects, including their budgeted or final costs, locations, and project scope. Because the travel demand model results include additional lane miles required for freeways or arterials (including road or bridge), the projects from the DOT websites were also organized by roadway type. Interstate projects fell under freeway, while arterials accounted for all other roads and bridges.

If a project qualified as a complete bridge reconstruction or a road-widening/replacement, it was entered into a table as the total project cost. The project costs were reported in terms of dollars for the year listed —either the start of construction or the year of the most recent estimate. The base year chosen for this analysis is 2010, so all projects not listed as 2010 were converted into 2010 dollars using the highway construction cost factors from the FHWA website. The indices used were reported quarterly starting in 2003, so an average over each year was used. Because some projects were constructed or estimated outside of the 2003-2010 window, the GDP direct capital deflator from the US Office of Management and Budget's FY 2012 Budget of the United States was used for these projects.

For project descriptions that did not define the number of lanes and length of roadway explicitly (yellow rows in Table 8 below), Google Maps was used to find the project location and map the approximate alignment. Multiplying the number of miles from Google Maps by the number of total lanes in the cross-section yields the number of lane miles. Dividing the total 2010 project cost by the number of lane miles produces the cost per lane mile for the project.

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[57] http://www.gpoaccess.gov/usbudget/fy12/xls/BUDGET-2012-TAB-10-1.xls
[58] Ibid.

In Table 8 below, the projects are labeled by the state or district in which they were constructed, and also are classified further by arterial-road, arterial-bridge, freeway-road, and freeway-bridge for ease of comparison. The costs per lane mile for each category were averaged in order to estimate the lane mile costs for each region and project type. Two major projects were not included in the analysis: the 9th Street Bridge and 11th Street Bridge in Washington, D.C. These bridge and the associated roadway and intersection projects were not included because there was no way to isolate how much of their costs were used for bridge or road lane miles. Consequently, these projects were not included in the analysis to avoid skewing the per lane mile costs for road and/or bridge capacity projects in the region.

Table 8: Sample Per Lane-Mile Construction Costs for Road and Bridge Capacity Projects in the Washington, D.C. MSA (2010$)

Project	Year	Length (lane miles)	$/Lane Mile			
			Freeway		Arterial	
			Road	Bridge	Road	Bridge
Maryland						
MD 5, Branch Ave.	2009	2.1400			$ 4,192,275	
I-70 (includes a bridge)	2010	3.1400	$15,635,350			
Woodrow Wilson Bridge	2009	90.0000	$17,447,482	$55,765,580		
MDSHA McMullen Highway	2010	1.0000				$ 13,171,000
MD 0404 Queen Anne's Highway	2005	22.6000	$ 334,623			
MD 287, Sandtown Road	2005	0.2000				$ 33,201,433
I-97 Bridge Replacement	2000	1.2000				$ 12,014,167
I-695 at Jones Fall Expy Bridges	2000	4.0000		$ 5,126,929		
I-495 at MD 187	2000	0.4545		$16,116,827		
I-83 over RR and Little Falls	2006	0.3409		$26,258,494		
District of Columbia						
O and P Streets rehab	2009	2.2591			$ 4,764,500	
Benning Road	2011	1.2000			$ 2,590,166	
New York Ave. Bridge	2011	2.4000				$ 16,036,717
Adams Morgan Streetscape	2011	2.0000			$ 3,217,212	
Sherman Avenue	2010	3.2000			$ 4,062,500	
Virginia						
Pacific Blvd widening	2010	0.8000			$ 6,250,000	
Rt 28 and Wellington Rd overpass	2010	1.6000				$ 27,500,000
Centreville Road Widening	2008	1.6000			$ 2,234,402	
I-66 widening in Gainesville	2010	10.0000	$ 9,000,000			
I-95 widening	2008	12.0000	$ 8,426,015			
I-495 HOT lanes	2010	56.0000	$25,000,000			
MD-DC-VA Average			$11,430,020	$25,816,958	$ 3,901,579	$ 20,384,663
MD-DC-VA Average (excluding high value)			$10,168,694	$15,834,083	$ 3,510,176	$ 17,180,471
MD-DC-VA Average without distinction for freeway/arterial					$ 7,665,799	$ 22,799,016
MD-DC-VA Average without distinction for freeway/arterial (excluding high value)					$ 6,512,877	$ 18,678,196

Notes:
(1) Green highlighted projects represent projects were all data (cost and lane miles) were provided from project sites. Projects highlighted in yellow indicate that the lane miles were estimated using Google Maps.
(2) The Woodrow Wilson Bridge Project is shown in Maryland to avoid double counting, but it was a joint project for Maryland and Virginia.

Source: AECOM assembled data from VDOT, DDOT, MDOT, and FHWA websites as well as Google Maps

Table 8 demonstrates that the per lane mile costs of road and bridge project can vary significantly from project to project based on the various circumstances and needs of each project. Road projects ranged from less than $500,000 per lane mile to $25 million per lane mile. Similarly, bridge projects ranged from $5 million per lane mile to more than $55 million per lane mile. However, the average per lane mile costs of the sample road ($6.5-7.7 million) and bridge projects ($18.7-$22.8 million) in the region are remarkably similar to those provided by the cost engineer to estimate the cost of the infrastructure needs associated with Scenario 1.

5.1.3 Results

The total capital costs (excluding ROW or land) required to construct the additional roadway and bridge lane miles necessary to accommodate Scenario 1 were estimated by multiplying the standard cost per lane mile developed using standard cost estimating procedures for the region by the number of lane miles estimated by the travel demand model. These results are shown in Table 9 below by road type.

Table 9: Total Highway/Bridge Capital Costs Avoided (excluding ROW or land) in the WMATA Compact Region for Scenario 1 (millions of 2010$)

Road Type and Location	Additional Lane Miles	Average Cost Per Lane Mile (millions)	Total Capital Cost Assoc. with All Transit (millions)	Total Capital Cost Assoc. with WMATA (millions)
Freeway - Road	207	$ 6.0	$ 1,248.8	$ 874.2
Arterial - Road	763	$ 6.0	$ 4,591.8	$ 3,214.3
Freeway - Bridge	23	$ 20.2	$ 461.3	$ 322.9
Arterial - Bridge	20	$ 20.2	$ 413.1	$ 289.2
Total	1,013		$ 6,715.0	$ 4,700.5

Source: AECOM calculation using Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use (Lane Miles) and standard per mile costs used by cost engineers for road and bridge projects in the region.

The total capital costs shown in Table 9 are one-time capital costs for the construction of additional road and bridge capacity required for Scenario 1 to maintain the same highway level of service as the 2007 Base Case. It is important to note that the costs shown in Table 9 exclude the cost of ROW or land purchases that could be required. These costs are not annual costs; however, they likely would be spent over a multi-year construction period.

5.2 Parking Investment

Scenarios 1 and 2 result in an increase in the number of automobiles used during the peak period, primarily in the form of home-based work trips. In order to accommodate these vehicles at their work destinations, additional parking infrastructure would be required for these scenarios, particularly in the D.C. and Arlington Cores[59] where available parking is more constrained than the rest of the region. The capital costs associated with this new parking investment represents a benefit of transit in the Washington, D.C. MSA because these investments would be required only if the transit system did not

[59] The D.C. and Arlington Cores include the District CBD and the CBDs of Rosslyn, Courthouse, Pentagon, and Pentagon City/Crystal City.

exist. This section summarizes the methodology used to estimate the capital costs associated with the additional parking infrastructure required in the Core due to the removal of transit from the region.

5.2.1 Methodology

The estimate of parking infrastructure needs for Scenarios 1 and 2 begins with the number of new vehicles traveling in the D.C. and Arlington Cores that will require parking spaces. Off-peak trips are not included in this analysis, as it is assumed that the greatest demand for parking will occur during the peak periods and will be sufficient to accommodate any off-peak parking demand.

The travel demand model estimated the additional vehicles destined for the D.C. and Arlington Cores for both Scenarios 1 and 2; however, it is important to note that these estimates are vehicle counts and represent an increase in demand for parking spaces, not actual new parking spaces required.[60] As a result, the travel demand model forecasts are also discussed in terms of percentage increases in parking spaces over the 2007 Base Case:

- Scenario 1 would increase parking demand by just under 200,000 cars/spaces, or a 127 percent increase over the Base Case for the D.C. and Arlington Cores.
- Scenario 2 would increase parking demand by just over 201,000 cars/spaces, or a 129 percent increase over the Base Case for the D.C. and Arlington Cores.

Once the parking demand was established, the demand was turned into an estimated square feet (SF) of parking garage space need in the D.C. and Arlington Cores. The analysis assumes that all parking infrastructure is composed of underground parking garages due to the density of development in these areas of the region. The average square footage required per parking space for WMATA's parking garages is 327. This square footage includes space for the actual parking space, as well as ramps, corners, and other necessary common areas. The costs per SF for underground garages in the Washington, D.C. MSA were taken from RS Means *Square Foot Costs* (2007). The costs were escalated to 2010 dollars using the GDP direct capital deflator from the US Office of Management and Budget's FY 2012 Budget of the United States.

5.2.2 Results

The total capital costs required to construct the additional parking necessary to accommodate Scenarios 1 and 2 were estimated by multiplying the RS Means costs per SF for an underground garage by the total SF of parking need to accommodate weekday peak vehicles in the D.C. and Arlington Cores as estimated by the travel demand model. These results are shown in Table 10 below for each scenario. Please note that the costs shown in Table 10 exclude the cost of ROW or land purchases that could be required. It is also important to note that the capital costs shown in Table 10 reflect the costs associated with the entire increase in demand for parking (not just the spaces in excess of current parking capacity).

[60] Unless all parking in the D.C. and Arlington Core is fully occupied, at least some of these vehicles will park in existing spaces. As a result, some of the increase in parking demand is likely to be met with existing parking inventory.

Table 10: Total Parking Capital Costs Avoided in the D.C. and Arlington Cores for Scenarios 1 and 2 (in millions of 2010$)

	Additional Parking SF	Average Cost per SF	Total Capital Cost Assoc. with All Transit (millions)	Total Capital Cost Assoc. with WMATA (millions)
Scenario 1	65,177,640			
Below ground garage		$ 62.57	$ 4,077.9	$ 2,854.53
Scenario 2	65,881,344			
Below ground garage		$ 62.57	$ 4,121.9	$ 2,885.3

Note: Assumes 327 SF per parking space (WMATA's average SF per space for its existing facilities).

Sources:

(1) Year 2007 MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use (parking spaces)

(2) RS Means Square Foot Costs, 2007 (parking SF costs), escalated to 2010 dollars using GDP deflator for Non-Capital Defense outlays

The majority of the increase in parking demand would come from federal employees. The federal government is the largest employer in the region. Almost one half of peak period riders are commuting to or from federal jobs, and, at other times of the day, federal employees use Metro to take care of government business. As a result, 35 percent of the weekday trips on Metrorail are made by federal employees, or 249,087 trips. Using the methodology described above, building parking to accommodate these employees would cost $2.4 billion for below ground parking ($2010).

6.0 Property Impacts

The presence of rail transit, particularly Metrorail, has had a significant impact on development, its location, and property values in the Washington, D.C. region. This section examines the share of property values within a ½ and ¼ mile buffer of Metrorail stations, the rail transit premium percentage associated with commercial and residential properties, and the tax revenues generated by these properties.

6.1 Share of Property Values Located Near Metrorail Stations

A GIS analysis of total assessed property values within the WMATA Compact area was performed to determine the percentage of this value that is located within a ½ mile and ¼ mile buffer of Metrorail station. The parcel-level assessed value for all the jurisdictions were compiled from GIS shapefiles obtained from either the real estate assessor's office or the department of tax administration. To avoid double counting, properties that fell within the buffers for multiple stations were assigned to the closest Metrorail station and were not included in the analysis of any other station. Similarly, the values located within a ¼ mile of stations are also included in the ½ mile buffer analysis. As a result, the values of the two buffers are not additive.

Of the more than $800 billion in assessed property values located within the WMATA Compact area, almost 15 percent is located within a ¼ mile buffer of Metrorail stations, and 28 percent is located within a

½ mile buffer. Table 11 below summarizes the property values within a ¼ mile and ½ mile of Metrorail stations for the Compact area jurisdictions.

Table 11: Percentage of Property Values within a ¼ and ½ mile of Metrorail Stations

		2011 Share Within	
	Total Value	1/4 Mile Buffer	1/2 Mile Buffer
Virginia	$ 292,196,731,524	9.3%	15.3%
City of Alexandria	$ 29,146,727,430	12.3%	27.5%
Arlington County	$ 64,613,483,800	35.0%	52.1%
Fairfax County	$ 195,090,350,694	0.5%	1.3%
City of Falls Church	$ 3,346,169,600	0.0%	8.6%
District of Columbia	$ 234,273,194,260	39.3%	68.1%
Maryland	$ 316,612,225,903	3.3%	9.9%
Montgomery County	$ 204,115,714,935	4.4%	12.1%
Prince George's County	$ 112,496,510,968	1.3%	5.8%
Total Compact Area	$ 843,082,151,686	15.4%	27.9%

Sources: Parcel data from individual counties for 2010. Values adjusted to 2011 dollars.

Of this total, residential properties (single family) make up $44.4 billion of the real estate within ½ mile of Metrorail stations and $13.4 billion within a ¼ mile. Similarly, commercial properties (multi-family, office, retail, and other) make up $188.6 billion of the real estate within a ½ mile of Metrorail stations, of which $115.9 billion is located within a ¼ mile. Government-owned and other non-taxable properties, on the other hand, represent $2.4 billion of real estate within a ½ mile and $0.5 billion within a ¼ mile of Metrorail stations.

6.2 Premium Value Associated with Proximity to Rail Transit

A series of hedonic regressions were estimated in order to determine whether the market places a value on proximity to rail transit, and if so, to estimate the value of proximity to rail transit in the Washington, D.C. metro area. Hedonic regression is a method used to determine the value of a good (a property in this instance) by breaking it down into its component parts. The value of each component is then estimated through regression analysis. For example, the value of an office building can be determined by separating the different aspects of the parcel – proximity to transit, class of the office building, amount of space in the building - and using regression analysis to determine the value of each variable.

6.2.1 Data

Obtaining and understanding data on the assessed property values in the Washington, D.C. metro region was very critical for the regression analysis. The parcel-level assessed value for all the jurisdictions were compiled from GIS shapefiles obtained from either the real estate assessor's office or the department of tax administration. In order to understand the relationship between assessed property values and actualized market values, data on "assessment ratio" was studied. The "assessment ratio" is a measure reported by the jurisdictions in the Washington, D.C. metro area and is a ratio of Property Assessed Value to the Property Sale Price. It was observed that the assessment ratios were in general close to one, indicating that the assessed value could be used as a proxy for the property market value in the D.C. metro area. Furthermore, the assessed values were observed to be generally lower than the market values. Hence, as a conservative approach, the assessed property value was set as the dependent variable for the regression analysis. Table 12 shows the 2009 assessment ratios reported by jurisdiction.

Table 12: Assessment Ratio by Jurisdiction for 2009

Jurisdiction	Median Assessment Ratio (2009)	
	Residential Properties	Commercial Properties
District of Columbia	97.2%	88.9%
Montgomery County	94.6%	99.1%
Prince George's County	96.0%	97.9%
Fairfax County	96.1%	95.8%
Arlington County	97.6%	87.8%
City of Alexandria	99.0%	100.2%
City of Falls Church	96.9%	-
City of Fairfax	100.5%	-

The hedonic analysis started with 1.2M parcels/properties across all property types and all jurisdictions. The actual number of parcels used in a particular analysis was a subset of this universe, one that varied with: type of property examined, match with CoStar records, the quality of the actual coding (some records did not make sense), and outliers that were not representative of the building stock and would skew the property premium analysis—extremely expensive residences and historic buildings for example. The following sub-sections describe the details on the data compilation efforts relevant to major property classes – office, multi-family and single-family/residential.

6.2.1.1 Office and Multi-family

For the office and multi-family class, the property level attributes of the buildings within a parcel were compiled from the CoStar database on commercial properties. The data to support the analysis was constructed by combining the assessor's records from each of the Compact area jurisdictions having rail transit service, and matching these records to data from the CoStar database. In the process of combining the two datasets, about 6 percent of the records were lost as the parcel IDs between the two databases could not be matched. Thus, the combined database yielded a large dataset with the assessed value of each parcel; the type of use (office, multifamily, residential, other); attributes about the building such as size/area, location, available parking, number of stories, condition/class of the building. The information about a property's location permitted the computation of its proximity to a rail station – a critical variable in the analysis.

The aggregation of data from so many different sources posed some challenges in reconciling differences in data fields, coding, as well as individual attributes of parcels. A number of assumptions were made in cleaning up the data. Chief among these are the following:

- If a parcel contained multiple properties that had more than one type of use indicated, for example - ground floor retail in a large office building, the parcel was coded to the dominant use based on the property's size/area.
- If a parcel contained multiple buildings with different classes of office space, the parcel was coded to the class that represented the majority of the space.
- If a parcel contained multiple buildings, the rentable area was summed to a single value.
- If a parcel contained multiple buildings with different parking ratios, a single parking ratio was constructed from the weighted average (weighted by rentable area) of the parking ratios.
- If a parcel contained multiple buildings with different percent leased values, a single value was constructed from the weighted average (weighted by rentable area) of the percent leased.

- A distance to transit variable was constructed as a class variable based on incremental changes in distance. Similar class variables were constructed for condition and building class.

- The data for assessed property values were available for different years across the jurisdictions. While assessment data for properties in D.C., Falls Church and Fairfax were available for 2011, data for Prince George's, Montgomery and Arlington counties corresponded to 2009. Assessment data for Alexandria was available for 2010. In an effort to minimize inconsistencies within the data, the assessment values were adjusted to a common 2011 value for all jurisdictions. Thus, for counties with assessment years 2009 and 2010, factors were applied to estimate the 2011 property value. MOODYs/REAL Commercial Property Price Index (CPPI) was used to derive the relevant factors. Table 13 shows the factors used during this conversion process.

  The selection of a base year for the property analysis represents a compromise solution. The year-to-year change in records reflects both physical changes to parcels as well as the assessed values. Thus, using a 2011 base was the best solution for the property analysis component of the work because 1) three of the jurisdictions are already in 2011 and 2) it is the most recent year and represents the best match with the CoStar data to which it is being matched. Where necessary the values were adjusted using real estate price indices—the peak values for the region were in 2007. Prices fell sharply through the end of 2009, with modest rebounds beginning in 2010 and extending into 2011 as the D.C. region weathered the recession much better than other parts of the country, anchored by the federal government. Thus, although it is surprising, the valuation adjustments show increases—these are increases from the trough and still represent a decline from 2007 peak values.

  The remaining question was whether to further adjust the values to 2010 to match exactly the other benefits (mobility, capital costs, etc.) reported in the study. The appropriate deflators to adjust these other non-property benefits to a comparable 2011 value are not published on the same schedule as the real estate deflators—they lag—and thus they were not available; 2010 was the most recent value available. The margin of error is small, recognizing that the deflators are themselves estimates, and that the assessment ratios reported in Table 12 indicate that the assessed values were underreporting market value; deflating to an estimated 2010 value would compound this bias. As the estimated values are not being summed, the 2011 estimates are reported as the best estimate available.

Table 13: Factors used to estimate 2011 Assessed Value for Commercial Properties

Jurisdiction	Assessment Year	Office: Factor for Assessment Year - 2011	Multi-Family: Factor for Assessment Year - 2011
Prince George's County	2009	1.051	1.129
Montgomery County	2009	1.051	1.129
Arlington County	2009	1.051	1.129
City of Alexandria	2010	0.993	1.061

- Data points with a property value less than $10/sq-ft were eliminated from the database for both office and multi-family. Similarly data points with a property value greater than $5,000/sq-ft for office and data points with a property value greater than $2,000/sq-ft for multi-family were eliminated. This was done as the properties were either misreported or not representative of the majority of building stock in the metro area.

To investigate any prevalent pattern between percent leased and transit proximity, the hypothesis that the share of leased space would be higher for building locations near a rail transit station and lower for those building locations that are more distance, further aggregation of data was performed to calculate a single percent leased value for all office spaces within a certain distance from the rail station. This aggregation was based on the weighted average of percent leased, weighted by the rentable building area. Table 14 shows the percent leased for each of the six transit proximity classes defined. The data do not support a correlation between the share of leased space and distance to transit.

Table 14: Percent Leased by Property's proximity to Rail Station

Transit Proximity	Percent Leased (Weighted by Rentable Area)
0 ~ 0.25 mi	81.64
0.251 ~ 0.5 mi	72.36
0.51 ~ 1 mi	86.86
1.01 ~ 2 mi	84.11
2.01 ~ 3 mi	85.00
> 3 mi	84.35

6.2.1.2 Single-Family/Residential

For the single-family/residential, the relevant property level attributes were compiled from the GIS shapefiles obtained from the real-estate assessor's office. This data was available only for D.C., Arlington, Prince George's and Montgomery counties. Hence, the aforementioned jurisdictions alone were included in the analysis for residential property out of necessity. While this omits some jurisdictions, the vast majority of the rail system's stations are located in those jurisdictions for which data could be obtained. Thus, the results from the hedonic equations are representative of the region.

Residential property data for the region was compiled from multiple jurisdictions; on reviewing the aggregated data, it was observed that the types of attributes reported were not consistent across the jurisdictions. For example, while D.C. and Arlington reported information on number of bedrooms in a residential building, this attribute was not reported for jurisdictions of Prince George's and Montgomery counties. Thus, only attributes that were commonly available across the four jurisdictions were included in the analysis. These attributes include proximity to transit, number of bathrooms, building condition and building size/area.

Similar to the exercise carried out for the office and multi-family, when a parcel consisted of multiple properties/buildings, data was aggregated to represent building attributes at the parcel level. Some of the assumptions made during the aggregation and cleanup process are:

- A class variable was constructed for the building condition. If a parcel contained multiple buildings with different classes for building condition, the parcel was coded to the class that represented the majority of the residential space.
- If a parcel contained multiple buildings, the building area was summed to a single value.
- If a parcel contained multiple buildings, the number of full-baths was summed to a single value and the number of half-baths was summed to a single value. Based on these two quantities,

number of bathrooms for each parcel was calculated as the sum of full-baths and half-baths. During this calculation two half-baths were assumed to translate as one full-bath.

- A distance to transit variable was constructed as a class variable based on incremental changes in distance.
- The data for assessed property values were available for different years across the jurisdictions. While 2011 assessment data was available for D.C., data for Prince George's, Montgomery and Arlington counties corresponded to 2009. To be consistent, the data were adjusted to a common 2011 year for all jurisdictions. Thus, for counties with assessment year 2009 factors were applied to estimate the 2011 property value. S&P/Case-Shiller Home Price Indices were used to derive the relevant conversion factors. Table 15 shows the factors used during this conversion process.

Table 15: Factors used to estimate 2011 Assessed Value for Residential Property

Jurisdiction	Assessment Year	Residential: Factor for Assessment Year - 2011
Prince George's County	2009	1.074
Montgomery County	2009	1.074
Arlington County	2009	1.074

- Data points with a property value less than $20/sq-ft were eliminated from the database. Similarly data points with a property value greater than $1,300/sq-ft were eliminated. This was done as the properties were either misreported or not representative of the majority of building stock in the metro area.
- Residential structures older than 200 years were excluded from the estimation as their historic quality seemed to make them outliers relative to the overall stock of houses in the metro area.

6.2.2 Estimation

A series of regression equations were estimated for each major class of property: office, residential, multi-family. An equation for retail could not be fitted because in some cases it was combined with office (a small share of the overall property). Furthermore, as a grouping, retail was too heterogeneous to provide a good model—there are too many varieties of retail establishments to capture a general trend with a regression model. Equations were estimated in log-log form.

A large variety of variables and specifications were examined as part of the estimation process. This was done to determine both the best way of using the available data and to ensure that the reported results were robust. Some of the variables that were examined but excluded included distance to White House and other focal or central points in the District, age, number of floors, and number of parking spaces.

In all regressions, the dependent variable was the property value (in dollars). A series of binary (0-1) variables were constructed as a proxy for the larger county attributes. For example, the Arlington County variable is coded 1 if the property was in Arlington County, 0 otherwise.

Similarly, a series of class variables were constructed to capture building attributes. The coding is summarized as follows.

- Proximity to Rail Station - Class: Six classes (1~6) were defined based on the location of transit station from the Property

  Class 1 -- < 0.25 mi

Class 2 -- 0.251 ~ 0.5 mi
Class 3 -- 0.51 ~ 1.0 mi
Class 4 -- 1.01 ~ 2.0 mi
Class 5 -- 2.01 ~ 3.0 mi
Class 6 -- > 3.0 mi

- Building Class: Four Classes were defined

  Class 1 -- Class A
  Class 2 -- Class B
  Class 3 -- Class C
  Class 4 -- Other

- Building Condition: Eight Classes were defined

  Class1 -- Excellent
  Class 2 -- Very Good
  Class 3 -- Good
  Class 4 -- Average
  Class 5 -- Fair
  Class 6 -- Poor
  Class 7 -- Very Poor
  Class 8 -- Default, Null

6.2.3 Results

This section summarizes the estimation results for office, residential, and multi-family. The models predict about 60 percent of the variation for residential and office and about 50 percent for multi-family. This is a good fit based on other hedonic results in the literature[61].

While the inclusion of additional variables would likely improve the R-squared statistic, the transit variable is significant in all regressions and the results were stable across a variety of specifications tested. Moreover, the sign is negative, indicating that property value falls as distance to rail transit increases. Thus, the conclusions based on the beta estimate for this variable are considered representative of the larger market. The county variables are proxy variables that capture a variety of market characteristics. The negative sign on the Prince Georges, Montgomery, Fairfax, Alexandria, and Falls Church variables in Table 16 for example, is simply an indication that the office market in these suburban counties is less attractive on average than the office market in the D.C. core and nearby Arlington. The coefficients capture broad trends—selected locations such as Tysons Corner can still be very favorable submarkets, but their size is not sufficient to change the sign on the suburban markets.

Table 16 summarizes the regression results for the office property. The analysis shows that Metrorail boosts property values, adding 8.9 percent more value (on an average) to office properties within the Metro Compact area.

[61] Bilal Farooq, Eric J. Miller, and Murtaza Haider obtain Adjusted R-squares that range from 0.43 to 0.45 (multiple specifications) for their analysis of the office market as reported in "Hedonic Analysis of Office Space Rent," Transportation Research Record: Journal of the Transportation Research Board, No. 2174, Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 118–127.

Table 16: Office Equation Results

Office		
Independent Variable	*Beta*	*t-statistic*
Proximity to Rail Station - Class	-1623869.8	-5.56
Building Class-Category	-6582682.1	-12.34
Parking Ratio	-100184.3	-0.39
Rentable Building Area (SF)	195.8	79.84
Percent Leased	63133.9	4.37
Prince George's County [1]	-3797471.0	-2.59
Montgomery County [1]	-6895884.2	-5.94
Arlington County [1]	4390832.8	2.43
Fairfax County [1]	-7532580.1	-5.07
Falls Church County [1]	-7397721.9	-2.38
Alexandria County [1]	-7089888.5	-5.46
District of Columbia [1]	-	-
Constant	23150000.0	11.21

R-Square	*0.603*
N	*6,313*
Premium Percentage	*8.9%*

[1] County included as a Binary Variable

Source: AECOM Analysis

Table 17 and Table 18 summarize the regression results for multi-family and residential respectively. Metrorail boosts property values, adding 9.4 percent more value to multi-family and 6.8 percent to residential properties.

These percentages are consistent with the findings from other studies in other cities[62].

[62] Jeffery J. Smith and Thomas A. Gihring with Todd Litman. 2011. Financing Transit Systems Through Value Capture: An Annotated Bibliography. American Journal of Economics and Sociology, Volume 65, Issue 3, July 2006, p. 751. A longer version was also developed as a white paper.

Table 17: Multi-Family Equation Results

Multi Family		
Independent Variable	*Beta*	*t-statistic*
Proximity to Rail Station - Class	-867305.8	-3.223
Number of Stories	2029532.0	15.965
Rentable Building Area (SF)	59.8	22.215
Number of Parking Spaces	21922.5	7.329
Prince George's County [1]	-2213004.5	-1.559
Montgomery County [1]	-1091486.5	-1.186
Arlington County [1]	8698892.9	8.091
Fairfax County [1]	6846877.3	3.959
Falls Church County [1]	1396159.1	0.426
Alexandria County [1]	3915840.9	2.818
District of Columbia [1]	-	-
Constant	-2375403.0	-2.50

R-Square	0.506
N	3,089
Premium Percentage	9.4%

[1] County included as a Binary Variable

Source: AECOM Analysis

Table 18: Residential Equation Results

Residential		
Independent Variable	*Beta*	*t-statistic*
Proximity to Rail Station - Class	-33343.9	-116.52
Number of Bathrooms	31590.1	65.59
Building Condition - Class	-112125.5	-184.32
Building Area (SF)	200.4	462.32
Montgomery County [1]	3997.7	3.86
District of Columbia [1]	-265826.5	-198.62
Arlington County [1]	17298.9	10.86
Prince George's County [1]	-	-
Constant	631922.4	177.64

R-Square	0.591
N	524,147
Premium Percentage	6.8%

[1] County included as a Binary Variable

Source: AECOM Analysis

6.3 Property Tax Revenue Impacts

To estimate the value of property tax revenues generated within ½ mile and ¼ mile of Metrorail stations, the base county and city property tax rates in 2011 were applied to the property values identified during the GIS analysis as being within the ½ and ¼ mile buffers (see Section 6.1). The base county and city property tax rates were collected from the city and county websites of the Compact area jurisdictions and are presented in Table 19 below. It is important to note that these base tax rates include special taxes assessed at the sub-county or sub-municipal level (i.e. those taxes that are not levied on all properties within the county or city). For example, Montgomery and Prince Georges County levies a variety of special taxes in the station areas. The tax rate shown for Montgomery is the average of rates for station locations: Silver Spring, Bethesda, and Rockville. The tax rate shown for Prince Georges County is the average of rates for station locations: Largo, Capitol Heights, College Park, Greenbelt, Hyattsville, Landover, New Carrollton. Fairfax County's reported rate includes the base rate plus leaf, stormwater, pest, and other additional rates for commercial and other sub county programs.

Table 19: Base 2011 Property Tax Rates for Compact Area Jurisdictions

	2011 Tax Rates (per $1 of Assessed Value)	Commercial
Virginia		
City of Alexandria	0.00998	
Arlington County	0.00958	0.010996
Fairfax County	0.01101	0.01211
City of Falls Church	0.0127	
District of Columbia		
Residential	0.0085	
Commercial (1st $3M)	0.0165	
Commercial (>$3M)	0.0185	
Maryland		
Montgomery County	0.0116	
Prince George's County	0.0131	

Sources: City and County websites for each jurisdiction

The real estate located within ½ mile and ¼ mile of Metrorail stations generated approximately $3.1B and $1.8B in property tax revenues for the Compact area in 2010, respectively.[63]

Within a ½ mile of Metrorail stations: D.C. collected $2.26B, Virginia collected $470M, and Maryland collected $355M. While within a ¼ mile of Metrorail stations, D.C. collected $1.37B, Virginia collected $290M, and Maryland collected $124M.

Additional explanation is required for the District of Columbia estimates provided below. The District's status as the nation's capital imposes a fiscal hardship in that the city's largest employer and landowner, the federal government, uses city services but does not pay property taxes. For many years the District received a payment from the federal government in lieu of taxes—the payment was based on the assessed value of government property as well as estimates of sales tax foregone. In 1997, however, the federal government phased out the payments in lieu of taxes and instead assumed the cost for the District's courts and the incarceration of the District's convicted felons to help offset the lost revenue associated with the federal government's exempt status for property and other taxes.

Because federal land ownership in the District is so large, to exclude this property type would understate Metro's impact on property values and collections by a significant margin—particularly as the District receives payments in other ways to compensate for this revenue loss. Moreover, the value of the government's property assets is more valuable because of Metro service. In order to estimate this portion of the District's revenue stream, the study team collected information on current federal government payments to the District and included a share of these as a placeholder for the District's tax revenues

[63] Estimate based on GIS analysis of parcel assessment data from Compact area jurisdictions, property tax rates for the local jurisdictions, Business Improvement Districts, and federal government payments to the District for courts, defender services, and offender supervision. The ½ mile revenues include the ¼ mile revenues.

associated with federal government properties. The share includes $258.4M for courts, $55M for defender services, $217.8M for court services and offender supervision.[64]

Additionally, the District tax revenue share includes Business Improvement District (BID) revenues). The estimate of BID revenues is based on the District Budget.[65]

Table 20: Estimated 2011 Total Property Tax Revenues Collected by Compact Area Jurisdictions for Properties Located Near Metrorail Stations

	2011 Tax Revenues	
	1/4 Mile Buffer	1/2 Mile Buffer
City of Alexandria	$ 31,461,396	$ 72,368,015
Arlington County	$ 247,187,782	$ 364,180,287
Fairfax County	$ 11,273,366	$ 29,843,041
City of Falls Church	$ 1,807	$ 3,672,140
District of Columbia	$ 1,365,893,642	$ 2,262,695,708
Residential	$ 67,168,558	$ 204,240,494
Commercial	$ 949,109,644	$ 1,504,321,214
BID	$ 14,511,211	$ 23,000,000
Federal Gov't Payment	$ 335,104,230	$ 531,134,000
Montgomery County	$ 105,352,891	$ 269,762,879
Prince George's County	$ 18,866,569	$ 85,568,835
Total for Compact Area	$ 1,780,037,454	$ 3,088,090,907

Source: AECOM calculation

An additional analysis was conducted to estimate the additional property tax revenues generated for the Compact area jurisdictions due to the premium associated with properties located near rail stations. The premium percentages for residential (6.8 percent), office (8.9 percent), and multi-family (9.4 percent) were estimated in the previous section were applied to the properties by type located within a ½ and ¼ mile of Metrorail stations to estimate the assessed values associated with this premium. The base county and city property tax rates then applied to these assessed values to determine the additional property tax revenues generated in 2011.[66]

The demand for locations near Metrorail stations produces $133 million (¼ mile) to $224 million (½ mile) in additional revenues from property taxes due to the premium associated with properties located near Metrorail stations. The results are presented in Table 21 below.

[64] Senate Bill 3677, 2011
[65] Budget is available at http://budget.dc.gov/
[66] The base property tax rates applied are shown in Table 19. It is important to note that these base tax rates do not include special taxes assessed at the sub-county or sub-municipal level (i.e. those taxes that are not levied on all properties within the county or city).

Table 21: Estimated 2011 Additional Property Tax Revenues Collected Associated with the Premium Identified for Properties Located Near Metrorail Stations

	2011 Tax Revenues Associated with	
	1/4 Mile Buffer	1/2 Mile Buffer
City of Alexandria	$ 645,613	$ 1,973,333
Arlington County	$ 12,179,189	$ 19,092,091
Fairfax County	$ 887,563	$ 1,876,331
City of Falls Church	$ 123	$ 251,331
District of Columbia	$ 111,475,103	$ 178,056,279
Residential	4,567,462	$ 13,888,354
Commercial	$ 75,791,867	$ 118,449,999
BID	$ 1,291,498	$ 2,047,000
Federal Gov't Payment	$ 29,824,276	$ 43,670,926
Montgomery County	$ 7,966,865	$ 18,913,471
Prince George's County	$ 621,354	$ 4,329,705
Total for Compact Area	$ 133,775,810	$ 224,492,542

Notes:
(1) Assumes 6.8 percent premium for residential, 9.4 percent for multi-family, and 8.9 percent for office.
(2) Excludes retail and other property impacts because premiums could not be established for these properties.

Source: AECOM Calculation

7.0 Summary

This purpose of this Technical Report is to assess the regional transportation and mobility benefits associated with the transit services currently provided by WMATA and all transit agencies within the Washington, D.C. metropolitan area. To do this, an analysis was undertaken to see what happens to the travel patterns, VMT, parking costs, toll costs, and lane miles required when transit is removed from the region. The analysis considered the following scenarios:

- **Base Case (2007)**:
  - Basis for comparing conditions in the absence of transit
  - Represents current travel patterns and level of service on highway and transit

- **Scenario 1**: Lane miles of additional road infrastructure averted due to transit
  - Removes all transit service from the Base Case
  - Maintains the Base Case travel patterns
  - Adds highway capacity to return to the Base Case level of service

- **Scenario 2**: No additional investment in infrastructure
  - Removes all transit service from the Base Case
  - Regional travel patterns allowed to change

The benefits in this section are estimated for Scenario 2 because this scenario represents a more realistic picture of transit's impacts today. If transit were not available, travelers would have to switch to auto travel and the additional infrastructure needed to support this increase in demand would take decades to arrive. As a result, people would face severe congestion and gridlock that would force many to alter their trip origins or destinations in order to reduce their trips lengths and travel times.

The results of the analysis indicate that Base Case offers reduced travel times and VMT in comparison to Scenario 2—generating savings for the region. These reduced travel times and VMT associated with transit service provide the region with significant annual travel time, travel cost, accident reduction, and emissions savings as shown in Table 22. In other words, if transit service did not exist in the D.C. region (as assumed in Scenario 2), residents and employees would have to travel more miles in their cars, have longer commutes, and spend more money on transportation.

Table 22: Annual Transportation Savings Associated with the Scenarios (in millions of 2010$)

	All Transit	WMATA Only
	Scenario 2	Scenario 2
Travel Time Savings	$ 1,007.5	$ 705.3
Travel Cost Savings	$ 488.5	$ 342.0
Accident Cost Savings	$ 321.0	$ 224.7
Emissions Cost Savings	$ 13.6	$ 9.5
Total Annual Transporation Savings	$ 1,830.6	$ 1,281.4

Note: Of the total regional savings, 70 percent is associated with WMATA transit services, based on the percentage of regional transit passenger miles on WMATA.

Source: AECOM Calculation

Transit service in the Washington, D.C. metropolitan area also provides an infrastructure benefit for Scenarios 1 and 2, because additional infrastructure would be required to support the additional cars on the roadways and the resulting increase in demand for parking in the D.C. and Arlington Cores, the central business districts of the region. Scenario 1 assumes that lane miles are added to the highway network in order to keep the highway level of service for the scenario the same as the 2007 Base Case level and additional parking structures are added to meet the resulting increase in demand for parking in the region's core. Scenario 2, on other hand, assumes no additional lane miles are added, but additional parking structures are needed to accommodate the new vehicles destined for the D.C. and Arlington Cores. The additional lane miles required for Scenario 1 and the additional parking structures needed for both scenarios have a capital cost impact on the region. These one-time capital costs were estimated using an average cost per lane mile for freeway and arterial roads and bridges based on road and bridge capacity projects in Maryland, D.C., and Virginia as well as SF capital costs for garages. These additional costs are summarized in Table 23 and since they are not a savings for the scenarios these numbers are negative.

Table 23: Total One-time Capital Costs Associated with the Scenarios (millions of 2010$)[67]

	All Transit		WMATA Only	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Highway Capital Cost Savings	$ (6,715.0)	$ -	$ (4,700.5)	$ -
Parking Capital Cost Savings	$ (1,278.9)	$ (2,042.1)	$ (895.2)	$ (1,429.4)

Notes:
(1) Scenario 2 assumes that no additional highway infrastructure is added to the current network.
(2) Of the total regional savings, 70 percent is associated with WMATA transit services, based on the percentage of regional transit passenger miles on WMATA.

Source: AECOM Calculation

8.0 List of Benefit Outcomes

Infrastructure Costs Avoided

- Over 1,000 lane miles of additional road infrastructure averted due to the availability of the current regional transit network (all providers, not just WMATA).[68] Several river crossings require 2-3 additional lanes in each direction.
  - The share of road infrastructure investment avoided specifically due to WMATA services is about 710 lane miles with an estimated capital cost of $4.7B ($2010)[69], which is the equivalent of adding 11 lanes to the entire circumference of the Capital Beltway.
- Over 125% more parking spaces would be needed in the D.C. and Arlington Cores if all current transit riders shifted back onto the roads.[70] This translates into an increase in demand for more than 200,000 parking spaces in the D.C. and Arlington Cores, and the square footage associated with these spaces is the equivalent of 10 Pentagons.[71] The estimated capital cost to accommodate this parking demand ranges associated with WMATA services is $2.9B for below ground parking ($2010).[72]

[67] Except for the Transit Investments, which are shown in year of expenditure dollars.
[68] Estimated by the MWCOG Version 2.3.17 Regional Travel Demand Model with 8.0 Land Use
[69] Uses average road and bridge construction costs per mile for the region. These costs do not include right-of-way purchases or the purchase of vehicles that would be required for some zero-car households.
[70] Estimated by the MWCOG Version 2.3.17 Regional Travel Demand Model with 8.0 Land Use
[71] Total parking square footage for all transit (not just WMATA) is more than 65 million square feet. The Pentagon contains 6.5 million square feet.
[72] Assumes 327 SF per parking space (the average for all WMATA parking facilities, including parking, curves, ramps, etc. and uses average SF construction costs from RS Means (2007) for underground garages. This cost of additional parking includes the parking costs associated with federal employees reported. It is not in addition to the federal parking costs. In addition, it is important to note that not all spaces would have to be built because some portion could be accommodated by excess capacity at existing garages or lots. However, the occupancy rates of current parking facilities in the D.C. and Arlington Cores is unknown.

Commercial Development and Employment

- More than $235.4B ($2010) of real estate is located within a ½ mile of Metrorail stations, and of this, $129.8B ($2010) is located within a ¼ mile of Metrorail stations. [73] Approximately 80% of the value within a ½ mile is associated with commercial properties, and more than 89% of the value within a ¼ mile is commercial.
    - Residential properties (single family) make up $44.4B of the real estate within ½ mile and $13.4B within a ¼ mile of Metrorail stations.
    - Commercial properties (multi-family, office, retail, government, and other) make up $191.0B of the real estate within a ½ mile and $116.4B within a ¼ mile of Metrorail stations.
    - Washington, D.C. and Arlington County make up $193.2B (or 82%) of the total real estate located within a ½ mile of Metrorail stations and $114.7B (or 88%) of the real estate located within a ¼ mile of the stations.
- Additionally, the value of real estate located within a ½ mile of Metrorail stations represents 27.9% of the Compact area's tax base, including 68.1% for D.C., 15.3% for Virginia, and 9.9% for Maryland. [74]
- The real estate located within ½ mile and ¼ mile of Metrorail stations generated approximately $3.1B and $1.8B in property tax revenues for the Compact area in 2010, respectively.[75]
    - Within a ½ mile of Metrorail stations: D.C. collected $2.26B, Virginia collected $470M, and Maryland collected $355M.
    - Within a ¼ mile of Metrorail stations, D.C. collected $1.37B, Virginia collected $290M, and Maryland collected $124M.
- Metrorail boosts property values, adding 6.8% more value to residential, 9.4% to multi-family, and 8.9% to commercial office properties within a half-mile of a Metrorail station.[76]
    - The demand for locations near Metrorail stations produces approximately $133M (¼ mile) to $224M (½ mile) in additional revenues from property taxes due to the premium associated with properties located near rail stations. [77]
- Metro supports over 10,970 jobs directly. [78] Adding in induced and indirect employment associated with WMATA operations, this total rises to over 14,900 jobs associated with Metro operations.[79]

[73] Based on GIS analysis of parcel assessment data from Compact area jurisdictions
[74] GIS analysis of parcel assessment data and total jurisdiction assessment values
[75] Estimate based on GIS analysis of parcel assessment data from Compact area jurisdictions, property tax rates for the local jurisdictions, Business Improvement Districts, and federal government payments to the District for court, defender services, and offender supervision. The ½ mile revenues include the ¼ mile revenues.
[76] Based on a series of hedonic regressions of data compiled from GIS shapefiles obtained from either the real estate assessor's office or department of tax administration.
[77] Estimate based on GIS analysis of parcel assessment data from Compact area jurisdictions, property tax rates for the local jurisdictions, Business Improvement Districts, and federal government payments to the District for court, defender services, and offender supervision. The ½ mile revenues include the ¼ mile revenues.

- Similarly, for every $1 million of in capital expenditures in $2007, Metro supports 14.3762 total jobs in the Washington, D.C. MSA, including 8.3983 direct jobs.[80]

- 2.0 million jobs (or 54% of all regional jobs) are accessible within a ½ mile of Metrorail stations and Metrobus stops. 300,000 more jobs are accessible within 1 mile of Metrorail stations and Metrobus stops.

Mobility

- Metrorail carried 217.2 million trips in 2010. Metrobus carried 123.7 million trips in 2010.[81]

- If all transit services were not available to the region's travelers, average travel times would increase by 25% during the peak travel period. Congestion would lead households to change their travel patterns and choose different work and activity locations. ***The travel patterns would shift so that fewer inter-jurisdictional trips are made, with an increase in intra-jurisdictional travel activity.*** The metropolitan economy becomes more fragmented and loses some of the benefits of its size. As a result, Washington, D.C. functions less like a large integrated metropolitan area and more like a grouping of several smaller physically proximate urban economies.
    - WMATA generated $705 million ($2010) in travel time savings in 2007.[82] This is an annually recurring benefit to the region.

- Transit-dependent populations (low income, senior, zero-car, disabled) make up a significant portion of Metrobus and Metrorail passengers. An estimated 61 million trips (rail and bus) are taken by low-income travelers annually.[83] Another 37 million rail trips are made by residents of zero-car households. Just under 8 million trips annually are taken by senior using the system (rail only, no data for bus) and about 500,000 bus trips are made by disabled passengers. MetroAccess also provides an additional 2.4 million trips for disabled passengers.

Public Safety and Emergency Preparedness

- Metro provides an indispensible part of the Capital Region's emergency preparedness. Regional evacuation plans rely heavily on Metro. On September 11, 2001, Metro facilitated the safe evacuation of hundreds of thousands of people; moving such numbers of people would not be possible without Metro.

[78] 2011 figure reported in WMATA's Proposed Fiscal 2012 Annual Budget
[79] Using RIMS II Direct Effect Multipliers for the Transit and Ground Passenger Transportation industry in the Washington, D.C. MSA (2002/2007).
[80] RIMS II Final Demand Multipliers for the Construction industry in the Washington, D.C. MSA (2002/2007)
[81] WMATA Facts
[82] Travel time saved is estimated by the MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use. This time is valued using the average wage for the Washington, D.C. region and US DOT guidance on values of travel time for work and non-work trips.
[83] Data in this bullet are from the Metrorail and Metrobus survey summary data. The numbers reported cannot be summed because the population groups may over lap. For example, a person can be part of a zero-car household and low-income or senior and low-income.

- Additionally, on Inauguration Day 2009, Metro provided 1,120,000 rail trips, 423,000 bus trips, and 1,721 MetroAccess trips for a total of 1,544,721 trips.[84]

Environment

- About 260 tons VOC, 22 tons PM, and 0.5 million tons of CO2 avoided in the region due to the reduced auto use associate with all transit services in the region.[85] Taking into account the emissions associated with WMATA's services, the estimated monetary value of environmental savings is $9.5 million ($2010) annually.[86]

- The diversion of auto travel to Metro services saves about 40.5 million gallons of fuel annually at a value of about $142 million (at $3.50/gallon).

Livability

- The annual household savings from lower car operation costs to families living near Metrorail stations and/or Metrobus corridors is $342M annually.[87]

- Metrorail and Metrobus provide more than 365,000 weekday trips to zero-car households.[88]

- Qualitative statement that cultural venues, restaurants, cafes, bars and parks are numerous near Metro rail stations and Metrobus corridors.

Regional Identify and Federal Workforce

- Special events in the area relied on Metrorail alone for over 3.5 million passenger trips during 2010. A few of the major events relying on Metrorail in 2010:[89]

  - Annual Cherry Blossom Festival, drawing visitors from around the world: 300,000 to 500,000 trips

  - July 4th celebration: over 580,000 trips

  - October Marine Corps Marathon: over 60,000 trips

  - Sporting events all year for the Nationals, Redskins, Capitals, Wizards, Mystics, and D.C. United: almost 1.5 million trips.

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84 Metro, "Metrorail sets new record for highest ridership day of all time", press release, January 20, 2009. http://www.wmata.com/about_metro/news/PressReleaseDetail.cfm?ReleaseID=2439

85 Based on estimated VMT avoided from the MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use and emissions rates from WMCOG Air Quality Conformity Determination of the 2010 Constrained Long Range Plan and the FY 2011-2016 Transportation Improvement Program and the Sightline Institute

86 Emissions rates for autos and buses were estimated from WMCOG Air Quality Conformity Determination of the 2010 Constrained Long Range Plan and the FY 2011-2016 Transportation Improvement Program, while emissions rates for rail are based on data from the Transportation Energy Data Book. The GHG emissions rates are based on data by mode from Sightline.org. Social costs of emissions are from the Final Regulatory Impact Analysis, Corporate Average Fuel Economy for MY 2012-MY2016 Passenger Cars and Light Trucks.

87 Based on estimated VMT avoided from the MWCOG Version 2.3.17 Regional Travel Demand Model with Round 8.0 Land Use and variable per mile costs of auto use from AAA's Your Driving Costs, 2010. These savings do not include vehicle that would have to be purchased by zero-car households.

88 From the Metrorail and Metrobus survey summary data.

89 WMATA estimation of ridership from special events.

- About 35% of the weekday trips on Metrorail are made by federal employees: 249,087 trips.[90]
    - This translates into an estimated need for 117,500 parking spaces.
- Every year, Metro provides more than 8 million trips for visitors to the nation's capital.[91]

[90] WMATA, 2007 Metrorail Passenger Survey adjusted to average weekday May 2011.
[91] Calculation based on the 2007 WMATA Metrorail Passenger Survey

To: Justin Antos & Metro team

From: Will Schroeer & SGA/AECOM team

Re: "Benefits of Public Transit in the Washington Metropolitan Region,"
Task 1.1, Literature Review

Task 1.1 calls for the Consultant Team to "collect and review existing nationwide literature on quantifying the benefits of public transportation investment and service for both bus and rail modes." The Scope of Work does not call for a formal deliverable from Task 1.1. Nonetheless, we summarize here our review of the literature, with two goals:

1. Describe to Metro what the literature shows is (a) possible, and (b) common in assessing the benefits of public transportation.
2. Describe to Metro which direction those findings suggest that we take in Task 1.2, and get Metro's input on defining the categories, measures, and metrics required by Task 1.2.

We look forward to discussing this review with you and getting your feedback.

Goals of review

Many previous studies have calculated costs and benefits of public transportation. Litman, 2010, cites well over 200 such studies. Our goals in this literature review were:

1. To take advantage of previous work in order to help choose the right categories of benefits, measures, and metrics for the rest of this project; and
2. To locate sources of existing methodologies as a foundation for Task 1.2.

Methodology of review

Rather than review all 200+ studies, we reviewed samples of the research in three types of work: 1) guidebooks to benefits analysis, 2) project reports, and 3) academic articles/research papers that focused explicitly on the benefits of public transportation or compared public transportation to auto transportation.

We also reviewed the D.C.-region-specific studies named in the Scope. These will be very helpful in future Tasks, particularly when assembling data. We do not summarize them here as we determined it to be more important to provide Metro with a summary of the relevant research on metrics. The research summarized here will be critical to determining which metrics Metro would like to pursue.

We have included a brief summary of the TIGER II regulations, as those regulations provide information as to some of the information required for federal applications, and we will rely on them heavily in preparing our final methodologies and report.

Results

The following table summarizes the metrics and methodologies covered in the literature reviewed, and shows how that literature categorizes the metrics. We discuss the implications of this summary following the table. The memo concludes with individual reviews/summaries of the literature in the table.

Table A-1:. Metrics: categorization and frequency

	GUIDEBOOKS			PROJECT REPORTS				RESEARCH PAPERS		
	Litman 2009	Cambridge Systematics (2006)	Litman (2010)	Keeler & Small(1975)	Nelson, et al. (2006)	Goldsmith, et al. (2006)	CUTA (2010)	NZTA (2009)	Litman (2010a)	Cambridge Syst. (2008)
1. Economic Benefits*										
Vehicle Ownership and Operations	✓	✓	✓	✓		✓	✓	✓	✓	
Transit Costs (Subsidies, Capital Costs, Fares, Operating Costs)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Parking Costs (Internal and External)	✓	✓	✓	✓	✓	✓		✓	✓	
Transportation Service Costs: policing, emergency services, etc.	✓	✓		✓		✓		✓	✓	
Transportation infrastructure costs	✓	✓	✓			✓		✓	✓	
Land Consumption Avoided			✓					✓		
Public Infrastructure savings: sewers, power lines, etc	✓									
2. Economic Development Benefits*										
Direct Employment by transit Agency/s and contractors	✓		✓			✓	✓			
Jobs and Businesses due to metro	✓						✓			
Increase in Property Value	✓		✓							✓
Land Uses around Metro - libraries, hospitals, etc	✓						✓			
3. Mobility Benefits*										
Travel Time Savings	✓		✓	✓	✓	✓	✓	✓	✓	
Congestion	✓		✓	✓		✓	✓		✓	
Parking Search time savings	✓				✓					
Mobility for non drivers	✓		✓			✓				
Mobility for non-car owners	✓					✓				
Service Availability		✓								
Service Quality		✓								
Service Reliability		✓								
Avoided Chauffeuring	✓	✓	✓			✓				
Barrier Effect	✓	✓	✓							
Levels of Use	✓	✓	✓					✓	✓	
Intermodal connectivity										

4. Environmental Benefits*										
Fuel Savings	✓	✓	✓			✓		✓	✓	
GHG Savings	✓					✓	✓	✓	✓	
Air Pollution	✓	✓	✓	✓		✓	✓	✓	✓	
Water Pollution	✓	✓	✓					✓	✓	
Waste Disposal	✓	✓	✓					✓	✓	
Noise	✓		✓			✓		✓	✓	
Natural resources conserved		✓	✓					✓		
5. Safety & Health Benefits										
Crash Cost (Internal & External)*	✓	✓	✓			✓	✓	✓		
Reduced Lung diseases - medical expense	✓		✓				✓	✓		
Increased Physical activity	✓	✓					✓	✓		

* Items marked with asterisks have specific criteria that must be followed in applying for federal grants, as outlined in the guidelines in TIGER II. The criteria used for various programs may vary somewhat.

Relationship to TIGER II

The regulations for TIGER II require quantified, monetized valuation of the costs and benefits of transportation projects seeking grant funding from the federal government. The Primary Selection Criteria are divided into Long-Term Outcomes and Job Creation and Economic Stimulus. The Long-Term Outcomes that must be addressed in an application are: (i) State of Good Repair; (ii) Economic Competitiveness; (iii) Livability; (iv) Environmental Sustainability; and (v) Safety. Secondary Selection Criteria require demonstrations of Innovation and of Partnership.

The regulations explain what types of benefits will cause a project to receive priority in receiving funding. Our analysis will address each of these benefits. The regulations also describe preferred methods and methods which will disqualify a project from consideration. Each methodology our analysis uses will comply with these requirements.

The appendix to the regulation will be especially helpful in framing the baselines and alternatives, the affected population, the appropriate discount rates, and the appropriate forecasts of usage levels. It will also provide guidance on calculating benefits to livability, economic competitiveness, safety, and environmental sustainability. It highlights particular areas where double-counting risks arise and where we will need to net out apparent benefits against related costs.

Implications for this project

Literature supports desired direction

Metro gave two pieces of guidance for metrics developed for this project:

1. Have no more than five general categories, and

2. Develop three metrics in particular:

- Value of development around rail stations,

- Greenhouse gases reduced, and
- Size and cost of avoided roadway and parking infrastructure.

The literature review supports both pieces of guidance: the metrics fall easily into five categories, and two of the three metrics of particular interest are commonly calculated. The value of development around rail stations is less frequently calculated. As originally anticipated, we may need to put more time into developing that metric. As you can see from Table 1, many of the other metrics have several sources that can guide us in forming a methodology. To remain within what is feasible given the project's scope of time and budget, we would recommend selecting only one or two of the rarely quantified metrics for inclusion in the final report.

A possible model for one of the project's products

We also found and reviewed a project report from Montreal that (while not included in the table above because it takes such a different approach) we believe offers a useful model for one of the final reports from this project: "Public transit: a powerful economic-development engine for the metropolitan Montreal region", Secor Consulting for the Board of Trade of Metropolitan Montreal. (www.ccmm.qc.ca/documents/memoires/2004_2005/BTMM_PublicTransit_study.pdf)

The Scope is clear that Metro desires a comprehensive list of metrics from which to choose, and not only economic metrics. On the other hand, the Scope also highlights the need for a "business case" for investment in Metro. A key early decision for Metro will be selecting the format of the report and the target audience. Two examples are provided below to illustrate alternative approaches.

1. A comprehensive benefits report, technical in nature, that covers all selected indicators, including environmental, etc., attempting to monetize as we are able; and
2. An economic development-focused report, more glossy and polished--much like the one from Montreal, which highlights only the economic and fiscal impacts of Metro.

We will be looking for your feedback on this issue in particular.

Summaries of selected reviewed materials

1. Measuring and Valuing Transit Benefits and Disbenefits. Cambridge Systematics.

This guidebook lists metrics related to cost benefit analysis, and briefly describes how these can be measured or quantified. The following metrics are tabulated from their report.

Category	Basis for Analysis
Mobility and Accessibility Impacts	
Levels of Use	Transit Ridership, modal split, ratios of use to seats capacity
Travel Time Savings	Transit travel times and speeds, transit service frequency, auto travel times and speeds
Service Availability	Transit system configuration and frequency
Service Quality	Comfort and convenience

Service Reliability	Transit system performance, auto use characteristics
Highway System Impacts	Congestion reduction
Economic Impacts	
Demand on Public Resources	Year-to-year revenue base
Cost-Effectiveness of Service	Return on investment
Cost Avoidance	User cost savings and government cost savings
Affordability for Users	Absolute and comparative trip costs
Jobs and Income Generation	Direct, indirect, and induced employment; disposable income to individuals; and revenue to business
Economic Growth	Business sales and income, company growth rates
Development and Land Use	Enhanced property values
Energy and Environmental Impacts	
Reduced Fuel Consumption	Auto consumption and transit consumption rates
Emissions	Auto emission rates and transit emission rates
Noise	Decibel levels of auto and transit modes
Ecology	Sites and acreage affected (NEPA studies)
Land Consumption	Acreage requirements
Personal Safety and Security Impacts	
Rider Safety and Health	Accident rates, severity costs, psychological effects
Transit Employee Safety	Accident rates, severity costs
Non-rider safety	Accident rates, severity costs
Rider Security	Incident frequency and severity
Neighborhood Integrity	Resident attitudes, perceptions, activity levels
Barrier Effects	Operational characteristics of facilities
Equity Impacts	
Level of Service	Transit service with respect to target population
Utilization	Ridership characteristics by population groups
Cost Incidence	Costs with respect to incomes
Service Availability	System configuration with respect to target population
Access to Opportunities and Destinations	Existence and extent of transit service by type

2. *Transportation Cost and Benefit Analysis -Techniques, Estimates and Implications* [Second Edition] Litman (2009)

This guidebook lists many metrics (which served as the basis for Table 1), explains how each metric is measured and quantified in monetary terms, and gives standard rates for the USA and Canada. Chapters elaborate on different data sources, methodologies, and illustrations for measuring and quantifying costs and benefits. The following metrics have entire chapters devoted to their quantification: vehicle costs, travel time, safety and health, parking, congestion, roadway facilities, roadway land value, traffic services, transportation diversity, air pollution, noise, resource consumption, barrier effect, land use impacts, water pollution and hydrologic impacts, and waste disposal. Each chapter includes sections quantifying sub-metrics (for example: vehicle costs include capital costs, operation and maintenance costs, insurance, registration costs, etc).

Later chapters summarize net value calculation, results, criticisms of this kind of analysis, some case studies, and conclusions.

3. *Raise My Taxes Please! – Evaluating Household Savings from High Quality Public Transit Service*; Todd Litman (2010a)

The research compares the fifty largest U.S. cities for transit fares, subsidies, capital costs, and operating costs; and auto transportation infrastructure costs, capital costs, and operational costs for the years 1998, 2003, and 2008. It evaluates incremental costs and benefits to users from high quality transit service. The study quantifies the costs and benefits from a comparison of vehicle costs and transit fares, and it also measures other benefits such as congestion reduction, increased traffic safety, pollution reductions, improved mobility for non-drivers, and improved fitness and health. The study further shows that ridership and household savings are higher in cities with high quality transit service.

4. *Evaluating Public Transit Benefits and Costs – Best Practices Guidebook*. Todd Litman (2010)

This guidebook describes how to create a comprehensive framework for evaluating the full impacts (benefits and costs) of a particular transit system or a system improvement. It draws from national and international trends, the statistics about travel trends, transportation problems such as congestion, parking, accidents, etc. in different countries. The paper points to different models for transit cost benefit analyses used, types of data used, breaks down analyses by types of buses, types of rail, other modes such as walking and biking. It then enumerates best practices applied in different places for each of the transportation problems such as congestion, pollution. And quantifies how it is beneficial to apply these best practices.

In subsequent chapters it provides guidelines for cost benefit analysis for a comprehensive list of categories, and for comparison between auto and transit transportation systems.

5. *The Full costs of Transport Part III: Automobile Costs and Final Intermodal Cost Comparisons*. Keeler and Small (1975)

This report developed cost estimates for the major urban transportation modes for intermodal cost comparisons: rail, bus, and automobile. The costs are analyzed for four scenarios: the system with (i) bus transit and auto travel, (ii) rail and auto travel, (iii) auto transport alone, and (iv) bus, rail, and auto travel modes.

The project includes operating and maintenance costs, time costs, and pollution costs. It further elaborates the sensitivities of measuring travel time costs and interest rates assumed since they depend on a number factors not included in the study.

6. ***Traffic Impact Analysis: Effect of the absence of BART service on the Major East Bay Corridors.*** **Laval, Cassidy, Herrera (2004)**

This research evaluates delays in travel times that could be caused on major corridors, if BART services were to be closed. The study suggests that traffic would come to a halt at the junctions and on these corridors for a couple hours due to a bottleneck effect. The study does not however consider downstream congestion due to absence of BART.

7. ***Relative costs and benefits of modal transport solutions*****. Smith, Veryard, Kilvington NZTA (2009)**

The first half of this report analyzes costs and benefits of transportation modes: walk, bicycle, car, taxi, bus, light rail, and heavy rail as costs for the user, the community, and the government. The metrics included were (i) for the users: vehicle costs, parking costs, travel time costs, health costs, accident and crime risk costs; (ii) for the community: accident costs, air pollution, noise pollution, greenhouse gas emissions, severance, health impacts, congestion impacts, and place-making costs and benefits; and (iii) for the government: whole of life construction cost, land cost, maintenance costs, and parking requirement costs.

The second half of the research elaborated four case studies: three from the New Zealand and one from the United Kingdom. The case studies are success stories where best practices were applied for solving transportation problems such as congestion, safety, etc. The major best practices included provision of bike path network in Hawke's Bay, New Zealand; improving quality of bus transit service in Christchurch, New Zealand; cost-effective provision of bus rapid transit to solve congestion problems in Auckland, New Zealand; and subsidies rendered unnecessary by 97% of transit agencies due to profits as a result of improved transit service in Nottingham, United Kingdom.

8. Peter Nelson, Andrew Baglino, Winston Harrington, Elena Safirova and Abram Lipman, ***Transit in Washington, D.C.: Current Benefits and Optimal Level of Provision*****, Resources for the Future (2006)**

This report attempted to measure the benefits of congestion relief and transportation choices resulting from public transportation in the D.C. region, by assuming that transit was reduced to zero. The report determined that the benefit of the system was equal to the resulting decrease in travelers' welfare minus the savings in operating costs. The report found "rail transit generates congestion-reduction benefits that exceed rail subsidies," and "the combined benefits of rail and bus transit easily exceed local transit subsidies generally." Additionally, time savings (congestion and parking search costs) to motorists alone exceeded operating subsidies. "[A]nnual net benefits of the system [were] more than $1.7 billion for the year 2000, or $6 per transit trip."

The report used "START," a Strategic and Regional Transport modeling suite developed by MVA Consultancy, which has been used to evaluate different urban areas in the United Kingdom. Although this program does not appear to be readily available online, it may be worth looking into contacting MVA Consultancy to see if we could use their model.

This report included an unexpected amount and variety of metrics in calculating its "Transit Trip Cost Calculation." Their calculation included the transit fare; the value of the time of transit riders; wait time, including the probability of missing a bus and having to wait longer; psychological perceptions in time increases due to overcrowding; travel time, including time involved in transferring; and the costs associated with using the park-and-ride facilities. The above list shows that Metro can go into great depth when calculating its benefits, and a feasible list of factors will need to be developed to ensure that the report remains within its scope, allotted time, and budget.

The report discusses that its results differ great from the results from a 2005 report by Winston and Maheshri who found negative net benefits in 2000. The authors explain that the difference occurs because of their more realistic figures for transit agency deficit, their calculation of benefits to drivers, and the addition of commuter rail (such as MARC). They found that "[d]rivers save about 45.9 million hours per year in travel time thanks to the existence of a transit system." We may want to find the Winston and Maheshri report to evaluate their methodology.

9. Scott Goldsmith, Mary Killorin and Eric Larson, *The Economic Benefits of Public Transportation in Anchorage*, Institute of Social and Economic Research, University of Alaska Anchorage, for the Public Transportation Department, Municipality of Anchorage (2006)

This study of the Anchorage community found annual benefits of $14.155 million, with a benefit-cost ratio of 1.71. This study broke the benefits down into three categories: (1) users' benefits from using transit instead of driving their own car or taking a cab; (2) access/social benefits for residents for whom transit is the only alternative; and (3) community benefits measuring how the whole community shares in savings achieved from reducing the number of cars on the roads.

Under user benefits, the study calculated: reduced vehicle-operating and ownership costs; reduced taxi fares; reduced costs of providing rides to others; parking costs, including land costs, construction, operations, and maintenance; reduced likelihood of a traffic accident; and cost of time.

For access/social benefits, the study looked at access to jobs, benefits to employers, and benefits to tax payers. The value of job access was calculated to be a $1.454 million value, according to a willingness-to-pay calculation. Employers' benefits were described using anecdotal evidence from several employers employing large numbers of transit riders. Taxpayer benefits were calculated by looking at savings in unemployment insurance payments, reductions in food stamps, and reductions in public assistance. Other benefits were described by trip quantity without assigning a price per trip cost to them: access to health care, education, shopping, and tourist areas by visitors.

Community benefits included quantified items and items which were not quantified. The report quantified cost savings resulting from reductions in parking costs, traffic services, congestion, barriers to movement, traffic accidents, air pollution, and noise pollution. The report described benefits to public health, reductions in energy consumptions, more efficient land use patterns, quality of life improvements, and water pollution.

The report also was able to calculate the benefits of jobs and income created by operating the public transportation system. They looked at local spending by transit system employees for goods and services; and spending by the system for fuel, vehicle parts, bus stop materials, and services. The report calculated that the economic effect of the Anchorage system was 354 jobs and $15.6 million of payroll in 2004.

10. CUTA, *The Economic Impact of Transit Investment: A National Survey*, Canadian Urban Transportation (2010)

This report of the national Canadian transit systems calculated the total economic benefit to be over $10 billion annually. They also calculated the value of:

(i) reduced vehicle operating costs for households;
(ii) reduced costs related to accidents;
(iii) savings to the health care system from reductions in hospital admissions;
(iv) direct and indirect employment of the transit industry; and
(v) capital investment in transit and the related jobs and economic output.

In organizing the inputs for their calculations, the study authors created “accounts” to which costs and benefits could be added or deducted. The Direct Project and Transportation Account included capital costs, operating and maintenance costs, operating revenues, net operating costs (operating revenues netted out against operating costs per passenger), employment generated, output generated, and taxes generated. The Direct Transportation User Benefits Account included travel time (time saved, value of time); travel speed in congestion conditions; vehicle operating costs per VMT, including fixed ownership costs; and accident costs. Then there was an environmental account, a land use/economic development account, and a social and community benefit account. They also had a set of ridership and traffic metrics that would be used in calculating the values in each account: mode distribution, passenger volumes, VMT, percentage dependent on transit, average occupancy, and peak period traffic.

The report referenced several studies quantifying the congestion costs to cities, and we should determine whether a similar study has been done for the D.C. area. The report also contains a literature review subdivided into different categories of benefits with a review of common methodologies and sources. This will be a good reference when selecting our methodologies. Specifically, they reference a 2009 study by Li and Newcomb showing that asthma-related hospital visits by children in Dallas were strongly correlated to auto-traffic density.

The report highlights pitfalls of conducting these economic analyses, including: the difficulty of attaching accurate values to non-monetary concepts; the risk of double counting (e.g., calculation of time travel savings overlaps with the increase land value because the land is more valuable due to reduced travel times); and the difficulty of isolating the relevant variables.

11. Cambridge Systematics, Inc., *Measuring the Economic Development Benefits of Transit Projects: Proceedings of an Expert Panel Workshop*, U.S. Department of Transportation Federal Transit Administration (2008)

The purpose of this report was to make recommendations to FTA regarding methods for forecasting the economic development of new transit projects, but the panel's discussions and recommendations would also be applicable to existing projects. Economic development was defined to be the impact transit has on land use patterns and the benefits associated with those impacts. It includes land use changes that generate economic value.

To be exact under economic theory, economic development valuation would need to add the changes in consumer surplus to the changes in producer surplus and tax revenue, but calculating all these changes is not really feasible. Therefore, they recommend other methods for simplifying the equation. Most of the panelists believed that changes in land values would be the closest approximation. Land values must be distinguished from improvement values – the value of the buildings on the land. Property values usually include the value of both the land and the improvements upon it.

The report gives arguments for and against the following methods: (1) integrated transportation/land use modeling approach; (2) historical analysis of transit investment, development and land values using econometric methods; (3) regional economic simulation modeling; (4) project-specific market assessments; and (5) a qualitative approach.

The second approach, a historical analysis of transit investment, development and land values using econometric methods appears to be the most appropriate method for our purposes. The model should look at measuring property values with hedonic price models, which look at the sales price or rent of properties while controlling for variables such as size, characteristics of the available buildings, zoning, and any other non-transit variables affecting the valuation. Hedonic modeling would take its data from actual sales of real estate and/or appraisals based on full market data. Residential information is maintained by the Multiple Listing Service, and their "excellent" datasets should be available to public agency or for research purposes. Commercial transaction data will be more difficult to find.

Development at station areas might not reflect a net addition of development region-wide because the development might be leaving another area to come to the station area. Therefore, to provide a more accurate measurement, we would need to look at changes in land values in other areas also. The panelists did not think it would be feasible to do this on a regional scale and concluded that any decreases in land value away from stations were likely to be too small to affect the outcome of the valuation.

12. *TCRP J-11 (7) – Economic Impact of Public Transportation, APTA.* Glen Weisbrod, Arlee Reno (2009)

This report comprehensively analyzes economic impacts of public transit in the US. It quantifies costs and benefits in monetary terms for some of its components, but it quantifies in respective units for most of the categories. The report does not quantify the impacts of environmental and societal benefits because it specifically focuses on economic benefits. It presents a methodology, which is derived from a study of the existing research in this area. The report is organized in two main parts, which could be called direct and indirect impacts or immediate and long-term impacts.

First, the immediate impacts include the impact of public transit on direct employment creation such as construction-related jobs and operation and maintenance jobs. The analysis indicates that capital investment on public transportation produces nearly 24,000 jobs per year, per billion dollars of spending on public transportation capital; and about 41,000 jobs for each billion dollars of annual spending on public transportation operations in the US, or a combined 36,000 jobs per billion dollars invested in public transportation. The report further quantifies how this employment spurs more benefits in sales and businesses, increases federal and state revenues through taxes, and creates savings to the government from paying unemployment costs, and finally how much it add the national GDP. The following is a summary table from the report:

Economic Impact	Per $ Billion of Capital Spending	Per $ Billion of Operations Spending	Per $ Billion of Average Spending[B]
Jobs (Employment. thousands)	23.8	41.1	36.1
Output (Business Sales, $ billions)	$ 3.0	$ 3.8	$ 3.6
GDP (Value Added, $ billions)	$ 1.5	$ 2.0	$ 1.8
Labor Income ($ billions)	$ 1.1	$ 1.8	$ 1.6
Tax Revenue ($ millions, rounded)	$ 350	$ 530	$ 490

The second part of the report analyzes mobility and economic development benefits of public transit, which are seen as long-term benefits (2010 -2030). Travel and vehicle ownership cost savings for public transportation passengers and those switching from automobiles, lead to shifts in consumer spending; reduced traffic congestion for those traveling by automobile and truck, leads to further direct travel cost savings for businesses and households; businesses save on operating costs associated with worker wage and reliability resulting congestion reductions; business productivity gains from access to broader labor markets with more diverse skills, enabled by reduced traffic congestion and expanded transit service areas; and additional regional business growth is enabled by indirect impacts of business growth on supplies and induced impacts on spending of worker wages. At a national level, cost savings and other productivity impacts can affect competitiveness in international markets.

The results show that, per $1 billion of annual investment, public transportation investment can lead to more than $1.7 billion of net annual additional GDP due to cost savings. This is in addition to the $1.8 billion of GDP supported by the pattern of public transportation spending. Thus, the total impact can be $3.5 billion of GDP generated per year per $1 billion of investment in public transportation.

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