PRELIMINARY ECONOMIC IMPACT STUDY: UPDATE

TEMS

Transportation Economics &
Management Systems, Inc.

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1 INTRODUCTION (STUDY PURPOSE AND CORRIDOR)

The purpose of this study is to update the Purple Line Economic Analysis developed by Transportation Economics & Management Systems, Inc. (TEMS) in 2010.

The aim of Purple Line light rail is to provide better connectivity between Bethesda in Montgomery County and New Carrollton in Prince George's County. As it is proposed by Maryland Transit Administration (MTA), U.S. Department of Transportation (USDOT) Purple Line 'would provide a direct connection to the Metrorail Red, Green and Orange Lines; at Bethesda, Silver Spring, College Park, and New Carrollton. The Purple Line would also connect to MARC, Amtrak (Northeast corridor), and local bus services'[1]. A map showing the proposed Purple Line Preferred Alternative[2] along with stations and other metro, MARC and rail lines is shown in Exhibit 1.1.

Exhibit 1.1: Purple Line Route and Station Map

The approach of the Economic Impact Study is to measure supply side benefits generated by the Purple Line Project. To do this, two impact analyses have been used by Transportation Economics & Management Systems, Inc. (TEMS) in evaluating the Economic Benefits for the Study. These are as follows:

Long-Term Supply Side Impacts: Used to identify the economic impacts of the 16-mile light rail line to the communities in the region, especially Montgomery and Prince George's Counties. Since the implementation of the Purple Line light rail project calls for the investments by both the public and private sectors it is clear

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[1] See: http://purplelinemd.com/about-the-project for details.

[2] According to MTA, The Preferred Alternative is a refined version of the Locally Preferred Alternative (LPA) identified in AA/DEIS 2009 (see http://www.purplelinemd.com/images/studies_reports/feis/volume_01/013_PL%20FEIS_Vol-I_Ch%209%20Evaluation-of-Alts.pdf for more information).

that a project needs to be fully evaluated in economic terms, which includes the economic impact of the project on the local economy. Typically, federal and state governments have required a demand-side analysis of the economic benefits of a project which may be characterized as traveler or user benefits that measure time, cost and energy savings, and also external resource savings associated with making trips in the study region. However, of real interest to policy makers and individuals who live in a corridor are the supply side benefits of a project which may be characterized as community benefits or productivity benefits such as increased jobs, income and wealth that result from implementing the project.

Economic Rent Analysis of supply side community economic benefits can be estimated using the TEMS RENTS™ model. This methodology is fully documented in the academic literature of transportation economics [1], [2], [3], and [4], and it is well established that while Consumer Surplus measures benefits from the demand side, Economic Rent measures benefits from the supply side. Because the economy is circular and demand must equal supply for the economy to be in equilibrium, Economic Rent analysis, is the "mirror image" of consumer surplus. Economic Rent is however a less well-used methodology. This is because it is more difficult to measure economic rent than to measure consumer surplus. The work on specific measurement methodologies for economic rent has only been conducted in the last twenty years. This reflects the growth of computer power and the ability of modern computers to handle the large number of calculations associated with conducting an Economic Rent Analysis.

As documented in the literature [5] through [6] the initial work on economic rent grew out of urban economics and in particular the measurement of property prices and commuting activity. This work was later supplemented by the development of transportation analysis methodologies that greatly enriched the economic rent measurement process. This included transportation access measurement (by measuring transportation utility) and traffic movement databases (showing market interaction) that are so critical to economic rent [7]. The final formulation of economic rent methodology required the inclusion of the Economic Theory of Location and, specifically, Central Place Theory [8], [9] to provide a structure of "markets" to which the general economic rent proposition could be applied. This then provided an effective application method. Essentially the economic rent measures the improvement in income, employment and property value that individuals receive as a result of a transport investment (improved accessibility) which allows the market to work more efficiently and to raise individuals' productivity.

Temporary Construction Impacts: The construction impacts of the Purple Line light rail will constitute a significant investment in the region, especially Montgomery and Prince George's Counties by the Federal Transit Administration (FTA). This Federal investment would comprise a major transfer payment to the region that would significantly increase total spending within the Montgomery and Prince George's Counties economy. The spending of federal dollars cannot be expressed as a benefit to the U.S. economy, since the investment might well have been made elsewhere, rather than in the Purple Line project. However, it is clear that such an investment choice on the part of the Federal government will have a significant economic impact on the local regional economy. To estimate the economic impact of the additional federal construction spending in the region, especially Montgomery and Prince George's Counties, an analysis was performed using the Bureau of Commerce, BEA, Regional Input-Output Modeling System II (RIMS II) economic model.

The following report updates these analyses to a 2015 base, and applies the update to the Purple Line Impact Study. The update is applied to databases, methodology and the results of the study. The report includes the following:

Chapter 1: Introduction - The study purpose and corridor

Chapter 2: Economic Analysis Framework – This includes a brief assessment of the overall economic framework and the relationship between Consumer Surplus and Economic Rent.

2.1: The Character of the Overall Economy in the Purple Line corridor.

2.2: Economic Rent Methodology – covers theoretical and technical issues of the developed methodology – Economic Rent (evaluating the supply side of the Study).

Chapter 3: The Economic Evaluation Databases – This describes the process of developing socioeconomic and transportation databases, as well as different methodologies necessary to perform both parts of economic benefits evaluation study.

Chapter 4: The Travel Demand Model and Traffic Forecasts describe the model developed by TEMS for this study. The chapter also shows how the model was calibrated for this study, illustrates the forecasting process, and the forecast results that were obtained.

Chapter 5: TEMS Economic Rent Model

Chapter 6: Economic RENT™ Results

Chapters 5 through 6 present the economic benefits associated with the Purple Line corridor and were evaluated by the Economic Rent model. Economic evaluation results for Montgomery and Prince George's Counties that especially benefit from the Purple Line project were analyzed. Transfer payments in terms of tax benefits are particularly discussed here.

Chapter 7: Input-Output Analysis: Construction of the Purple Line – This Chapter presents an Input-Output analysis to identify the transfer payment benefits of a major investment like the Purple Line Preferred Alternative (cost $1.9 billion) on the economy in terms of temporary construction and permanent operating jobs.

Chapter 8: Conclusion: This chapter describes the overall benefits to the study region of the Purple Line project.

Appendix A: Data Sources and Methods for RIMS II – This discusses an Input-Output (I-O) Matrix which is an accounting framework that mainly underpins the RIMS II methodology.

Appendix B: Stated Preference Survey – This describes the methodology, the purpose, the process and the results of the Stated Preference Survey undertaken by TEMS in 2010.

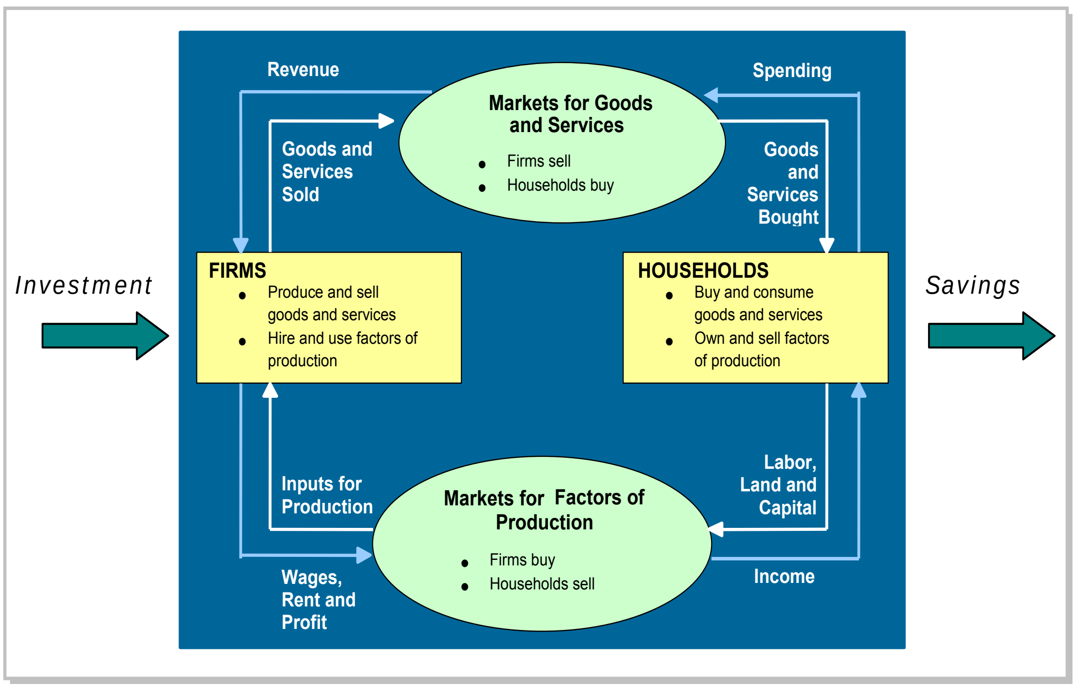
2 ECONOMIC ANALYSIS FRAMEWORK

In order to estimate the economic impact of the Purple Line project, it is important to understand the character of the different economic benefits to be quantified. These benefits arise from developing and operating the system and have a substantial impact on the productivity of the local and state economy.

2.1 THE CHARACTER OF THE OVERALL ECONOMY

A model of the economy [10] shows that an economy is circular in character, with two equal sides (see Exhibit 2.1). On one side of the economy is the consumer side – the market for goods and services – in which consumers buy goods and services by spending the income earned by working for a commercial enterprise. For example, a transportation investment improves individuals travel times and costs and, therefore, increases consumer (traveler) surplus (travel and money savings). An analysis of the impact of a transportation investment in the market for goods and services quantifies the level of consumer surplus generated by a project, by showing how much money and travels individuals save because a given project (i.e., a transportation improvement) reduces their cost of travel, or makes their travel more efficient.

Exhibit 2.1: Simple Model of the Economy



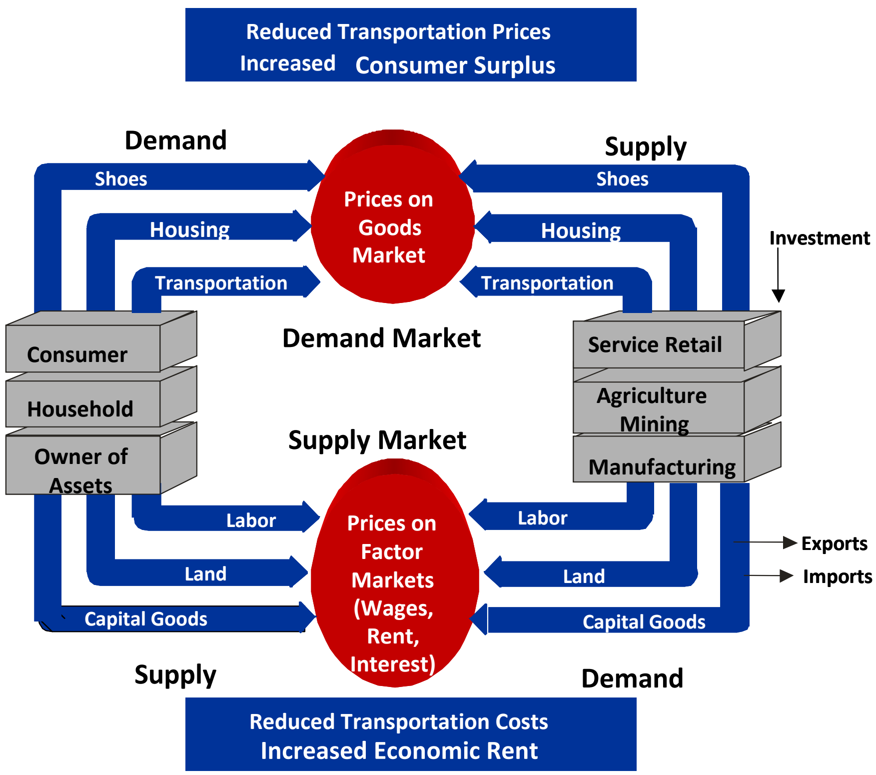
The notion that a transportation project can be worthwhile if travel is made more cost effective is based on the idea that not only the cost, but also the time of a trip, has value. This axiom is agreed to by most transportation companies and by business travelers as well as by both academia and important transportation authorities such as USDOT Federal Highway Administration (FHWA)[3] and Maryland State Transit Administration (MTA). In addition, academic and empirical research has shown that this concept holds true for commuters and social, recreational travelers as well [11]. Considerable research has been carried out to both identify the theoretical justification for value of travel time and to quantify its value.

[3] See: http://ops.fhwa.dot.gov/tolling_pricing/value_pricing/tools/truce_st_devpfrom3_0.htm

On the other side of the economy is the market for factors of production. Most importantly, it is the market for land, labor and capital, which individuals provide to firms in exchange for wages, rent and profit. From the perspective of policy makers and the local community, this side of the economy is very interesting as it shows how investment in a new transportation infrastructure changes the efficiency of the economy and how the investment increases transportation efficiency, creates new jobs, opportunities, and, therefore, increases income and wealth and expands the tax base.

One of the most important aspects of the circular economy model is that it shows that any project has two impacts, one in the consumer market – the benefits to travelers; the second, in the factor markets or supply side of the economy – the benefit to the community in terms of improved welfare such as increases in jobs, income and wealth (see Exhibit 2.2).

Exhibit 2.2: Relation between Consumer Surplus and Economic Rent in the Economy



For the economy to reach equilibrium, both sets of benefits must be realized. As such, the benefits of a project are realized twice, once on the demand side and once on the supply side. As a result, there are two ways to measure the productivity benefits of a transportation project and, theoretically, both measurements must equal each other [12]. This is a very useful property since in specific analysis one can be used to check the other, at least at the aggregate level. This is very helpful and provides a check on the reasonableness of the estimates of project benefits.

However, in assessing the benefits of a transportation project, it is important not to double-count the benefits by adding supply side and demand side benefits together. It must be recognized that these two sets of benefits are simply different ways of viewing the same benefit. The two markets are both reflections of and measure the same thing. For example, if both sets of benefits equal $50 million, the total benefit is only $50 million, but expressed in two different ways: travelers get $50 million of travel benefits and the community gets $50 million in jobs, income, increased profits. As a ripple effect (or transfer payment) the economy also gets an expanded tax base.

Therefore, if a given transportation project is implemented, equivalent productivity benefits will be seen in both the consumer market for goods and services (as the economy benefits from lower travel times and costs), as well as in the supply side factor markets. In the supply side market, improved travel efficiency is reflected in more jobs, income and profit. For a given transportation investment, therefore, the same benefit occurs on both sides of the economy. In the consumer markets, users enjoy lower travel costs and faster travel times. On the supply side of the economy, the factor markets take advantage of the greater efficiency in transportation. As a result, both sides of the economy move to a new level of productivity in which both sides of the economy are balanced in equilibrium.

Improved efficiency will generate supply-side spending and productivity benefits that have a very real impact on the performance of the local economy. The method that develops estimates of productivity jobs and wealth creation is an Economic Rent Methodology. It measures how the performance of a new transportation facility raises the efficiency of the economy. This efficiency improvement creates jobs and income, and raises local property values to reflect the improved desirability of living or working in the area. Specific methods for applying Economic Rent economic theory will be identified and appropriate measurement methodologies will be developed. In particular, the issue of measuring the quality of the transportation system will be addressed.

2.2 ECONOMIC RENT METHODOLOGY

The concept of Economic Rent is derived from basic Ricardian economic theory and provides a means of explaining the increased value of economic resources (land, labor and capital) and their change in value in different circumstances or market conditions. For a transportation investment, accessibility is a key spatial variable that affects the likely uses of economic resources and, therefore, their value. Changes in accessibility result in changes in the economic rent (or monetary value) that economic resources can command and, therefore, the value and character of the economic activities that take place at any location. As a result, for important economic welfare criteria (such as employment, household income, and property values) an evaluation can be made of the likely change in economic rent that will be associated with an improvement in accessibility generated by a given transportation investment [13].

Economic Rent may be defined as the difference between what the factors, or productive services, of a resource-owner earn in their current occupation and the minimum sum he/she is willing to accept to stay there. It is then a measure of the resource-owner's gain from having the opportunity of placing his factors in the chosen occupation at the existing factor price, given the prices his factors would earn in all other occupations. It is the proper counterpart of consumers' surplus when this is regarded as the consumers' gain from having the opportunity of buying a particular good at the existing price, where all other prices are given. And like a change in the consumers' surplus, it is a measure of the change of his welfare when the relevant prices in the market are altered. Whereas the increase of consumers' surplus is a measure of his welfare gain for a fall in one or more product prices, the increase in that person's economic rent is a measure of his welfare gain from an increase in the price or the volume of the sale of his factors, i.e., increased sales should generate increased profit.

Typically, the level of economic rent can be calculated as follows:

Economic Rent (ER) = $f(P_t, I_t, E_t, C_t, T_t)$

Where:

P_t is a measure of Population structure of an area in year t;

I_t is a measure of Industrial structure of an area in year t;

E_t is a measure of Education level of an area in year t;

C_t is a measure of Cultural characteristics of an area in year t;

T_t is a measure of Transportation efficiency of an area in year t.

Any analysis region (area) has its own 'Economic Rent Profile'. Economic rent profile shows the spatial distribution of the economy in terms of key factors such as income, property value and wealth. Each of the characteristics listed above can have a significant impact on economic rent profile.

Population Structure: The population structure can affect the economic potential of an area positively or negatively. For example, an aging population could have a negative effect on the economy as the number of workers in the work force may fall. This can reduce productivity and, as a result, reduce the economic rent profile. The U.S. might experience this problem in the second quarter of this century as baby boomers age if technology improvements and increased output do not raise productivity sufficiently. Typically, the more productive the adult population of an area is, the higher the economic rent profile.

Industrial Structure: The nature of the industrial structure and resource base defines the potential economic rent profile of an area, e.g., manufacturing, commercial, agricultural, residential, and service industry. The higher the value added by industry, the higher the area's economic rent profile. For example, the "new economy" jobs in biotech, computers and finance all have very high incomes and economic rent profiles associated with them.

Education Level: Educational levels can have a dramatic impact on economic rent potential of an area. Typically, a higher education level (especially Ph.D.'s or other high degrees) will increase the wealth generated by the population. The Baltimore-Washington region, for example, boasts one of the highest concentrations of Ph.D.'s in the U.S., which supports the growth of high tech industry in the region[4].

Cultural Characteristics: Differences in cultural, ethnic and other social characteristics of an area can impact its economic potential. For example, cultural belief systems can impact the ability of a population to work at certain jobs or in a certain way and, therefore, the level of economic rent that can be attained. A survey by the United Nations of the economic growth potential of Arab countries found that the low level of freedom, limited Internet use and the absence of women in the workforce have had a marked negative impact on economic productivity [14]

Transportation Efficiency: Transportation efficiency can greatly affect the economic potential of an area. The more effective a transportation system in moving people and goods, the greater its ability to generate wealth if the economy is responsive to the opportunity presented. It is no coincidence that most of the U.S.'s large east coast cities grew as 'break of bulk' ports at locations that had good harbors and good routes to the interior resources and markets of the U.S. Since the quality of a transportation system is a management variable and can be changed in the short term, investment in the transportation system can generate economic development if the investment is made in a growing and vibrant economy. The level of response that the economy will have to a transportation investment is measured by the economic rent profile.

[4] According to the data assembled by the Metropolitan Washington Council of Governments (source: US Census Bureau), 20.6 percent of individuals over the age of 25 residing in the Baltimore-Washington region have a graduate or professional degree. This is well above the national average of 8.9 percent.

Where it is important to recognize that education, population, industry, structure, and culture can change over time changing the economic rent profile. However, these are not characteristics that typically change rapidly. Only if an area experiences a significant dislocation or migration associated with rapid and dramatic population and industrial base shifts will it experience a radical change in its economic rent profile. For example, the influx of Hong Kong residents to Vancouver, Canada, in the 1980s dramatically changed the economic rent profile of several areas of the city's downtown. The effect was largely due to the wealth and "entrepreneurial" capability of this new population. In the United States one of the issues for the Midwest is the fact that while it has some of the country's leading academic institutes, it is still losing much of this talent because it is not developing the New Economy businesses at a sufficient rate.

In the absence of a major dislocation, we can assume that the economic rent factors I_t, E_t, P_t, and C_t will remain largely unchanged in the short term (10-20 years). However, transportation efficiency can change significantly in the "short term." Major transportation infrastructure projects can dramatically change the accessibility of markets and the opportunity for economic growth. This can apply to the measurement of goods in a manufacturing-dominated economy or to the movement of people in a service industry-dominated economy. The economic rent generated by transportation improvements (T_t) has driven the desire to move people more quickly and cost-effectively over time. As a result, if population, industrial structure, education levels, and cultural characteristics remain constant, the Economic Rent (ER) model reduces to:

$$ER = f(T_t)$$

By using socioeconomic variables (SE_i) as a proxy for economic welfare and generalized cost (GC_i) as a specific metric for transportation efficiency measured in terms of time and cost the economic rent equation can be rewritten as:

$$SEi = \beta_o GC_i^{\beta_1} \qquad (3)$$

Where:

SE_i – Economic rent factors – i.e., socioeconomic measures, such as: employment, income, property value of zone i;

GC_i - Weighted generalized cost of auto travel for all purposes from (to) zone i to (from) other zones in the study area;
β_o and β_1 - Calibration parameters.

The resulting curve generated by this function is the economic rent profile for transportation accessibility. The generalized cost of auto travel includes all aspects of travel time (in-vehicle time), travel cost (tolls, fuel costs and parking charges).

The generalized cost of travel is typically defined in travel time rather than dollars. Costs are converted to time by applying appropriate conversion factors. The generalized cost of auto travel between zones i and j for purpose p is calculated as follows:

$$GC_{ijp} = TT_{ijp} + \frac{TC_{ijp}}{VOT_p} \qquad (4)$$

Where:

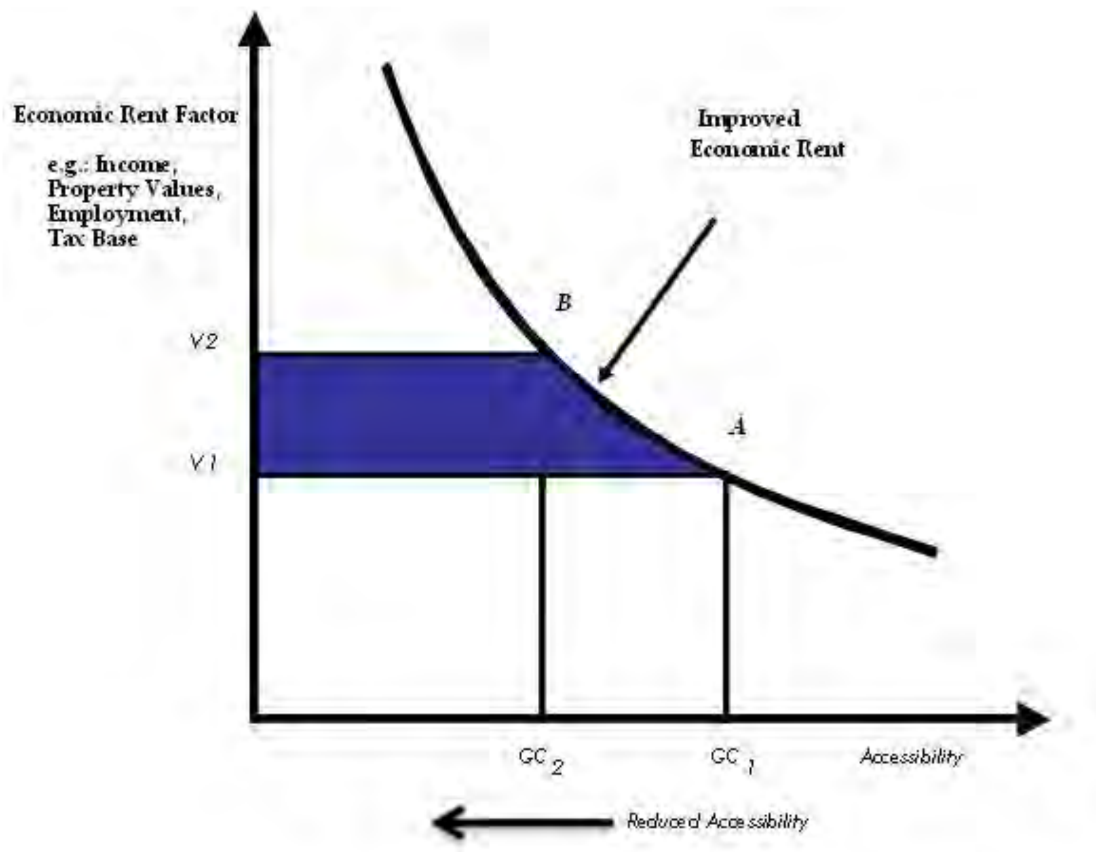
TT_{ijp} = Travel time between zones i and j for purpose p[5];

TC_{ijp} = Travel cost between zones i and j and purpose p (toll and operating costs for auto);

VOT_p = Value of Time for purpose p

The Economic Rent theory builds from the findings in Urban Economics, and Economics of Location that support Central Place Theory[6]. Central Place Theory argues that in normal circumstances places that are closer to the "center" have a higher value or economic rent. This can be expressed in economic terms, particularly jobs, income, and property value. There is a relationship between economic rent factors (as represented by employment, income, and property value) and impedance to travel to market centers (as measured by utility or generalized cost). As a result, lower generalized costs associated with a transport system improvement lead to greater transportation efficiencies, and increased accessibility. This, in turn, results in lower business costs/higher productivity and, consequently, in an increase in economic rent. This is represented by moving from point A to point B in Exhibit 2.3.

Exhibit 2.3: Economic Rent Illustration

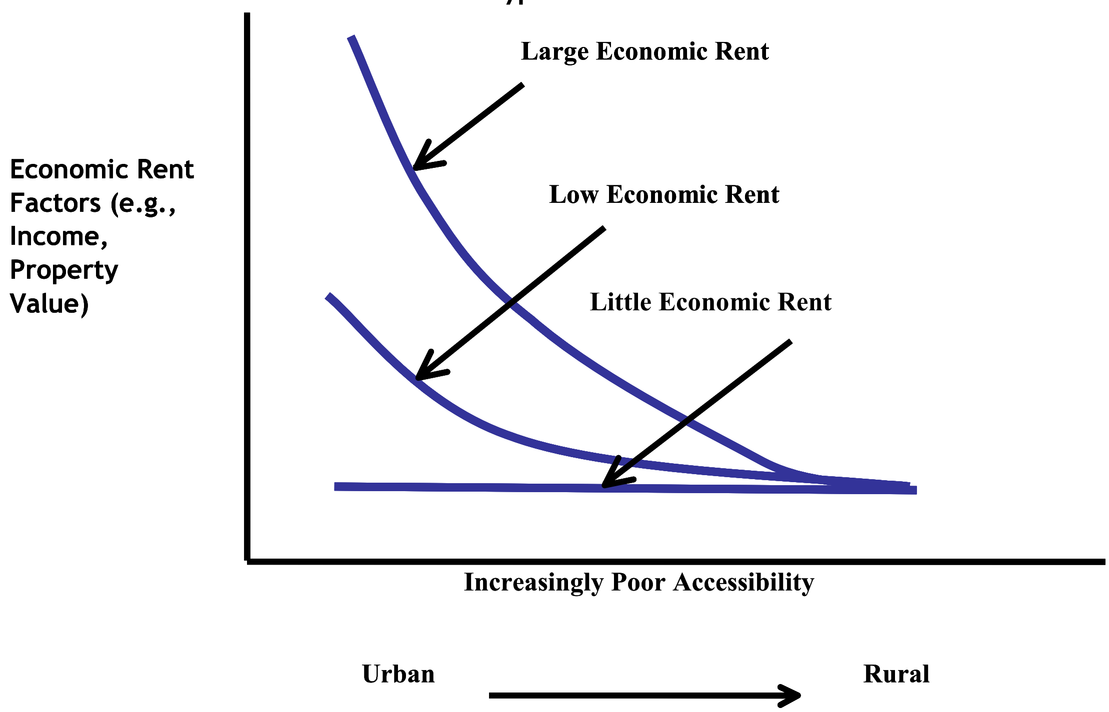


[5] Issues of travel time calculation, including the weighting factor for travel time is broadly discussed in the literature. See, for example: [15] and [16].

[6] See: [7] and [8].

It should be noted that the shape of the economic rent curve reflects the responsiveness of the economy to an improvement in accessibility. Large cities typically have very steep curves, which indicate more significant economic impacts due to a transportation improvement; smaller communities have less steep curves, and rural areas have very flat curves that indicate lower economic responsiveness (see Exhibit 2.4).

Exhibit 2.4: Types of Economic Rent Curve



3 THE ECONOMIC EVALUATION DATABASES

3.1 INTRODUCTION

The purpose of the Purple Line Economic Impact Study update is to explore the economic productivity impacts that will result from the Purple Line rail corridor. The tool being developed to estimate these impacts is TEMS Economic Rent model (RENTS™) which generates producer impacts. To meet this need a series of databases calculation processes were developed for the study. The following section outlines the development and calibration process adopted by the study.

3.2 ECONOMIC BENEFITS STUDY PROCESS

The modeling and calibration process for the Economic Rent assessment is shown in Exhibit 3.1. This overall process has five main stages as follows:

- ***Stage 1:*** Auto and transit networks, origin-destination and socioeconomic databases are developed in order to provide input to the evaluation tools, so that they can meet the assessment requirements. Those databases are related to a comprehensive zone system that defines specific geographic areas.

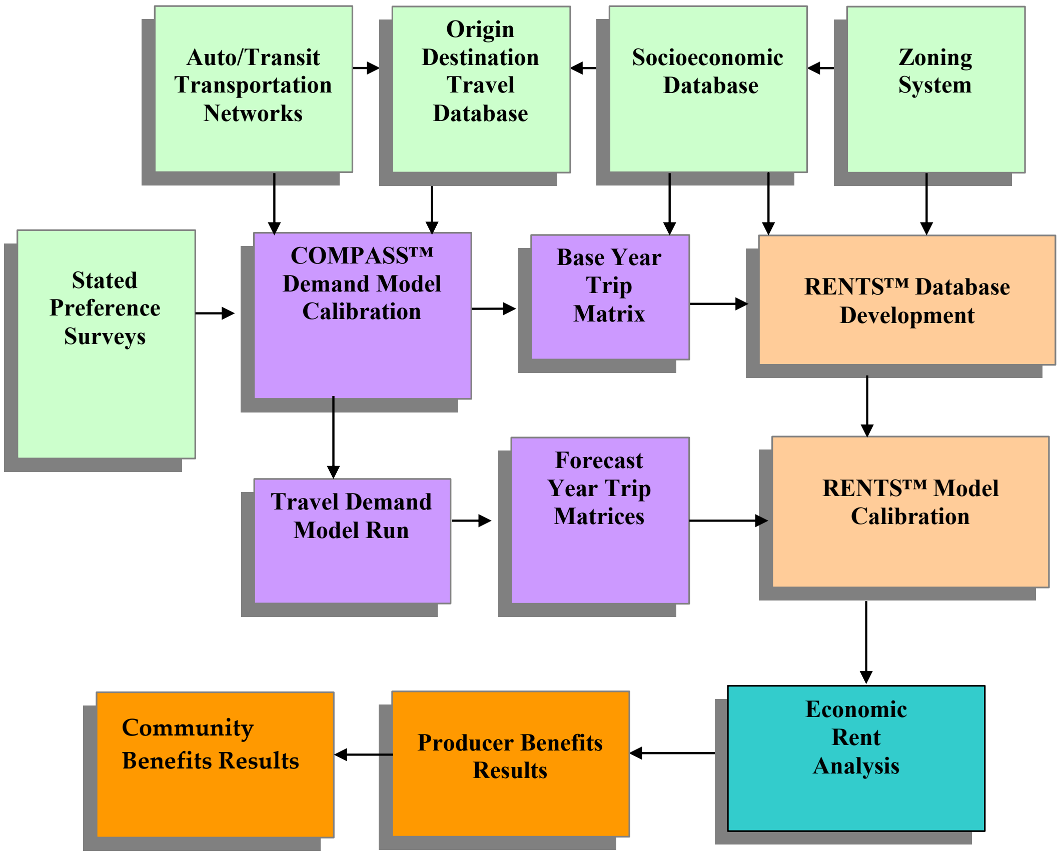
- ***Stage 2***: Stated Preference Surveys were undertaken. The surveys aimed at the better understanding the transportation needs of the local business and providing the data needed to evaluate travel demand functions for transportation demand model.

- ***Stage 3***: A transportation demand analysis applies the calibrated demand functions in the COMPASS™ travel demand model to provide traffic volumes and the cost of travel (generalized cost) that are used in Economic Rent Model.

- ***Stage 4:*** Economic Rent modeling and supply curve calibration is developed using the RENTS™ model.

- ***Stage 5:*** Economic Rent analysis with producer benefits results and community benefits are generated.

Exhibit 3.1: Economic Impact Study - Modeling and Calibration Process



3.3 TRANSPORTATION NETWORKS: GENERAL OVERVIEW

Industry-standard procedures were implemented to develop the road networks that represented travelers' route choices. The current transportation networks and future networks for the study area were developed based on the latest transportation networks provided by Parsons Brinckerhoff, Inc. (PB) and the two regional Metropolitan Planning Organizations – Metropolitan Washington Council of Governments (MWCOG) and Baltimore Metro Council (BMC). The networks for the study region were developed based on Transportation Analysis Zones (TAZ) system either from MWCOG or BMC, depending on the area.

The networks were constructed using a node numbering system to reflect the relevant auto and transit travel segments within the study area. The segments were coded using network-mapping software to obtain a latitude/longitude location mapping and segment distances for all relevant highways and arterial roads. Equivalency files developed for the PB and MPOs network attributes were used to extract the segment attributes for the aggregated road link types in the system. A two-mode network system was developed for the Purple Line study. Auto and transit networks that are parts of this system are described in more detail on the following page.

3.4 AUTO NETWORK

The 2015 network database developed based on PB, MWCOG and BMC contained latitude-longitude coordinates, node-to-node coded links, distance, lane numbers, speed codes, and capacity codes. The base and future network maps were provided to highlight all major highways segments within the study region of MWCOG. An aggregate equivalency file was developed to transform the urban networks into an inter-urban context that more closely reflected the purpose of this study. This equivalency file also allowed the filtering of urban links that would not be relevant to the study. Exhibit 3.2 illustrates the major segments that were included in the network.

Exhibit 3.2: Major MWCOG Highway Links Coded within Network

Highway Description	Segment Description
Interstate-95	Fredericksburg to I-195
Interstate-495	Entire Beltway
Interstate-66	Linden to Downtown Washington DC
Interstate-395	Entire Highway
Interstate-270	I-495 to Frederick, MD
Interstate-295	I-495 South of Downtown Washington DC to I-195
Interstate-70	Frederick, VA to I-695 Beltway
SR 267	I-495 to Leesburg, VA
George Washington Parkway	Entire Parkway
US 29	Downtown Washington DC to I-70
US 1	Downtown Washington DC to I-495 Beltway
US 301	US 50 to Waldorf, MD
US 50	Downtown Washington DC to Annapolis, MD

The BMC highway network was developed for specified links within its study area. The BMC network files contained latitude-longitude coordinates, node-to-node coded links, distance, lane numbers, speed codes, and capacity codes. An aggregate equivalency file was built to filter relevant links within the study area. The BMC network attributes were applied to highway links within its modeling jurisdiction. Exhibit 3.3 illustrates the major segments from the BMC network that were used in the TEMS Purple Line network.

Exhibit 3.3: Major BMC Highway Links Coded within Network

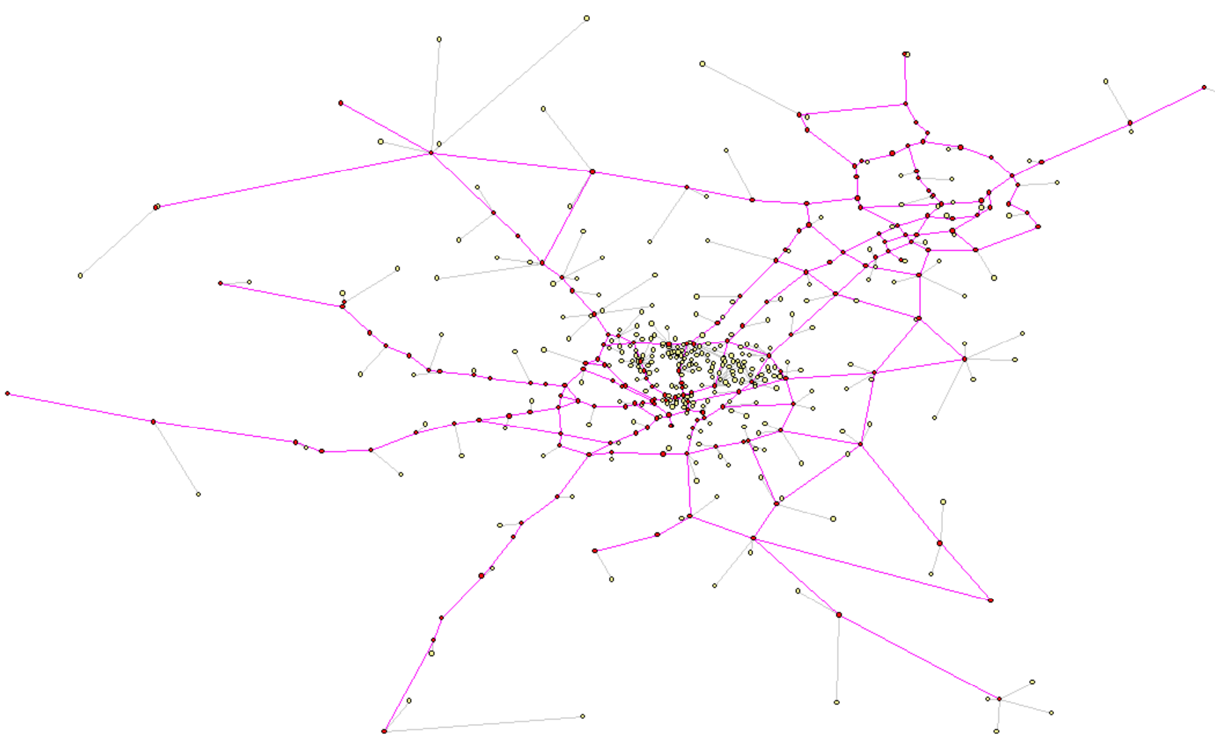
Highway Description	Segment Description
Interstate-95	I-495 to Aberdeen, MD
Interstate-695	Entire Beltway
Interstate-895	Entire Highway
Interstate-795	I-695 to Reisterstown, MD
Interstate-83	Downtown Baltimore, MD to Hunt Valley, MD
Interstate-295	I-495 to Downtown Baltimore, MD
Interstate-70	Frederick, MD to I-695 Beltway
Interstate-97	I-695 to US 50
Interstate-195	I-95 to BWI

MD 100	US 29 to I-97
US 29	I-495 to I-70
US 32	US 29 to I-97
US 40	I-695 to Downtown Baltimore, MD

The highway network was an aggregated amalgamation of the PB, MWCOG and BMC networks plus additional roads in the study area. Exhibit 3.4 shows the highway network developed by TEMS for the Purple Line Study. Exhibit 3.5 shows the detailed network developed for the improvement area under study.

The auto operating costs were adjusted using common procedures to reflect the perceived costs that different markets exhibit behaviorally. The auto cost was allocated as 57.5 cents/mile for the business travel purpose based on the 2015 IRS standard mileage reimbursement rate for business travel[7]. This rate reflects the full vehicular operating cost and includes indirect costs such as depreciation, maintenance, wear and tear, and insurance as well as direct costs such as gasoline. The assumption is that business travelers' decisions are based on the full cost of travel that reflects the anticipated amount that will be reimbursed for the trip. The non-business markets, however, do not consider all the indirect costs of operating a vehicle when making a decision to drive and typically only consider the direct costs. The non-business auto operating costs are therefore factored by 0.3 to yield an operating cost of 17 cents/mile. This cost better reflects the perceived cost that this market behaviorally responds to. This adjustment is a typical and standard procedure implemented within the modeling process.

Exhibit 3.4: Study Region Auto Network



[7] http://www.irs.gov/uac/Newsroom/New-Standard-Mileage-Rates-Now-Available;-Business-Rate-to-Rise-in-2015

3.5 TRANSIT NETWORK

Base (2015) transit network was developed using mainly PB, WMATA and MTA networks. PB provided information on proposed station and links of the transit services. Since PB network base year was 2005, such information as fare and frequency was updated using WMATA data for the year 2015. In order to develop the networks outside PB or WMATA study regions (mainly in Baltimore metro and surrounding areas) the information from MTA and BMC was used. The transit services covered in the transit networks included the Metro, MARC, light rail, and local bus. Exhibit 3.5 provides the details of transit services coded in the network. The transit network developed for the study is presented in Exhibit 3.6.

In the future transit network, the Purple Line Preferred Alternative was incorporated into the base transit network. The Purple Line Preferred Alternative is principally the medium investment light rail transit alternative of the AA/DEIS with several features taken from the high investment alternative, and several other refinements. The total length of the Preferred Alternative is 16.2 mile and total travel time is 60/63 minutes (60 minutes during off peak hours and 63 minutes during peak hours). Exhibit 3.7 provides information on distance, travel time and average speed between stations of Preferred Alternative. All this information has been coded to the future network. Exhibit 3.8 shows the Purple Line corridor in the future transit network.

Exhibit 3.5: Study Region Network

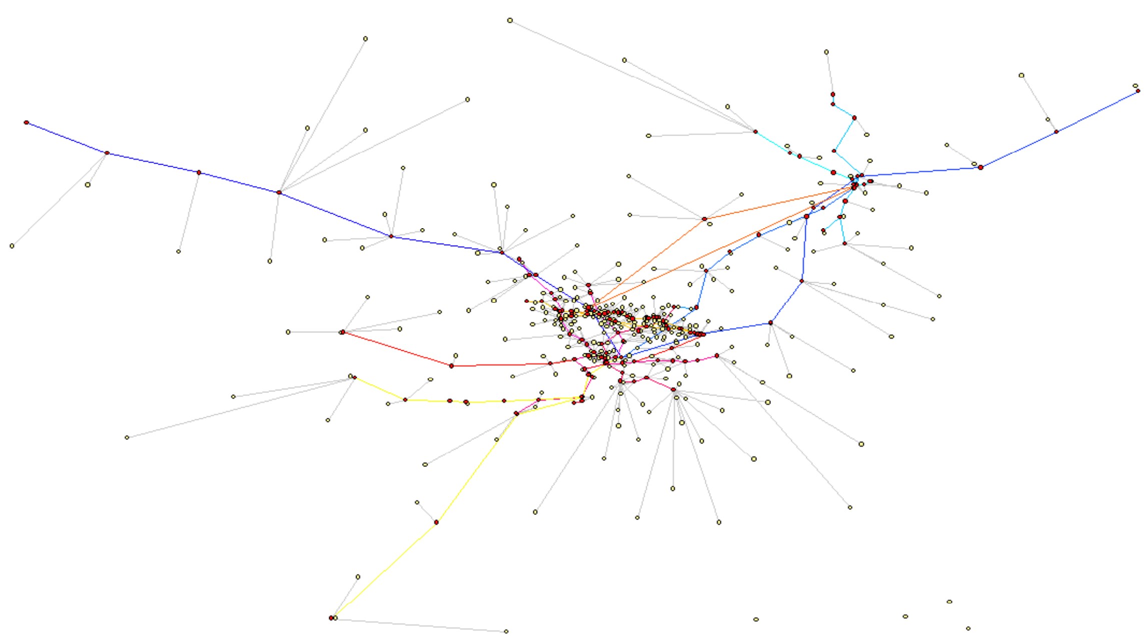


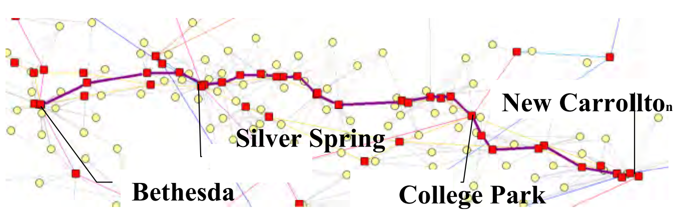
Exhibit 3.6 Major Transit Links Coded within Network

Transit Services Description	Segment Description
Washington Metro	Red, Green, Blue, Yellow, Orange Line
MARC	Penn Line, Camden Line, Brunswick Line
Washington Metro Bus	WMATA J1, J2, J3, J4, C2, F4, F6, UM Shuttle, etc.
Amtrak VRE	Fredericksburg Line, Manassas Line
Baltimore Transit	Baltimore Metro, Baltimore Light Rail

Exhibit 3.7: Travel Attributes of the Purple Line Preferred Alternative

Station-to-Station	Station-to-Station		
	Distance (feet)	Time (decimal minutes)	Average Speed (Mph)
Bethesda - Connecticut Avenue	7150	2.9	28
Connecticut Avenue - Lyttonsville	7200	2.8	29
Lyttonsville – Woodside	5400	2.2	27
Woodside - Silver Spring Transit Center	2800	1.8	18
Silver Spring Transit Center – Silver Spring Library	2200	3.5	7
Silver Spring Library – Dale Drive	3050	2.5	14
Dale Drive – Manchester Place	2900	2.6	13
Manchester Place – Long Branch	2250	1.8	14
Long Branch – Piney Branch Road	2500	3.8	7
Piney Branch Road – Takoma/Langley Transit Center	3400	2.8	14
Takoma/Langley Transit Center – Riggs Road	3250	2.6	14
Riggs Road – West Campus	7350	3.8	22
West Campus – UM Campus Center	3200	2.6	14
UM Campus Center – East Campus	2750	2.9	11
East Campus – College Park Metro	4800	5.3	10
College Park Metro – M Square	4450	2.7	19
M Square – Riverdale Park	4250	2.8	17
Riverdale Park – Beacon Heights	5150	4.5	13
Beacon Heights – Annapolis Road	6250	2.5	29
Annapolis Road – New Carrollton	5250	5.2	12

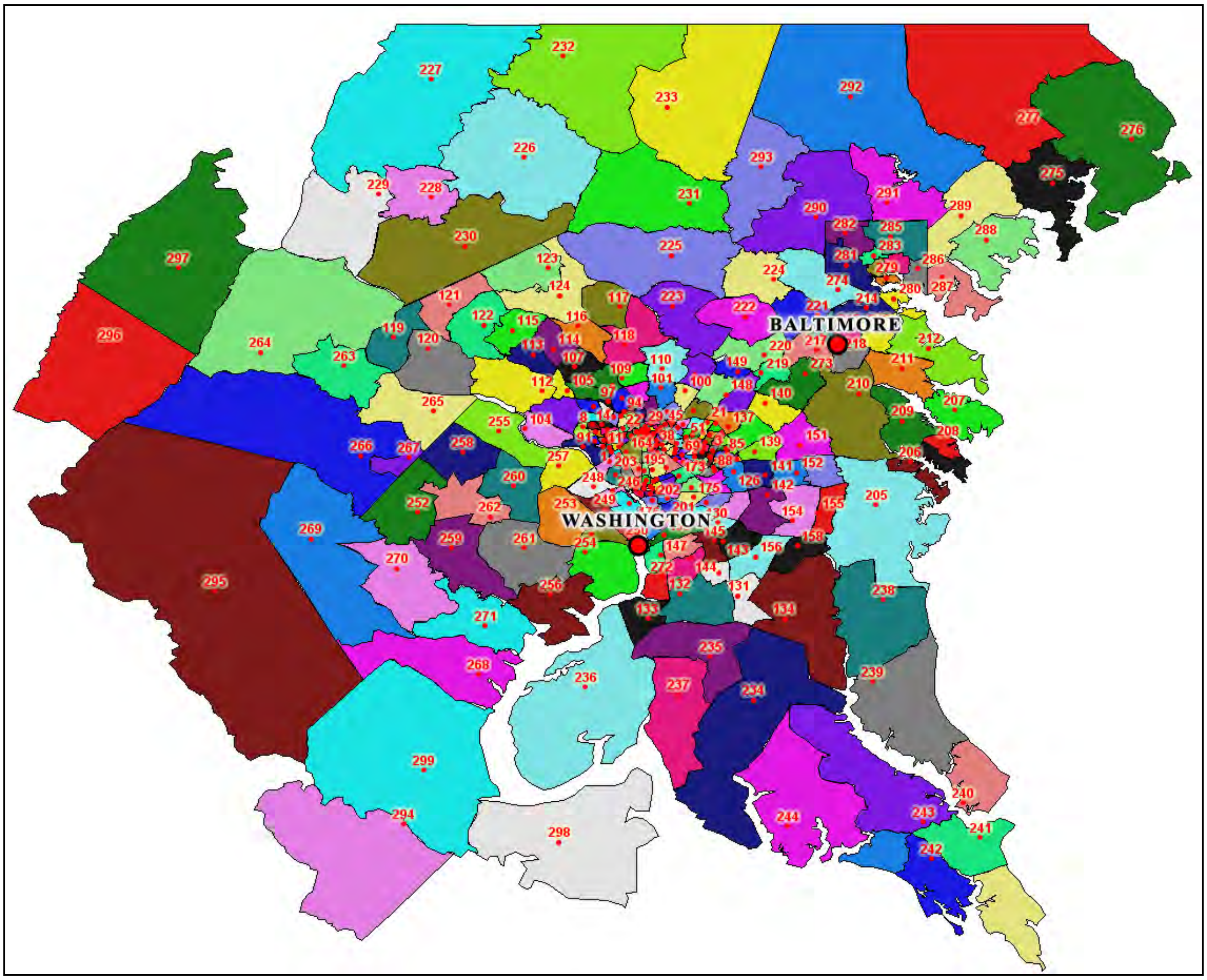
Exhibit 3.8: Transit Network with Purple Line Highlighted



3.6 ZONE SYSTEM

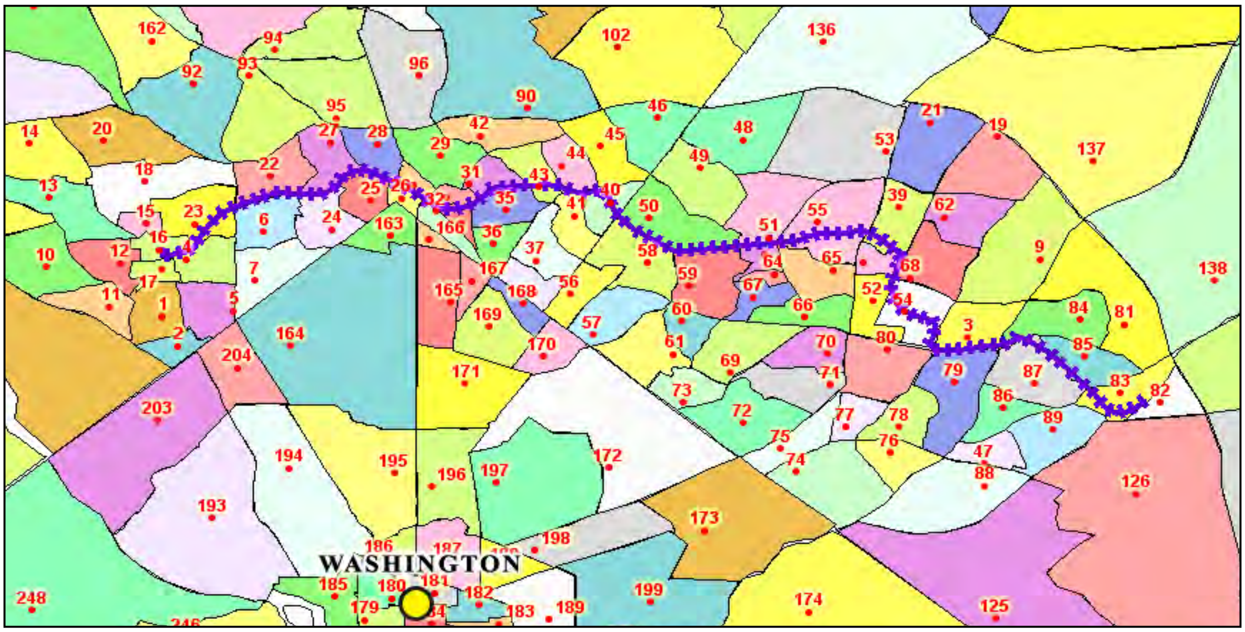
The major step in the development of travel demand model and the economic benefits study was establishing a transportation zoning system. The zone system provides a reasonable representation of the market area where travel would occur between origins and destinations. 299 traffic zones were developed for the Purple Line economic analysis study area (see Exhibit 3.9). The zoning system covers Washington DC, North Virginia, the majority of Maryland counties, as well as Jefferson County of West Virginia.

Exhibit 3.9: Purple Line Regional Study Area Zoning System



Zones from 1 to 273 were developed using boundaries of the traffic analysis zones (TAZ) developed by MWCOG[8] and with consideration to zones developed by PB. Where it was reasonable for study purposes TAZ were aggregated. For zones from 274 to 293 the zoning system was developed using boundaries of the TAZ by BMC[9]. Zones from 294 to 299 are developed using county boundaries. In order to establish the highest possible level of accuracy in regional economic analysis zones in Montgomery and Prince George's Counties, especially in the areas located within 5 miles from the Purple Line rail corridor, were developed without the minimum level of aggregation and often correspond to MWCOG TAZ (see Exhibit 3.10).

Exhibit 3.10: Purple Line Regional Study Area Zoning System – Purple Line Corridor Zoom In



3.7 SOCIOECONOMIC DATABASE

In the COMPASS™ model forecasting travel demand between the model's zones require base year estimates and forecasts of three socioeconomic variables – population, employment and household income – for each of the zone in the study area. Socioeconomic database with the data for the base-year (2015) and the forecast years up to 2040 at five-year intervals was developed using the most recent data, as well as the latest economic forecasts. To allow for assessment of the financial and operational feasibility of the system over 25 years, socioeconomic variables were forecasted through the year 2040.

For the Metropolitan Washington region, population and employment projections up to the year 2040 were developed using MWCOG Cooperative forecasts by traffic analysis zones (TAZ)[10]. For the Baltimore region (city and county) as well as Harford County population and employment forecasts up to the year

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[8] MWCOG - Metropolitan Washington Council of Governments, http://www.mwcog.org

[9] BMC - Baltimore Metropolitan Council, http:/www.baltmetro.org

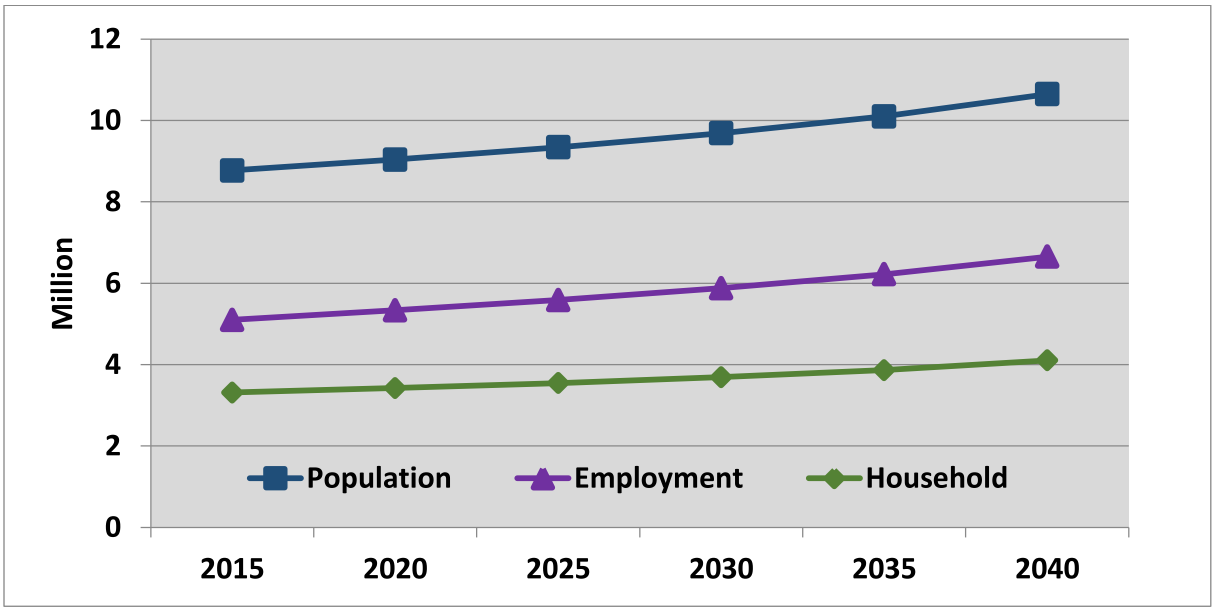
[10] Metropolitan Washington Council of Governments. Information Center. Cooperative Forecasting; Population and Household Forecasts by Traffic Analysis Zone. http://www.mwcog.org/publications

2040 were developed using BMC Cooperative Forecasts by corresponding transportation analysis zones[11]. Projections beyond 2035 are based on 2000-2035 trend lines.

Income projections for zones were developed using multiple sets of data from the official government and private sources. Among the main datasets are: historic 1969-2008 Bureau of Economic Analysis data on per capita income by county[12]; data on average household income and households by county and census tract from U.S. Census data and Applied Demographic Solutions; U.S. Census American Community Survey data on aggregate household income and number of households by county[13]; MWCOG and BMC population and household projections by TAZ. Bureau of Labor Statistics Consumer Price Index (CPI) data was used to bring historical average household income data from current into constant 2014$[14].

Exhibits 3.11 and 3.12 summarize the base-year and forecast-year socioeconomic data for the Purple Line study area.

Exhibit 3.11: Purple Line Region Population, Employment and Households Projections



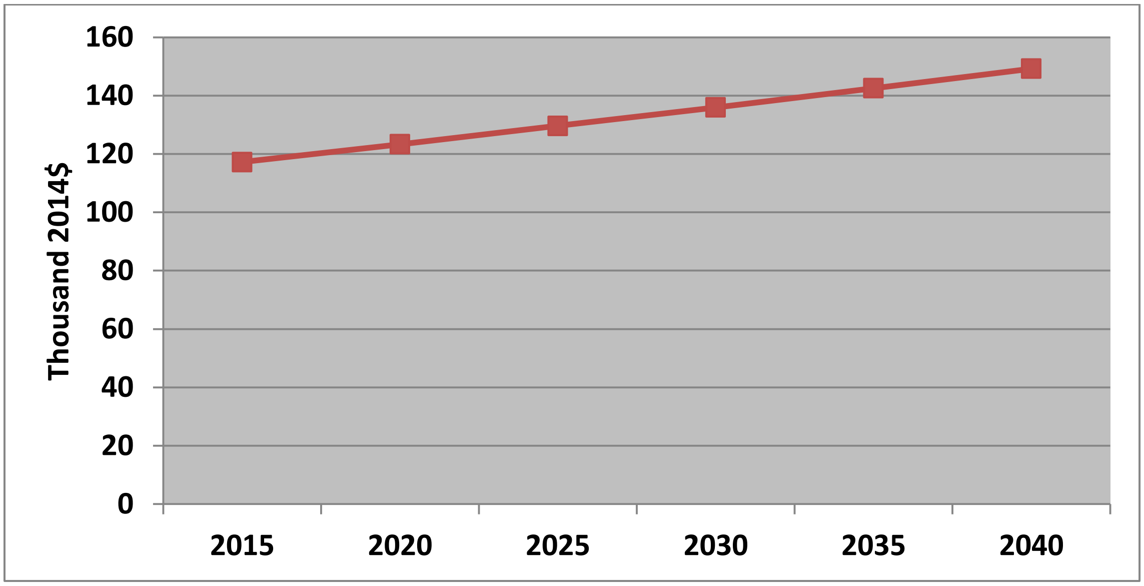
[11] Baltimore Metropolitan Council. Cooperative Forecasts by Jurisdiction. Community profiles http://baltometro.org

[12] Local Area Personal Income and Employment, Regional Economic Accounts, Bureau of Economic Analysis, U.S. Department of Commerce, http://www.bea.gov/regional/reis/

[13] American FactFinder database, http://factfinder.census.gov and MapPoint demographic database.

[14] Bureau of Labor Statistics, http://bls.gov/pub/special.requests, ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt

Exhibit 3.12: Purple Line Region Average Household Income Projections



It can be seen that the economy will expand with population annual growing by 0.9%, employment growing 1.2% and income growing 1.1%.

3.8 TRIP DATABASE

Forecasting the future trends of the travel market within a region hinges upon the ability of the models used to depict the present travel patterns within the system. Capturing traveling characteristics requires proper market segmentation and travel demand volumes for each market segment. The trip databases from PB, MWCOG and BMC are the main data sources for developing the trip database for this study. The trip databases of PB and MWCOG divide trips based on the local urban travel market characteristics:

- Home-based work (HBW)
- Home-based other (HBO)
- Non-home based (NHB)

Though this classification is used in studying urban auto travel market, it is found that such classification is insufficient to provide an effective interpretation of traveler behavior for the more complex transit travel market. TEMS' market segmentation/purpose formulation was established to account for the major markets that would likely be affected by changes in the travel conditions in the study area. For example, business travelers are typically more concerned with travel time, regularity and availability of service than personal travelers, shopping and social travelers, who are more concerned with cost. For the purposes of this study, the desired market segmentation included:

- Business travel - all who were on work-related business for one trip-end
- Commuter - all who reported home-to-work trips or vice versa
- Other (shopping/leisure/social) travelers

Direct equivalency and interpretive methods were used to convert the MPO trip databases into the designated TEMS trip purposes. The business purposes were not explicitly defined within the MPO's purpose splits since the total non-commuter market contained a mixture of business and non-business markets. The business share and non-business shares were obtained by applying breakout factors to the total non-commuter market trip segments. This breakout process used MPO trip share data, regional trip databases and survey information collected to determine the final distribution shares. The conversion of the urban trip purposes into an inter-urban aggregate trip purpose is illustrated in Exhibit 3.13.

Exhibit 3.13: Purpose Split Equivalency

TEMS Purposes	MPO Equivalents
Business	Interpolated share of NHB, HBO
Commuter	HBW
Other	Interpolated share of NHB and HBO

The conversion of the urban zonal MPO trip files into the inter-urban zonal trip files involved an aggregation process. This aggregation process resulted in the exclusion of internal trips from the intra-urban trip file. These internal trips constitute all trips made within the individual aggregate zones and represented short distance trips. The exclusion of short-distance trips will not affect the analysis of study area subject to improvement, because the zones in that area have been developed in a way so that all trips that use the route would be captured. In addition, the exclusion of short-distance trips will make the calibrated travel demand model more appropriate for this study due to the inter-urban nature of it.

3.9 CONCLUSION

It was found that the developed socioeconomic and converted transportation databases provided a solid basis for the evaluation of Economic Rent. The use of these two databases will allow an evaluation of both demand and supply sides of the economic benefits of the project.

4 THE TRAVEL DEMAND MODEL AND TRAFFIC FORECASTS

4.1 TRAVEL DEMAND MODEL

The travel demand model used to forecast volume of traffic is based on the COMPASS™ Demand Model that was specifically developed for analyzing the statewide traffic flows in Maryland. The COMPASS™ Demand Model is a flexible forecasting tool that models the decision-making characteristics of travelers resulting from changes in the underlying travel network. The model system combines the various socioeconomic variables, attitudinal parameters, network attributes and origin-destination data, and calibrate them all against observed traveling distributions and traffic volumes. The COMPASS™ Demand Model has two parts: Total Demand Model and Hierarchy Model Split model. The two models are connected interactively. The Total Demand Model provides a mechanism for assessing overall growth in the travel market. The role of the Hierarchical Modal Split Model is to estimate relative modal shares, given the Total Demand Model estimate of the total market.

TOTAL DEMAND MODEL

For the Purple Line Regional Economic Analysis Study, the travel demand models were developed and calibrated separately for three trip purposes, i.e., Business, Commuter and Other (shopping/leisure/social). The models were calibrated for 2010 base year data. In applying the models for forecasting, an incremental approach known as the "pivot point" method is used. By applying model growth rates to the base data observations, the "pivot point" method is able to preserve the unique travel flows present in the base data that are not captured by the model variables. Details on how this method is implemented are described below.

The Travel Demand Model used in this analysis is

$$T_{ijp} = e^{\beta_{0p}} SE^{\beta_{1p}} e^{\beta_{2p} GC_{ijp}} \qquad (5)$$

where:

T_{ijp} = Volume of trips between zones *i* and *j* for purpose *p*
SE_{ijp} = Socioeconomic variables for zones *i* and *j* for purpose *p* determined by population, employment, and average household income of zones *i* and *j*
GC_{ijp} = Generalized cost of travel for zones *i* and *j* for purpose *p*
B_{0p}, B_{1p}, B_{2p} = Calibration parameters for purpose *p*

As shown in equation (5), the total number of trips between any two zones for all routes of travel, segmented by trip purpose, is a function of the socioeconomic characteristics of the zones and the generalized cost of the transportation system that exists between the two zones. The generalized cost provides a logical and intuitively sound method of assigning a value to the travel opportunities provided by the overall transportation system. It is a measure of the quality of the transportation system in terms of the times, costs, and level of service provided by all routes for a given trip. The Travel Demand Model equation may be interpreted as meaning that travel between zones will increase as socioeconomic factors such as population and employment rise or as the utility (or quality) of the transportation system is improved by providing new facilities and services that reduce travel times and costs. The Travel Demand Model can then be used to evaluate the effect of changes in both socioeconomic and travel characteristics on the demand for travel by using the incremental "pivot point" method described below.

$$\frac{T_{ijp}^{\ f}}{T_{ijp}^{\ b}} = \left(\frac{SE_{ijp}^{\ f}}{SE_{ijp}^{\ b}}\right)^{\beta_{1p}} \exp(\beta_{2p}\,(GC_{ijp}^{\ f} - GC_{ijp}^{\ b})) \qquad (6)$$

Where:

T^f_{ijp} = Number of Trips between zones *i* and *j* for trip purpose *p* in forecast year *f*
T^f_{ijp} = Number of Trips between zones *i* and *j* for trip purpose *p* in base year *b*
SE^f_{ijp} = Socioeconomic variables for zones *i* and *j* for trip purpose *p* in forecast year *f*
SE^b_{ijp} = Socioeconomic variables for zones *i* and *j* for trip purpose *p* in base year *b*
GC^f_{ijp} = Generalized Cost of the transportation system for zones *i* to *j* for trip purpose *p* in forecast year *f*
GC^b_{ijp} = Generalized Cost of the transportation system for zones *i* to *j* for trip purpose *p* in base year *b*

HIERARCHY MODAL SPLIT MODEL

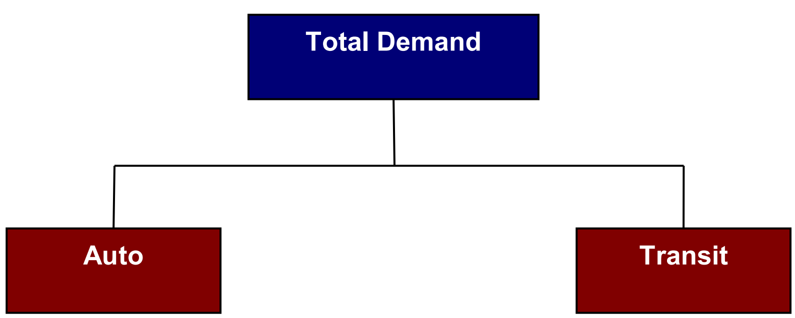
The role of the Hierarchical Modal Split Model is to estimate relative modal shares, given the Total Demand Model estimate of the total market. The relative modal shares are derived by comparing the relative levels of service offered by each of the travel modes. The COMPASS™ Hierarchical Modal Split Model uses a nested logit structure, which has been adapted to model the intercity modal choices available in the study area as shown in equation 7. The utility of travel between zones i and j by mode m for trip purpose p is a function of the generalized cost of travel. The coefficients of this utility function are based on the MWCOG model split model[15]. As shown in Exhibit 4.1, two levels of binary choice are used for auto and transit modes.

$$P_{ijmp} = \frac{\exp(U_{ijmp}/\rho)}{\exp(U_{ijmp}/\rho) + \exp(U_{ijnp}/\rho)} \qquad (7)$$

where:

P_{ijmp} = Percentage of trips between zones *i* and *j* by mode *m* for trip purpose *p*
U_{ijmp}, U_{ijnp} = Utility functions of modes *m* and *n* between zones *i* and *j* for trip purpose i
ϱ is called the nesting coefficient

Exhibit 4.1 Hierarchical Modal Split Structure



[15] Based on Figure 6.11 of TPB Travel Forecasting Model, Version 2.3: Specification, Validation, and User's Guide. http://www.mwcog.org/transportation/activities/models/files/V23_Draft_Jun30_2008_Report.pdf

4.2 SOCIOECONOMIC VARIABLES

The socioeconomic variables in the Travel Demand Model show the impact of economic growth on travel demand. The COMPASS™ Model System, in line with most behavioral modeling systems, uses three variables (population, employment and average household income) to represent the socioeconomic characteristics of a zone (see Chapter 3). In the development of the original gravity models, these terms were customarily referred to as production and attraction terms, since they quantify the production and attraction that specific origins or destinations exert on trip volumes. A more detailed discussion on the incorporation of these terms in the theory of demand modeling can be found in [17] and [18]

Denote *(i,j)* as an origin-destination pair, and let P_i, E_i and I_i, be the population, employment, and average household income of zone *i*, respectively. These quantities are combined in order to produce socioeconomic variable SE_{ij} that is used in the travel demand model. Different combinations were tested in the calibration process and it was found that the most theoretically justifiable and empirically stable relationship consists of the following set of formulae shown in equation (8) through (10):

Business: $$SE_{ij} = E_i E_j \frac{I_i + I_j}{2} \tag{8}$$

Commuter: $$SE_{ij} = \frac{P_i E_j + P_j E_i}{2} \frac{I_i + I_j}{2} \tag{9}$$

Other: $$SE_{ij} = P_i P_j \frac{I_i + I_j}{2}. \tag{10}$$

The Business formula in equation (8) consists of a product of employment in the origin zone, employment in the destination zone, and the average household income of the two zones. Since business trips are usually made between places of work, the presence of employment in the formulation is reasonable. The role of income reflects the fact that higher paid employees make more intercity trips than lower paid employees. The Commuter formula in equation (9) consists of the product of population in the origin zone and employment in the destination zone and the product of population in the destination zone and employment in the origin zone for returning commuter trips. The average household income is included for the Commuter trip purpose because higher-income people tend to make more auto trips. The Other (shopping/leisure/social) formula in equation (10) consists of a product of population in the origin zone, population in the destination zone and the average household income of the two zones. Trips for Other purposes encompass many types of trips, but the majority is home-based and thus, greater volumes of trips are expected from zones from higher population, and higher income.

4.3 DEMAND MODEL CALIBRATION

For the purpose of extrapolating a statistically valid distribution of trips in relation to demographic characteristics and trip disutility, we have assembled a base year database including the base year trip volume, base year demographic indicators (Population, Employment and Average Household Income), and generalized costs of travel between zones as obtained from TEMS' generalized cost-based networks. We performed calibrations of the travel demand model defined above in equation (5).

In evaluating the validity of the statistical regression of the calibrations, there are two key statistical measures: t-statistics and R^2. The t-statistics refers to each coefficient to be estimated, while the R^2 refers to the model equation (5). The t-statistics is a measure of the significance of the model coefficients; absolute values above 2 imply that the variable has significant explanatory power in estimating trip levels. The R^2 is a statistical measure of the "goodness of fit" of the model to the data. The higher it is, the better the model equations represent the distribution of data points. Given the large volume of data, and thus degrees of freedom, a value of 0.4 and higher is considered a valid result. The calibration results are shown in Exhibit 4.2. It can be seen that, all t-statistics are large and highly significant, and the R^2 is good for the travel demand models calibrated for all trip purposes.

Exhibit 4.2: Calibration Results of Base Travel Demand Model

Purpose	B_0	*t*-stat	B_1	*t*-stat	B_2	*t*-stat	R^2
Business	-4.9263	-35	0.4791	69	-0.0561	-127	0.58
Commuter	-19.1426	-206	0.8283	250	-0.0887	-209	0.71
Other	-7.9123	-59	0.3783	81	-0.0542	-110	0.58

These coefficients represent the trip elasticities with respect to the socioeconomic variables and the generalized cost of travel between zones within the study area. From the coefficients associated with socioeconomic variables, it can be seen that 1% growth in socioeconomic variables leads to 0.3% ~ 0.7% increase in travel demand based on trip purpose. For the coefficients associated with generalized cost, 1% improvement in generalized cost leads to 0.05% ~ 0.08% increase in travel demand based on trip purpose. These elasticities are in line with travel demand models developed earlier for the travel market of Maryland.

4.4 TRAVEL DEMAND FORECAST

The calibrated travel demand models shown in Exhibit 4.1 were then used in travel demand forecast with future year socioeconomic variables and generalized cost network updates by using the incremental method described in equation (6). The travel demand forecast was performed for the existing Purple Line infrastructure ('No Build') and the Preferred Alternative (PA) –the medium investment light rail transit alternative of the AA/DEIS with several features taken from the high investment alternative, and several other refinements. PA is a 16-mile light rail line that would extend from Bethesda in Montgomery County to New Carrollton in Prince George's County, providing a fast and reliable transit service for people moving east-west in the corridor. It will link both branches of the Washington Metrorail Red Line at Bethesda and Silver Spring, the Green Line at College Park, and the Orange Line at New Carrollton. The PA would also connect to all three MARC Train lines, Amtrak, and local bus services. New generalized costs of PA were computed from the updated network for each purpose, and then they were used to forecast future travel demand in the study area together with projected socioeconomic variables. Exhibit 4.3 shows year 2030 trips of the corridor by each travel purpose in the study area under the PA option.

Exhibit 4.3: Year 2030 Trip Forecasts

Purpose	2030 Trips	% of Total Trips
Business	10,177	15%
Commuter	16,302	24%
Other	40,512	60%
Total	**66,990**	**100%**

5 TEMS ECONOMIC RENT MODEL

5.1 MODEL CALIBRATION

In the Purple Line study area, we have three types of trip purposes *p:* business, commuter, and other. For each zone *i* of the zone system, the accessibility, measured in generalized cost is estimated as follows:

$$GC_i = \sum_p \sum_j GC_{ij}^p * T_{ij}^p \quad , i=1,N \qquad (11)$$

Where:

GC_{ij}^p - generalized cost of travel from zone *i* to zone *j* for purpose *p;*

T_{ij}^p - number of trips from zone *i* to zone *j* for purpose *p;*

N - total number of transportation zones in the network.

The economic rent function in equation (3) shown in Section 2.3 can be transformed into a linear function (linear regression model) by applying the natural logarithm[16] (ln) to both parts of the original economic rent function:

$$\ln(SE_i) = ß_o + \beta_1 \ln(GC_i) \qquad (12)$$

or simply[17]:

$$\ln(SE_i) = \beta_o + \beta_1 \ln(GC_i) \qquad (13)$$

Where:

SE_i - Economic rent factor (socioeconomic variable) of zone i;

GC_i - Weighted generalized cost of travel for all purposes from (to) zone i to (from) other zones in the zone system (GC_i is calculated using formula in equation (11));

βo and β_1 - Regression coefficients.

In the regression equation (13) logarithm of (SE_i) is the criterion (dependent) variable, while logarithm (GC_i) is the predictor (independent) variable. βo and β_1 are the coefficients of the regression line (βo is the intercept and β_1 is the slope). Regression coefficients βo and β_1 are to be estimated in the regression model.

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[16] Natural logarithm is a logarithm to base 'e' of a given number, where 'e' is an irrational constant approximately equal 2.71828183. The natural logarithm of x is written: ln (x) or ln x. See, for example: http://www.mathwords.com/n/natural_logarithm.htm or http://www.themathpage.com/aPreCalc/logarithms.htm

[17] $\beta_o = \ln(ß_o)$

Application of regression analysis to the equation (13) allowed developing the Purple Line Economic Rent Model. In this process we established the mathematical relationship between the measure of accessibility (generalized cost of travel) and the economic rent socioeconomic variables (employment, income density and residential property value density) for each transportation zone. Exhibit 5.1 through 5.3 shows the observed values for natural logarithm (LN) of socioeconomic variable (employment, income density and residential property value density) versus natural logarithm (LN) of generalized costs of travel. The regression line reflects the relationship between socioeconomic indicators in each transportation zone included in the zone system and corresponding generalized costs, calculated using formula in equation (11). By the tight clustering of data points around the regression line, it can be seen that in each case a very strong relationship was identified. In order to identify the strength of the relationships, statistical methods were used to analyze the values of the coefficient of determination (R^2) and Student's t statistics (t).

Exhibit 5.1: Employment Density as a Function of Accessibility

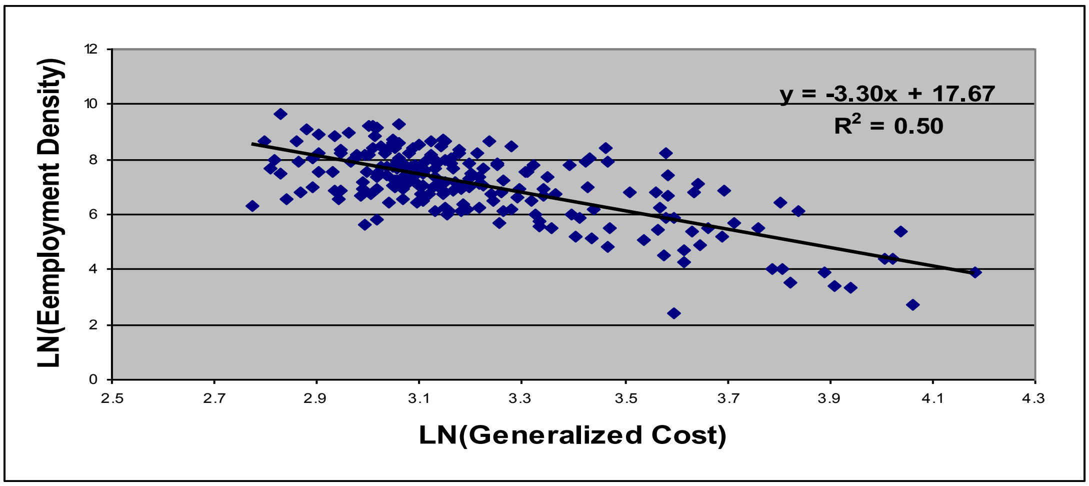


Exhibit 5.2: Income Density as a Function of Accessibility

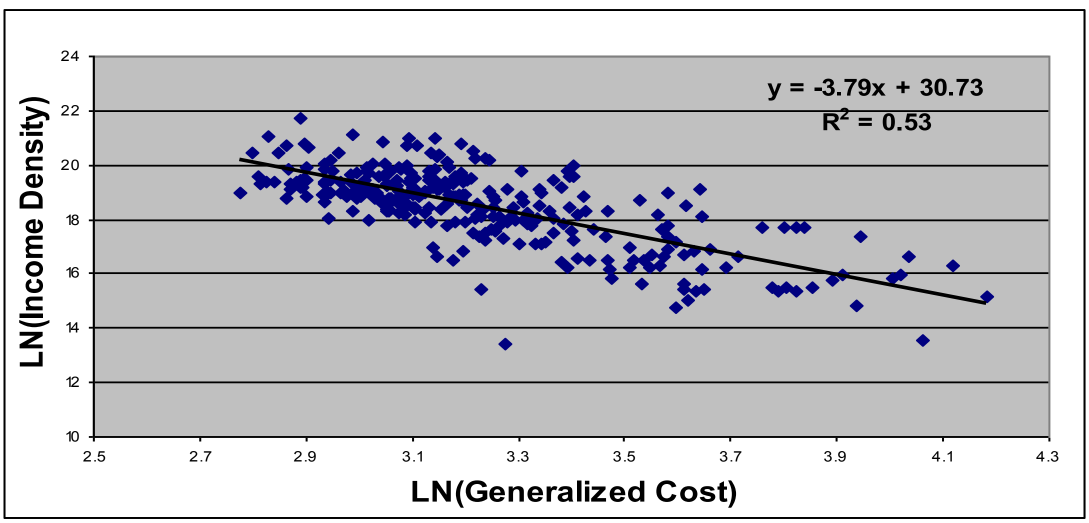
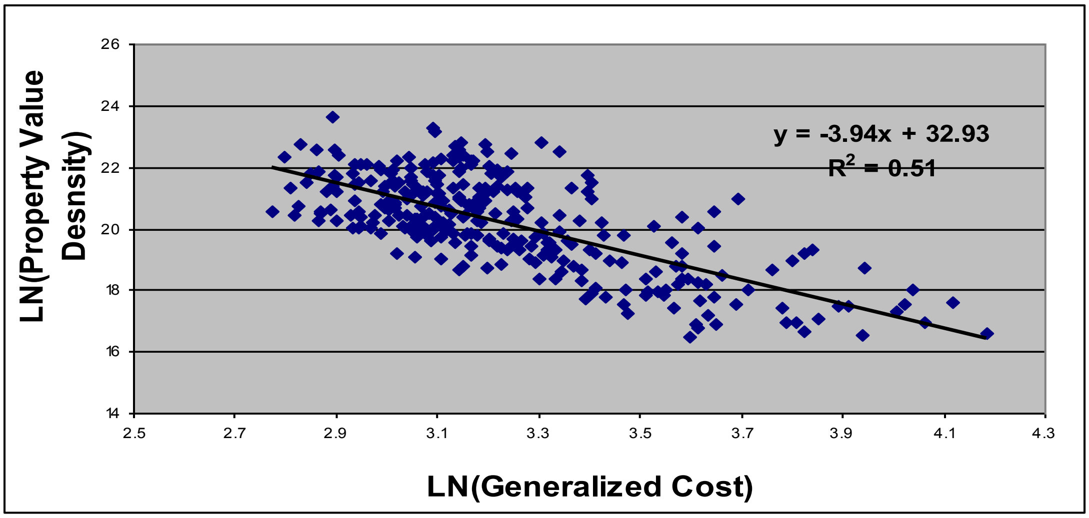


Exhibit 5.3: Residential Property Value Density as a Function of Accessibility



The value of the ***coefficient of determination*** (R^2) shows how much the criterion (dependent) variable is influenced by predictor variable chosen in the study [19]. In other words, the coefficient of determination measures how well the model explains the variability in the dependent variable. As a result, the coefficient of determination illustrates the strength of the relationship between the criterion and predictor variables.

Performing 't-test' and calculating Students' ***t statistics*** [19] for both regression coefficients - β_0 (the intercept) and β_1 (the slope), we analyze how significant the regression coefficients are. Assuming a Normal distribution, a t-statistics that equals two in absolute value is generally accepted as statistically significant.

Regression statistics for each of the three socioeconomic indicators used in the model, as well as statistical measures of confidence are presented in Exhibit 5.4.

Exhibit 5.4: Economic Rent Coefficients for Employment, Income Density and Residential Property Value Density

Economic Rent Factor	Intercept (β_O)	T-statistics for β_O	Slope (β_1)	T-statistics for β_1	Coefficient of Determination – 'R square' (R^2)
Employment	17.68	24.22	-3.30	-14.63	0.50
Household Income Density	30.73	45.36	-3.79	-18.15	0.53
Residential Property Value Density	32.93	44.83	-3.94	-17.40	0.51

It can be seen that the calibration was successful and regression coefficients in each equation were shown to be significant. This proves that the economic rent profiles are well developed for the Purple Line corridor. Each equation has highly significant 't' values and coefficients of determination (R^2). This reflects the strength of the relationship and, given the fact that there is a strong basis for the relationship, shows firstly that the socioeconomic variables selected provide a reasonable representation of economic rent, and, secondly, that generalized cost is an effective measure of market accessibility.

Given the performance of the models, the next step in developing the Economic Rent model is to determine the change in socioeconomic indicators as a result of accessibility improvement. In order to calculate change in economic rent factors, we differentiate the economic rent function in equation (13) with respect to generalized cost. The result of such differentiation is present in equations (14) through (16). It is easy to see that slopes β_1^E, β_1^I and β_1^{PV} in each regression equation represent economic rent elasticities. Each particular elasticity shows how much each economic rent factor changes when generalized cost of travel changes [18].

$$\partial Emp_i = \Delta Emp_i = \frac{\partial Emp_i}{Emp_i} = \beta_1^E \frac{\partial GC_i}{GC_i} \quad (14)$$

$$\Delta IncD_i = \frac{\partial IncD_i}{IncD_i} = \beta_1^I \frac{\partial GC_i}{GC_i} \quad (15)$$

$$\Delta RPvD_i = \frac{\partial RPvD_i}{RPvD_i} = \beta_1^{pv} \frac{\partial GC_i}{GC_i} \quad (16)$$

Where:

GC_i - Weighted generalized cost of zone i;

Emp_i, - Employment of zone i;

$IncD_i$ - Income density of zone i;

$RPvD_i$ - Residential property value density of zone i;

β_1^E β_1^I β_1^{pv} - Slope coefficients in regression equations.

It is seen from equations (14) through (16) that the relative absolute change in employment (ΔEmp_i), relative change in household income density ($\Delta IncD_i$) and relative change in residential property value ($\Delta RPvD_i$) for each particular zone *i* equals the relative change in generalized cost $\frac{\partial GC_i}{GC_i}$ multiplied by regression coefficient β_1^E, β_1^I or β_1^{PV}, respectively.

[18] More about the role of elasticity in a measurement of economic rent profile change see: [20], [21].

The value for each slope coefficient (β_1) is obtained from the corresponding regression equation. Since area (size - S_i) of each transportation zone remains constant, absolute change in household income (∂Inc_i) and residential property value (∂RPv_i) will be obtained from the following equations:

$$\partial Inc_i = \partial IncD_i * S_i = \beta_1^I \frac{\partial GC_i}{GC_i} IncD_i * S_i \tag{17}$$

$$\partial RPv_i = \partial RPvD_i * S_i = \beta_1^{Pv} \frac{\partial GC_i}{GC_i} RPvD_i * S_i \tag{18}$$

In order to calculate the impact of accessibility improvement on average household income and average residential property value we also had to determine how the improvement in accessibility influences the number of households/housing units that are supported by any given area. To do this we used the Economic Rent model to predict household density/housing units' density that is supported by any given level of market access. The results of regression analysis are shown in Exhibit 5.5 and 5.6 and economic rent coefficients are given in Exhibit 5.7. Again, it can be seen that good statistical relationships are derived with strong 't' values and coefficients of determination R^2.

Exhibit 5.5: Household Density as a Function of Accessibility

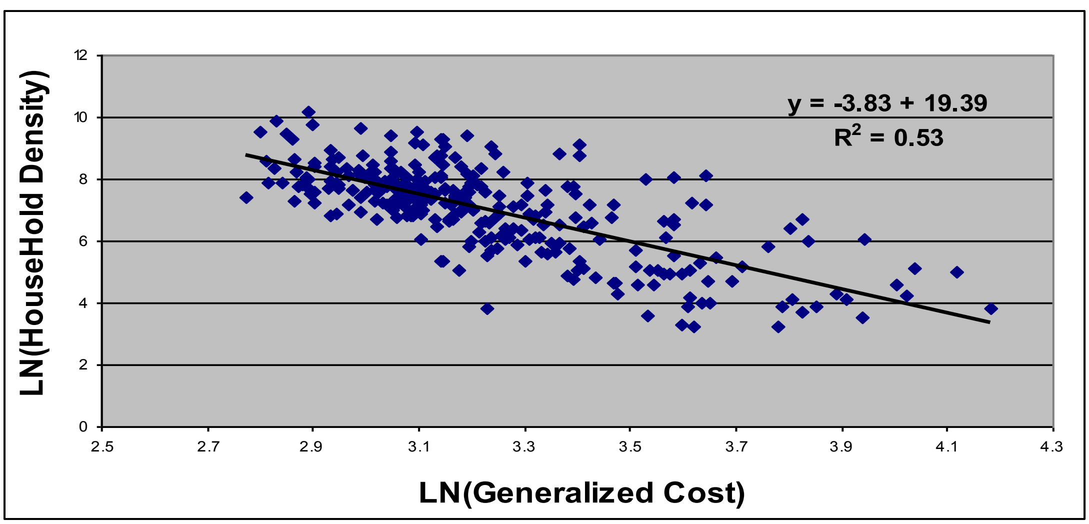


Exhibit 5.6: Housing Units Density as a Function of Accessibility

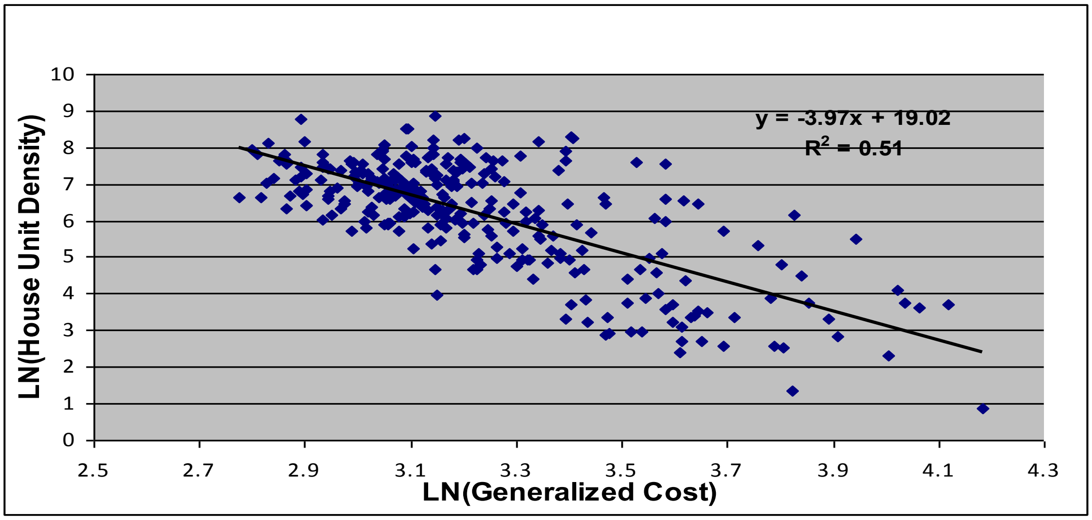


Exhibit 5.7: Economic Rent Coefficients for Household and Housing Units Density

Economic Rent Factor	Intercept (β_0)	T-statistics for β_0	Slope (β_1)	T-statistics for β_1	Coefficient of Determination – 'R square' (R^2)
Household Density	23.39	28.04	-3.83	-17.94	0.53
Housing Units Density	19.02	25.81	-3.97	-17.47	0.51

Change in average household income ($\partial AvInc_i$) in zone *i* is calculated as follows:

$$\partial AvInc_i = \frac{\partial Inc_i}{(Hh_i + \partial Hh_i)}, \tag{19}$$

And change in average residential property value $(\partial AvResPv_i)$ in zone *i* was calculated as follows:

$$\partial AvResPv_i = \frac{\partial RPv_i}{(Hu_i + \partial Hu_i)}, \tag{20}$$

Where:

$$\partial Hh_i = \beta_1^{Hh} * \frac{\partial GC_i}{GC_i} HhD_i * S_i \text{ and } \partial Hu_i = \beta_1^{Hu} * \frac{\partial GC_i}{GC_i} HuD_i * S_i \tag{21}$$

$\partial ResPv_i$ - the change in residential property value in zone *i* as a result of accessibility improvement

∂Hh_i / ∂Hu_i - the change in the number of households/housing units in zone *i* as a result of accessibility improvement

Hh_i / Hu_i - the base number of households / housing units in zone *i*

HhD_i / HuD_i - the base household density / housing units density in zone *i*

$\beta_1^{Hh} / \beta_1^{Hu}$ - the regression coefficients for household/housing units' density are obtained from Exhibit 5.7.

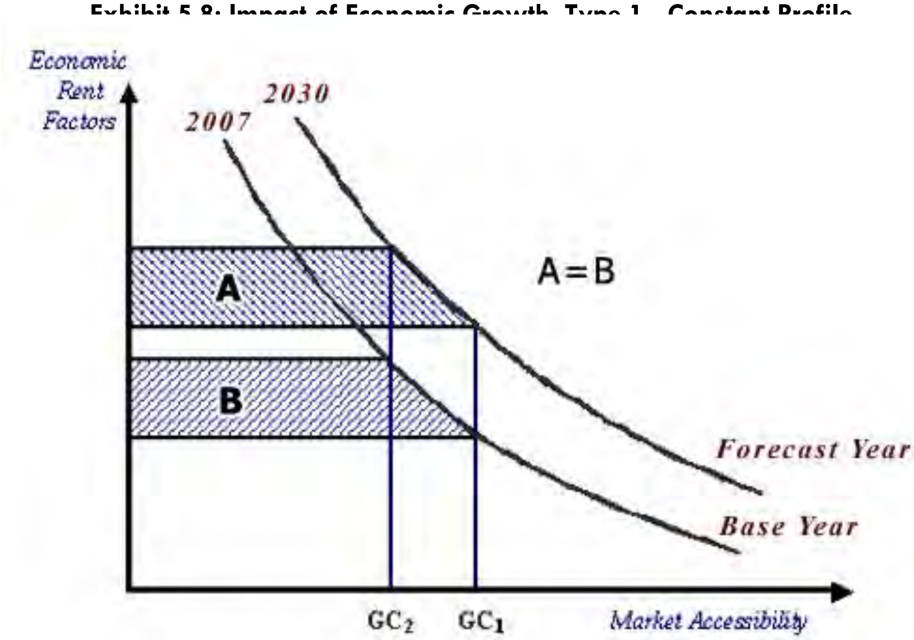
Total change in property values is calculated by applying the share of residential property in the particular county obtained from the statistical source[19] to the total residential property value benefits in this county obtained from the Economic Rent model.

The results of the analysis show that a statistically powerful Economic Rent model is developed that reflects the responsiveness of the economy to improved transportation access.

5.2 ASSESSMENT OF THE IMPACT OF ECONOMIC GROWTH

A key assumption in the Economic Rent analysis is the impact of economic growth on the economic rent profile[20]. Economic growth will cause the economic rent profile to grow as each component that supports the economic rent profile, land, labor and capital becomes more valuable. As the economy expands, labor wages increase, so space becomes more valuable, and assets become more expensive. This increase in factor prices results in a rise in the economic rent profile. If the rise in the economic rent profile is constant as shown in Exhibit 5.8, then the increase in economic rent associated with an improvement in market accessibility (i.e., a reduction from GC_1 to GC_2) for the region is the same. As a result, in Exhibit 5.8 area A is equal to area B. This means that economic growth will not change the economic rent benefits of the project. This is the assumption made in this study.

Exhibit 5.8: Impact of Economic Growth, Type 1 – Constant Profile

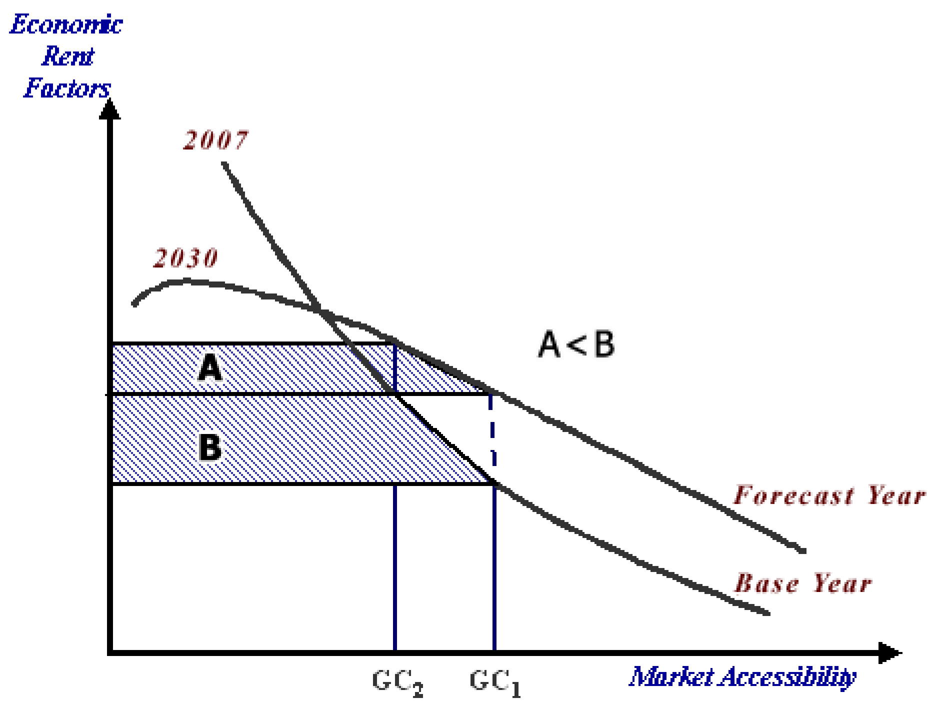


[19] 2007 Assessment Ratios Survey Report. State of Maryland Department of Assessment and Taxation. See: http://www.dat.state.md.us/sdatweb/stats/07rr_rpt.pdf

[20] Economic Rent profile as it was defined in Chapter 2 shows the special distribution of the economy in terms of its key factors - income, property values and wealth.

Under most economic conditions, however, the growth in economic rent is not the same over the region and the profile will not grow proportionally along its entire length. For example, in Exhibit 5.9 there is a decline in the forecast year economic rent profile at the market center while in the more peripheral areas (surrounding the market center) there is economic growth, i.e., growth occurs in the suburbs, but not the market center. In this environment the forecast year benefits, as measured by area A, are smaller than the base year economic benefits, measured by area B. This would suggest that using the base year economic rent profile would overstate benefits.

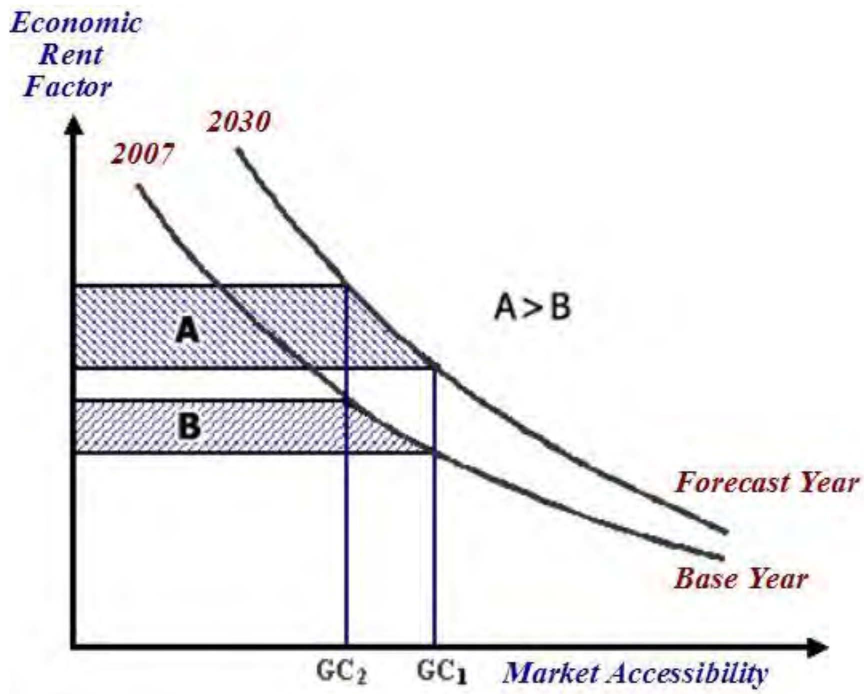
Exhibit 5.9: Impact of Economic Growth, Type 2 - Decrease in Profile



This type of growth, however, does not occur in normal markets, but rather in markets that suffer economic dislocations. For example, in the United States both Detroit and Buffalo experienced this type of growth impact when their downtown businesses failed in the 1970's. In Buffalo the issue was the decline of metal industries, while in Detroit it was more related to social demographic pressures. In this case a forecast of economic benefits based on a base year assessment will be an overstatement of the benefit. Certainly if any city market areas along the Purple Line corridor and, particular, the improvement area suffer a major dislocation (such as experienced by Buffalo) during the life of the project, then the forecasts prepared for the Purple Line corridor study would be overstated.

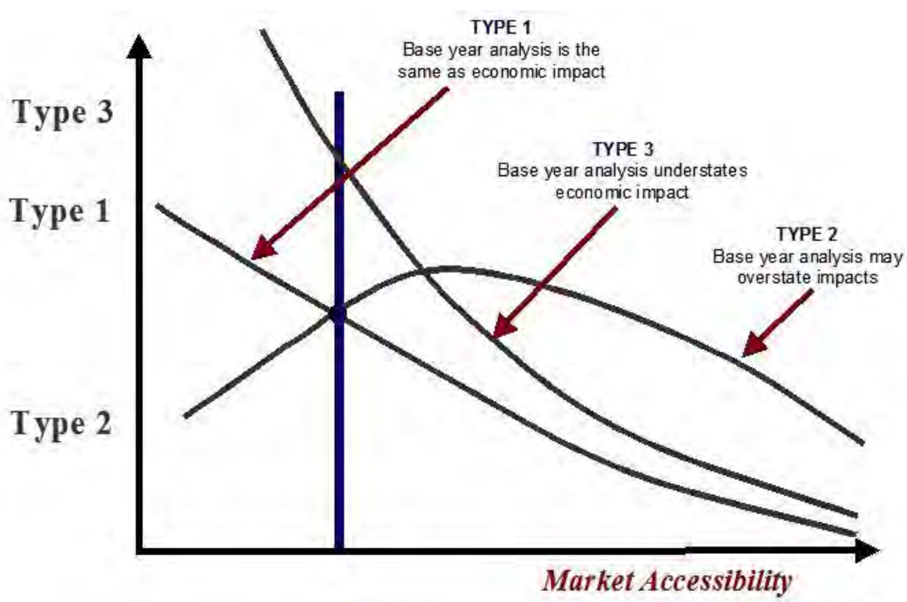
Under a normal economic growth situation in which the economy expands for a corridor, the typical impact is for growth to expand much faster at the market center than in the periphery. This reflects the fact that the market center provides the greater opportunities for growth in a normal economy and market. For example, the flood of Hong Kong Chinese into Victoria, Vancouver in the 1990s increased economic growth and income across the city. However, the impact was most severely felt in the city center with the development of new high-rise buildings, restaurants and businesses within the downtown area. This increased the economic profile of the downtown area more that it did in suburban areas. In this case the measurement of economic benefit using the base year economic profile will understate the size of the benefits to be derived from the project. In this case Area A will be larger than area B (see Exhibit 5.10). Since this is the usual impact of economic growth on a market center, and as our study suggests ongoing long-term economic growth it is likely that using area B to estimate economic rent benefits understates the overall economic benefits to be derived from an Economic Rent analysis.

Exhibit 5.10: Impact of Economic Growth. Type 3 - Increase in Profile



As a result, it can be seen in Exhibit 5.11 that there are three conditions that can exist in the forecast year.

Exhibit 5.11: Types of Economic Growth



- Type 1 has constant growth. This means that base and forecast year impacts along the economic rent are the same, and the base year analysis understates the benefits.

- Type 2 has negative growth at the market/city center. This typically results from a dislocation to the economy due to a loss of the economic base of the region. If this occurs the economic rent results, particularly in market centers, would be less than those that would be achieved if a base year economic rent profile is used. Using the base year economic rent profile will overstate the benefits.

- Type 3 has increased positive economic growth at the market center. As a result, the future year benefits are higher than suggested by measuring the economic rent profile in the base year.

While Type 3 is the normal situation for a city or market center, we have selected Type 1 as the basis for estimating economic benefits, which we believe is a reasonable and conservative assumption. In most towns a Type 3 environment will generate benefits greater than those estimated in this study. In one or two towns it is possible that a Type 2 conditions could prevail and lower economic benefits would be generated from the project. However, it is worth noting that such a weak performance would not be consistent with the current economic projections for the Purple Line corridor study used in the Purple Line Regional Economic Analysis (see Exhibits 3.11 and 3.12).

6 ECONOMIC RENT RESULTS

6.1 OVERALL ECONOMIC RENT RESULTS

For the Purple Line Economic Impact Study, the Preferred Alternative scenario of 16 mile improvement will create more than a 27 thousand jobs; will increase property value by 12.8 $ billion and the household income is estimated to increase by $2.2 billion. Two Maryland counties – Montgomery and Prince George's Counties and Washington DC, will obtain most economic benefits from the undertaken transportation improvement[21]. Overall state, local and federal tax benefits are estimated about $635 million. Exhibit 6.1 represents the overall annual Economic Rent results, while Exhibit 6.2 represents these results over 30-year life of the project. It should be noted that the increase in employment, income and property value for the study region represents a growth in their overall economy of between 0.5 and 0.6 percent on current levels (see Exhibit 6.3).

Employment Benefits: 27,183 annual jobs as estimated will be added to the regional economy as a productivity impact of the transportation project. This is a 0.5 percent increase. These jobs derived from the Purple Line Preferred Alternative improvement are productivity jobs and not temporary construction jobs associated with building the project (see Exhibit 6.1). While construction jobs actually result from transfer payments (relocating government money from one area to another), the jobs estimated in the frame of Economic Rent model result from productivity improvement – increase in the regional Economic rent profile and attracting new businesses to the region. Assuming 30-year life of the project, the productivity jobs in the region are estimated to be more than 815,000 person years of work (see Exhibit 6.2). Taking into account that 30-year life of the project is a very conservative estimate of the project's life (which might be 40 and even 100 years) the real productivity jobs in the area could be doubled.

Income Benefits: $2.2 billion a year or more than $43 billion over 30-year life of the project is estimated to be obtained in terms of income by the households in the region (see Exhibits 6.1 and 6.2). This represents a 0.6 percent increase. These income benefits are derived from the increased attractiveness of the region due to the accessibility improvement. Income benefits result from both, the increase in the number of households in the area (by 18,382 households) and the increase in the average household income per household (by over $661 for the study region).

Development Potential (Real Property Value Benefits): The Purple Line project is estimated to provide more than $12.8 billion in development potential. This represents an increase of 0.6 percent. The total property value benefits (see Exhibit 6.2) result from the increase of the number of properties in the region as well as increase in the average value of commercial and residential buildings.

Transfer Payments (Tax Benefits): Transfer payments play an exceptional role in the overall project evaluation. As shown in Exhibit 6.2, the Purple Line project should bring an expansion of the tax base by $12.4 billion over 30-year life of the project. Since total costs over the life of the project are estimated at the level of $1.9 billion[22], the total government spending on the project would be far less than the benefits that the project should return in taxes. As a result the Federal and State government will receive a full payback directly for their investment over and above the benefits to the local communities.

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[21] Multiple Economic Rent studies performed by TEMS show that the maximum economic benefits are achieved in the radius of 5 miles from the improvement area. (For example, see [22] or [23] for more details).

[22] Purple Line Capital Costs Technical Report, Aug., 2013

Exhibit 6.1: Overall Annual Economic Rent Benefits for Study Region Derived from the Purple Line Preferred Alternative

Economic Rent Factor	Benefit
Direct Productivity Benefits:	
Employment (Number of Productivity Jobs)	27,183
Income (billion 2014 $)	2.2
Average Household Income (2014 $)	$661
Average Residential Housing Value (2014 $)	$2,150
Number of Households	18,382
Transfer Payments – Tax Values:	
Federal Income Tax[23] (million 2014$)	286
State and Local Income Tax[24] (million 2014$)	153
Real Property Tax[25] ((million 2014$)	90
Sales Tax[26] (million 2014$)	106
Total Tax Values (million 2014$)	**635**

Exhibit 6.2 Overall Economic Benefits over 30 years Project Life

Benefit Parameter	Discount Rate @3%
Supply Side Benefits:	
Income Benefits: (Billions 2014 $)	**$43**
Employment (Thousands of person years of work)	**815**
Residential- Property Value (Billions 2014 $)	**$12.8**
Transfer Payments - Tax Values (Billions 2014 $):	
State and Local Income Tax	$3.0
Federal Income Tax	$5.6
Residential Property Tax	$1.8
Sales Tax	$2.1
Total Tax Values	**$12.4**

23 Federal income tax rate are calculated based on the Tax Foundation document http://www.taxfoundation.org/files/ff231.pdf

24 State and Local income tax benefits are calculated by applying the median of personal income tax rates of Maryland, Virginia, West Virginia and Washington DC State. The state income tax rates are from Federation of Tax Administrators http://www.taxadmin.org/fta/rate/ind_inc.pdf . Local income tax only applied to the counties in Maryland and the rates are from

25 Real Property tax benefits are calculated by applying real property tax rates from Property Taxes on Owner-Occupied Housing by State from Tax Foundation http://www.taxfoundation.org/taxdata/show/24078.html

26 Sales Tax benefits are calculated by applying sales tax rate from Federation of Tax Administrators http://www.taxadmin.org/fta/rate/sales.pdf

Exhibit 6.3: Economic Benefits as a % to the Current Levels

Benefit Parameter	Benefit (Increase from the Current level)
Employment (productivity jobs)	0.5%
Income	0.6%
Residential- Property Value	0.6%

The increase in Economic benefit is less than one year's growth for the Baltimore-Washington regional overall economy, and close to one year's growth for Montgomery, Prince George's counties and DC. This provides a strong enhancement of the corridors economies.

In terms of the time scale associated with the presented benefits it is likely that these benefits will begin to be achieved within two to five years after the completion of the Purple Line Preferred Alternative improvement. The benefits will be proportional to the development of the system routes and schedules. It should be noted that the benefits of the system are likely to increase over time in line with the growth in the economy, as the analysis used the base year economic rent profile not the forecast year economic rent profile. Increases in the economic rent profile will significantly expand these results. If the economy grows by 50 percent by 2050, the estimated benefits will at least increase accordingly.

6.2 ECONOMIC RENT FOR MONTGOMERY, PRINCE GEORGE'S AND WASHINGTON DC

An important feature of the Purple Line improvement is its role to the communities especially in Montgomery and Prince George's Counties and Washington DC. Successful implementation of the project will provide a local, regional and national gateway for the communities in these areas. With the introduction of Purple Line," considerable employment opportunities and development potential will exist. Such activity will generate both commercial and residential development. Industries looking for a home in the Purple Line corridor will see it as a good "seeding" ground for business.

To estimate county level results, the results obtained at a zone level were aggregated to county levels. Exhibit 6.4 and Exhibit 6.5 show the estimated benefits for Montgomery and Prince George's Counties in Maryland and Washington DC – major recipients of such benefits. While Exhibit 6.4 presents the absolute values of estimated benefits, Exhibit 6.5 illustrate the increase in socioeconomic indicators as a percentage to the current levels.

As shown in Exhibits 6.4 and Exhibit 6.5 both Montgomery and Prince George's Counties derive significant benefits from the Purple Line improvements. The zones that include 16-mile improvement area have the major share of the benefits obtained by their counties. In accordance with the Economic Rent model the absolute value of each particular type of benefit primarily depends on the strength of the economy and the level of accessibility improvement resulted from the Purple Line project. Exhibit 6.6 shows the benefits received in these areas on the map.

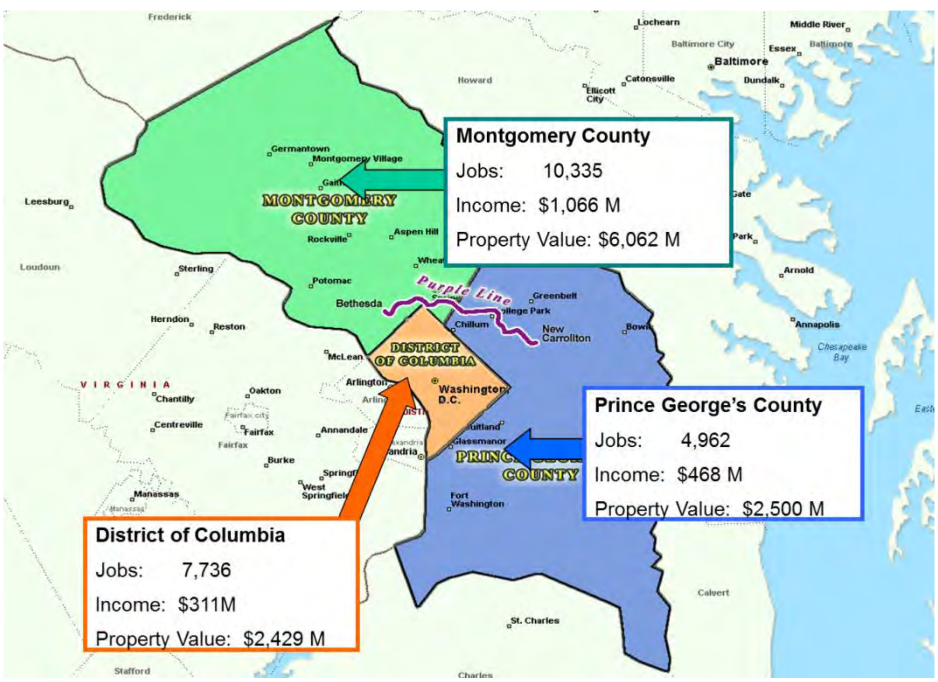
Exhibit 6.4: Economic Rent Analysis by Counties – Montgomery, Prince George's and Washington DC

County	Employment (# Jobs)	Household Income (Millions 2014 $)	Property Value (Millions 2014 $)	Mean Household Income (2014 $)	Mean Residential Household Value(2014 $)
Montgomery	10,335	1,066	6,062	2,363	7,742
Prince George's	4,962	468	2,500	1,548	2,306
Washington DC	7,736	311	2,429	454	4,703
Total	**23,033**	**1,845**	**10,991**	**-**	**-**

Exhibit 6.5: Economic Rent Benefits by Community – Montgomery, Prince George's and Washington DC : Increase from the Current Levels (%)

County	Benefit (% to the current levels)		
	Employment	Household Income	Property Value
Montgomery	1.9%	2.0%	2.2%
Prince George's	1.4%	1.4%	1.5%
Washington DC	0.9%	1.1%	1.1%

Exhibit 6.6: Major Recipients of the Economic Benefits in the Purple Line Regional Study Area



The Exhibit 6.7 shows the employment increase on different categories for Montgomery and Prince George's Counties and Washington DC (major industries were obtained from NAICS classification[27]). Exhibit 6.8 shows the tax benefits received by these areas.

Exhibit 6.7: Employment Benefits by Areas – Montgomery, Prince George's and Washington DC

County	Employment Increase by Categories		
	Professional Service	Health Care	Accommodation/Food Service
Montgomery	1,818	1,550	785
Prince George's	499	634	486
Washington, DC	1,503	1,019	1,005
Total	**3,820**	**3,203**	**2,275**

Exhibit 6.8: Tax Benefits by Areas – Montgomery, Prince George's and Washington DC

County	Tax Benefits (Millions 2014 $)			
	Federal Income Tax	State +Local Income Tax	Property Tax	Sales Tax
Montgomery	133.0	79.4	46.7	52.1
Prince George's	58.5	34.9	19.3	22.9
Washington, DC	49.5	19.4	10.4	15.2
Total	**240.9**	**133.7**	**76.4**	**90.3**

Exhibits 6.9 and 6.10 illustrate the comparison between socioeconomic indicators for Montgomery and Prince George's Counties and Washington DC[28]. Absolute numbers for population and employment are higher in Montgomery County than Prince George's County and Washington DC. This explains why the Montgomery County receives the most benefits. The current employment of Washington DC is higher than the Prince George's County so Washington DC receives more employment benefits, though the increase in employment rate is less than that of Prince George's County. As it is shown in Exhibit 6.10, the Median household income in Montgomery County is 33 percent higher than that in Prince George's County and median property value is 65 percent higher than Prince George's County. This shows that Montgomery County is wealthier than Prince George's County and this is the reason for it getting higher economic benefits than Prince George's County.

[27] The North American Industry Classification System (NAICS) is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy, see for more details: U.S. Census Bureau, http://www.census.gov/eos/www/naics/

[28] US Census Bureau, http://www.census.gov; MWCOG, BMC, US Census Bureau State & County QuickFacts

Exhibit 6.9: 2015 Population and Employment in Montgomery, Prince George's and Washington DC

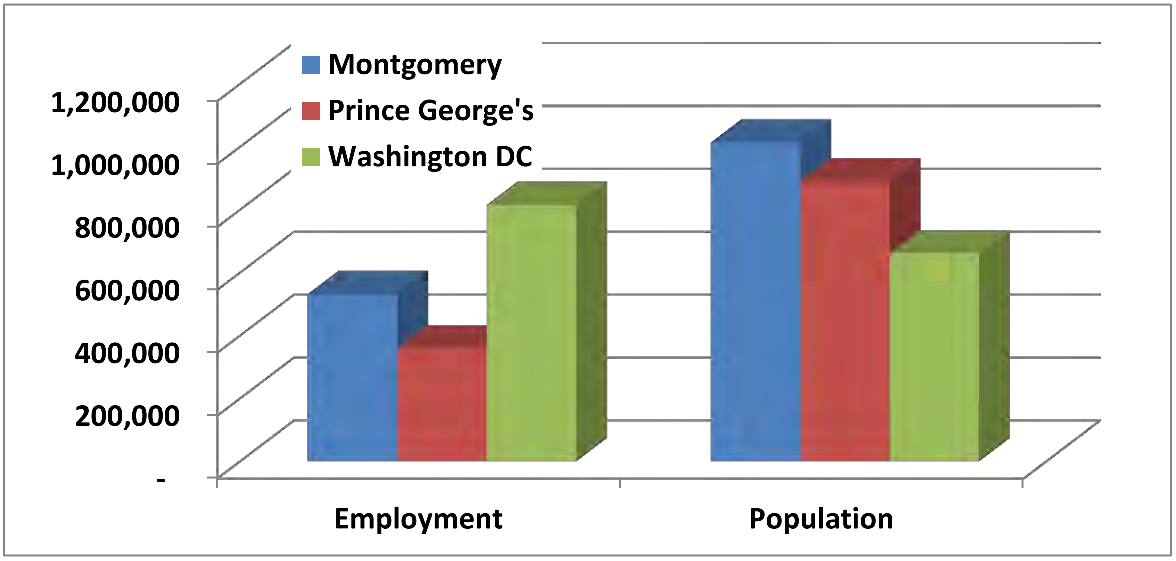
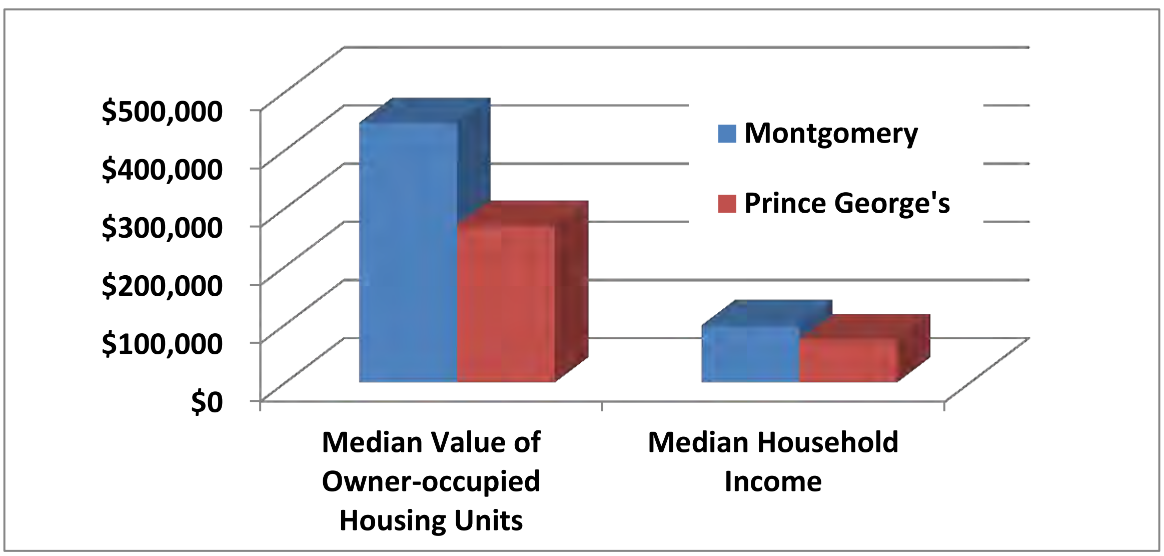


Exhibit 6.10: 2009-2013 Average Median Household Income and Median Value of Owner-occupied Housing Units for Montgomery and Prince George's Counties



As to the difference in levels of transportation interaction, analysis of auto network shows that improvement in accessibility as a result of the Purple Line improvements is higher for Montgomery County than that of Prince George's County and Washington DC. With the light rail option for Montgomery County, average relative improvement in accessibility (measured in relative change in weighted generalized costs[29]) is 1.1 percent, while for Prince George's County the corresponding improvement is 0.8 percent and DC is 0.6 percent.

As we can see from this analysis, difference in the economic benefits estimated for Montgomery and Prince George's Counties and Washington DC are mainly explained by the socioeconomic characteristics of the counties, and the level of improved connectivity to other areas using Purple Line project.

[29] Relative improvement in accessibility in each zone is measured as the fraction between the absolute change in generalized costs (after implementation of the improvements) and the base generalized costs (before their implementation).