Appendix 1. The Interstate 270 Metro Red Line Corridor Serving Washington, D.C.

Executive summary

The pilot study's purpose was to test the methodology to develop a performance metric which, efficiently, measures transit effectiveness in congestion management. This report provides an application of the methodology using the door to door trip times collected by Hickling Lewis Brod Decision Economics (HLB) in 1994 and the ones newly collected. First, the report estimated the model's structural parameters to calculate the hours of delay saved due to transit for 1994 and applied the same equations to estimate the savings for the years 1995, 1996, and 1997. Second, the report re-estimated the structural parameters of the model to calculate the 1998 delay savings due to transit.

The benefits are calculated for three user groups:

Benefits to highway users (Club), these are the hours saved by the common segment user of the I-270 corridor.

Benefits to Transit users (Market), these are the hours saved by the users of transit between Shady Grove and Farragut North station.

Benefits to the highway network users within the corridor (spillover), these are the hours saved by users of parallel and adjacent highways to the common segment within the corridor. .

Findings for 1994 and 1999

Hours of Delay Saved Using the 1994 Data Using convergence level from the 1994 corridor study, HLB found that peak period delay saving due to transit is around seven minutes. Using a travel time value of $15 per hour and an average of 250 working days per year, Table A 1.1 shows the peak delay saving due to the metro rail on I-270 corridor can be valued at $87.4 million for 1994 alone. HLB does not discern any anomalous results, indicating that the methodological framework is operating as expected.

Table A 1.1 Delay Savings Due to Transit based on the 1994 convergence data

Benefit Category	Daily Savings In Hours	Daily Savings In Dollars	Yearly Savings In Dollars
Market	9,848	$ 147,720	$ 36,929,998
Club	7,725	$ 115,879	$ 28,969,725
Spillover	5,727	$ 85,904	$ 21,475,877
Total	23,300	$ 349,502	$ 87,375,600

Table A 1.1 shows that the 1994 delay saving attributed to transit on the I-270 corridor is estimated at about $87.4 million. This can be translated to $3.05 million per rail mile.

Similarly, feeding the volume levels for 1995, 1996, and 1997, for the Washington-Gaithersburg I-270 corridor into equations (1) and (2), HLB estimated the hours of delay saved due to transit for each of the three years. Figure A 1.1 shows the "with-" and "without transit" curves using *the 1994 convergence data* for the I-270 corridor.

Because the model parameters were estimated based on historical HPMS data, a decrease in door to door travel time due to recent infrastructure improvements—opening of HOV lanes—is not reflected in the results shown in Table A 1.2. Therefore, the above results may overestimate the results for the years after the opening of the HOV lanes.

Regarding the methodology accuracy, HLB does not discern any anomalous results, indicating that the methodological framework is operating as expected. In fact, the methodology report states that in *the absence of major infrastructure improvement,* the structural parameters of the estimated equations are stable. Therefore, the trip volume in the corridor along with the ridership level can be inserted into these equations to estimate the delay savings due to transit. It is only in the presence of major changes in the level of highway supply or transit service that the behavioral equations underlying mode choice will change and need to be re-estimated.

Hours of Delay Saved Using the 1998 Data

Similarly, using the convergence level from the newly collected data, Table A 1.3 through Table A 1.5 show the 1998 delay savings due to transit per user category.

Table A 1.2 Summary Table of Delay Savings based on the 1994 convergence data

	Transit Effect on Corridor Travel Time (in minutes)		Hours of delay saved due to transit		
	With Transit	Without Transit	Min.per PeakTrip	Thous. Daily Hrs. (1,000)	Annual Dollar Savings
1994	71.1	77.8	6.7	23.3	$87,375,600
1995	72.3	79.1	6.8	24.0	$89,812,666
1996	73.6	80.6	7.0	24.7	$92,489,113
1997	74.9	82.0	7.1	25.4	$95,307,355

Table A 1.3 Daily Club Benefits for Red Line I-270 Corridor

Station	In-bound Trips	Out-bound Trips	Savings (hours)
Shady Grove	9,377	9,368	1,438.99
Rockville	3,696	3,644	535.29
Twinbrook	3,547	3,513	487.78
White Flint	3,905	3,935	511.57
Grosvenor	3,522	3,404	425.35
Medical Center	4,131	4,133	475.80
Bethesda	8,056	8,385	883.48
Friendship Heights	8,617	8,784	868.28
Tenleytown-AU	5,985	6,183	560.46
Van Ness-UDC	6,692	6,280	547.70
Cleveland Park	4,548	4,480	346.52
Woodley Park-Zoo	5,892	5,648	398.65
Dupont Circle	20,109	20,939	1,260.45
Farragut North	25,302	25,107	1,354.41
Total			10,095

Table A 1.4 Daily Market Benefits for I-270 Corridor

	Distance (miles)	Traffic Volume	Savings (hours)
Common Segment			
K Street	0.1	16,850	5.43
Whitehurst Freeway	1	16,850	48.86
Canal Street	0.1	16,850	4.89
Clara Barton Parkway	3.3	16,850	161.25
Cabin John Parkway	1.5	16,850	73.29
I-495	4.17	219,650	1,475.63
I-270	14.12	194,475	6,193.50
Access Segment			
(on average)	4.3	16,850	233.46
Total	28.59		8,196.31

Table A 1.5 Daily Spillover Benefits for I-270 Corridor

Highways in the corridor	Distance (miles)	Traffic Volume	Savings (hours)
MD 355	12.62	63,550	1,938.10
MD 191	9.84	19,050	302.00
MD 187	5.32	128,950	1,878.85
MD 185	8.59	68,625	949.70
MD 190	5.86	47,575	673.72
MD 396	2.21	11,075	59.15
MD 188	3.25	11,150	58.38
Total			5,860

Table A 1.6 Network Benefit Summary

Benefit Category	Daily Savings		Yearly Savings
	In Hours	In Dollars	In Dollars
Market	10,095	$ 151,421	$ 37,855,246
Club	8,196	$ 122,945	$ 30,736,165
Spillover	5,860	$ 87,898	$ 21,974,568
Total	24,151	$ 362,264	$ 90,565,978

Table A 1.6 shows that the 1998 delay saving attributed to transit on the I-270 corridor is estimated at about $90.6 million. This can be translated to $3.2 million per rail mile.

Figure A 1.1 shows that the vertical difference between the "with-" and "without transit" curves did not vary between 1994 and 1998. This is due to the slight change in the convergence level between 1994 and 1998.

The methodology implies that in the absence of major infrastructure improvements or strong growth in volume of traffic the performance metric will remain stable. So, it should suffice to gather corridor travel time—degree of convergence—once every several years. In the case of major infrastructure improvement or a change in the transit service, however, door to door travel time data should be collected to estimate an accurate performance metric.

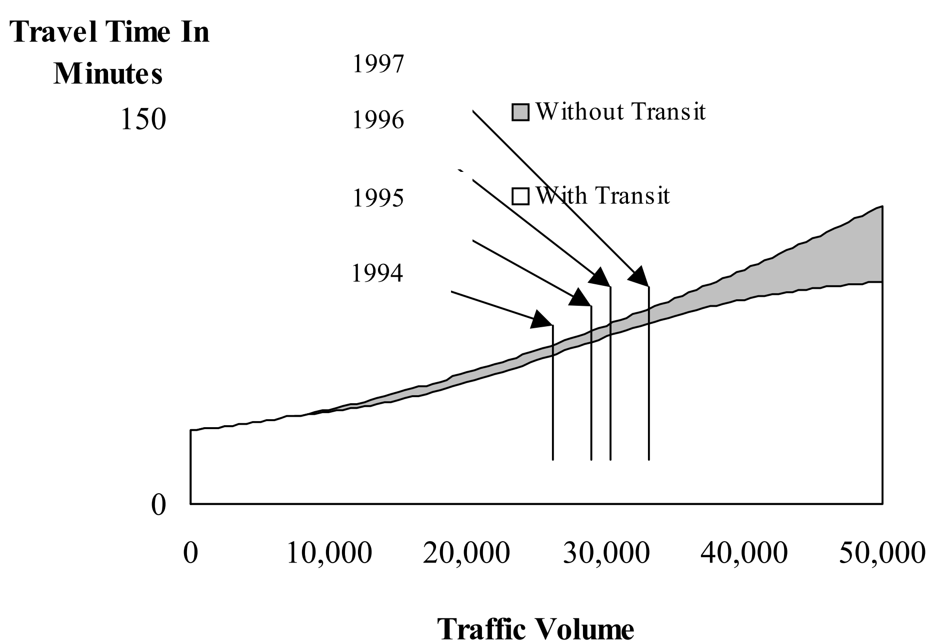


Figure A 1.1 Highway Travel Times With and Without Transit, Washington, D.C. I-270

Introduction

This is the Pilot Study report, which completes Subtask 2a of Streamlined Strategic Corridor Travel Time Management study. The purpose of the study is to use the convergence measurement technique to derive a repeatable performance measurement for rail transit in congested corridors. The pilot study purpose is to test the methodology to develop a performance metric which, efficiently, measures transit effectiveness in congestion management.

Study Methodology

The pilot study was conducted on the Washington-Gaithersburg I-270 corridor during the first 2 weeks of December 1998. The study consisted of testing the methodology in two phases. In the first phase, HPMS data was used to estimate the model parameters, then HLB's data from 1994 study was used to populate the model and calculate the hours of delay saved due to transit. In the second phase, data was collected on site—I-270 corridor—by a survey team, and the hours of delay saved were estimated using the new data.

Each survey crew was required to follow specific routes that consisted of an access segment—which depends on the catchment zone considered for the trip—and a common segment (which is the same segment for all the trips). The data collected included start times and arrival times by mode, congestion level, seating availability, weather, road conditions, and travel costs for each segment.

Data was collected over a period of three consecutive days (Tuesday to Thursday) during a two weeks period. The same days of the week were sampled to eliminate fluctuations in traffic patterns and volumes due to the day of week effects. More than one day of sampling was required to ensure a statistically adequate sample size and to minimize the effects of unusual or circumstantial conditions.

This pilot study employed the exact same maps and routes used in the 1994 study. Consequently, the results from this study allowed for not only a comparison of the metric-hours of delay saved due to transit—between 1994 and 1998 but for an interpretation of how the convergence level affects the metric over time as well.

Methodology Testing

The testing of the methodology consists of analyzing the travel times in the "with-" and "without transit" cases, and the hours of delay metric based on 1994 data and data newly collected. The analysis is critical in determining the consistency and the reliability of the methodology.

To estimate the model parameters HLB relied on traffic data from Washington Council of Governments (WASHCOG) and Montgomery County Department of Park and Planning, and on metro rail ridership data from Washington Metropolitan Area Transit Authority (WMATA).

HLB also used HPMS/STEAM delay models developed by Cambridge Systematics to obtain historical travel time in the corridor. The model estimation process was performed in several three steps:

> Step 1: HLB used the 1994 door-to-door travel time data, historical HPMS data, and the convergence level to estimate the "without transit" and the "with transit" curves and calculate the travel time saved due to transit per person, per day.

Step 2: Traffic volume for the years 1995, 1996, and 1997 were used to calculate the hours of delay saved due to transit per person, per day.

Step 3: The door-to-door travel times were collected and used to re-estimate the “without transit” and the “with transit” curves.

Then, the delay metric is estimated and compared to the previous years-estimated metrics. The comparison analysis determines the effectiveness of the “hours of delay saved due to transit” metric as a rail transit performance indicator.

Plan of the Report

The objective of this report is to present the results from the I-270 Washington-Gaithersburg corridor pilot study. After this introduction, Chapter 2 presents an overview of the model and methodology to estimate the delay saving. Chapter 3 shows the model estimation results using 1994 convergence level on historical traffic data. The chapter gives an estimation of the hours of delay saved due to transit per person per day, and provides a monetary value of the delay saved for the years 1995 through 1997. Chapter 4 presents the results from the 1998 door-to-door travel survey and shows the model estimation of the delay saving using the new data. The chapter concludes with an interpretation of the effect of the convergence level on the estimated metric. The appendices at the end of this report provide supporting data and supplementary results on the survey findings by route.

Methodology and Model Overview

The methodology consists of four steps:

1. Estimating the Corridor Performance Baseline
2. Estimating the Corridor Performance in the Absence of transit
3. Extrapolating Delay Savings Due to Transit
4. Estimation of Corridor Performance without Re-calibration
5. Estimating the Corridor Performance Baseline

The Model This model establishes a functional relationship between the person trip volume – all modes—and the average door to door travel time by auto in the corridor.

The door to door travel time by auto can be determined using a logistic function which calculates the door to door travel time in terms of travel time at free flow speed, trip time by high capacity rail mode, and the volume of trips in the corridor for all modes. The door to door travel time can be estimated as follows:

$$\mathbf{T = (T_c - T_{ff}) / (1 + e^{-(\delta + \varepsilon V1)}) + T_{ff}} \quad \mathbf{(1)}$$

Where T_{a1} is auto trip time,

Tc is trip time by high-capacity rail mode

T_{ff} is auto trip time at free-flow speed,

V is person trip volume in the corridor by auto, and

δ, ε are model parameters

Equation 1 implies that the door to door auto trip time is equal to the trip time at free-flow speed plus a delay which depends on transit travel time and the person trip volume in the corridor.

In other words, when the highway volume is close to zero, travel time is equal to travel time at free flow speed.($T = T_{ff}$). As the volume increases, the travel time is equal to T_{ff} plus a delay due to the high volume, but adjusted to the travel time by high capacity transit. That is the high capacity transit alleviates some of the highway trip delay as some trips shift to transit.

Equation 1 is transformed into a linear functional form before the parameters δ and ε can be estimated, the transformed equation will be:

$$\mathbf{U = \delta + \varepsilon V_1} \qquad \mathbf{(2)}$$

Where $U = \ln [(T_c - T_{ff}) / (T - T_{ff}) - 1]$

Equation 2 is estimated using Ordinary Least Squares regression.

Data The data required for the estimation of the above equations are:

person trip volume on the highway which can be calculated by dividing the traffic volume by the average vehicle occupancy (auto and buses). This data are available through HPMS data base and MPO's traffic data.

free flow trip time is a constant.

high capacity trip time is a constant.

The parameters δ and ε do not have to be re-estimated each year, they are both specific to the corridor and are relatively stable over the years. So periodically, the person trips volume can be inserted into Equation 1 to estimate the door to door travel time by auto.

Estimating the Corridor Performance in the Absence of transit

The Model This model represents the concept to quantify the role of transit in congestion management. In the absence of transit, the travel time Ta is estimated as:

$$\mathbf{T_a = T_{ff} * (1 + A (V^*)^{\beta})} \qquad \mathbf{(3)}$$

Where T_a is the door to door travel time in the absence of transit,

T_{ff} is the trip travel time at free-flow speed,

V^* is the volume of person trips by auto in the absence of transit,

A is a scalar, and β is a parameter.

Equation 3 implies that the door to door travel time in the absence of transit depends on the travel time at free-flow speed and the level of congestion on the road in the absence of transit.

The volume of person trips by auto in the absence of transit, however, depends on several factors:

The existing auto and bus person trips on the highway.

The percentage of person transit trips shifting to auto

The percentage of person transit trips shifting to bus

The number of additional cars in the highway

The number of additional buses in the highway

The occupancy per vehicle in the absence of transit

The volume of person trips by auto, in the absence of transit, can then be estimated as:

$$\mathbf{V^* = V_1 + \alpha_1 V_c + \alpha_2 V_b} \qquad \textbf{(4)}$$

Where V_1 is the existing auto volume,

V_c is the transit person trips diverted to cars,

V_b is the transit person trips diverted to buses, and

α_1, α_2 are the coefficients that incorporate the passenger car equivalent factor, and the occupancy per vehicle (cars and buses).

The trips diverted to cars and buses depend mainly on the degree of convergence in the corridor. This degree of convergence reflects the transit user behavior and the composition of these users. The transit users can be divided into 3 categories:

Type 1: “Explorers” who are casual switchers and who will divert to Single Occupancy Vehicles in the absence of transit.

Type 2: Commuters with low elasticity of demand with respect to generalized cost and who will divert to use the bus or carpool.

Type 3: Commuters with high elasticity of demand with respect to generalized cost and who will forgoes the trip.

The higher the degree of convergence (auto and rail door to door travel times are very close), the higher the shift of transit riders to cars and buses. Therefore, higher degree of convergence will lead to higher delay, which translates into higher savings due to transit.

In words, Equation 3 shows that in the absence of transit and in the case of a high degree of convergence, the person trip volume is very high which translates into a high trip time (excessive delay). The relationship between trip time and person trip volume can be expressed as a convex curve (as the volume increases, travel time increases at an increasing rate). Figure A 1.2 illustrates the relationship between the volume and travel time both in the presence and in the absence of transit.

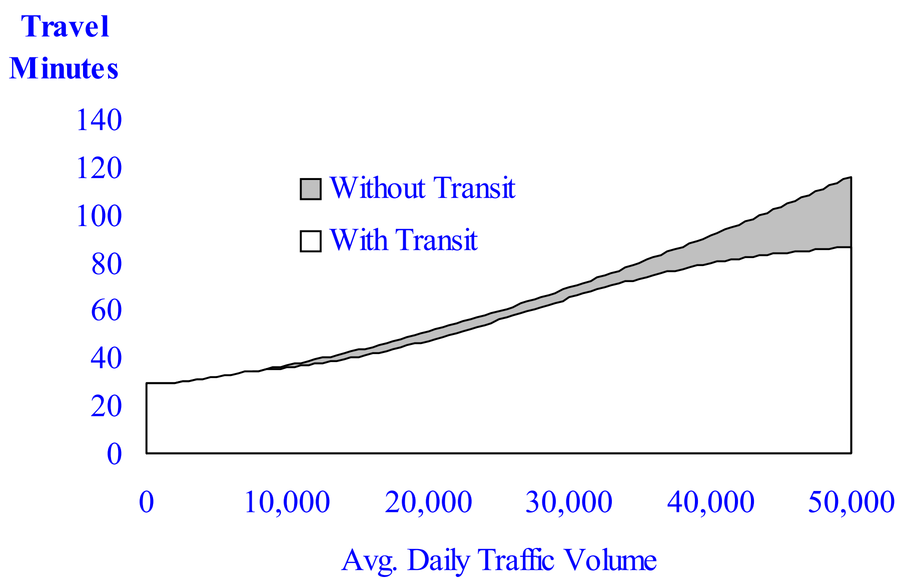


Figure A 1.2 Highway Travel Times With and Without Transit: I-270 Red Line Corridor, 1998

Data The data required to populate this model consist of:

Highway person trip volume (used in the previous model)

Transit ridership data

Fleet composition (cars and buses percentages out of the total traffic)

Cars and buses vehicle occupancy

Passenger car equivalent factor

Degree of convergence to determine the percentage person trips shifting to cars and buses

Free-flow travel time which is a constant

Equation 3 is specific to the corridor and does not need to be estimated each year. It will only be necessary to re-estimate them with an updated degree of convergence if a major change is made to the transit level of service or the highway structure.

Extrapolating Delay Savings Due to Transit

While the MLC hypothesis proves to be valid during the peak period only, the delay savings due to transit can be estimated during off-peak as well. This metric can be estimated as the vertical difference between the "without transit" curve and the "with transit" curve. That is at a specific person trip volume, the difference in travel times between the two cases can be defined as "the hours of delay saved due to transit".

The estimated hours of delay savings due to transit are an aggregation of three different user savings: savings by Metro riders (market benefits), savings by highway users (club benefits), and savings by users of parallel highways (spillover benefits).

The *market* benefits are estimated based on delay saved (which depends on the distance traveled) for each rider within the common segment.

The *club* benefits are estimated based on the volume on the common segment using origin-destination table and the daily trip distribution.

The *spillover* benefits are estimated based on the savings per mile, traffic volume, and the distance traveled on segments parallel to the common segment. The spillover benefits are calculated by multiplying the traffic volume with a percentage of the delay savings. This percentage decreases as the distance between the common segment and the parallel highway increases.

Estimation of Corridor Performance without Re-Calibration

The framework, presented above, provides an MLC-based approach to making repeated measures of transit-induced savings in corridor delay without the need for repeated MLC surveys. The approach rests on the theoretical proposition, that a stable and measurable relationship exists between roadway traffic growth over time and the inter-modal (highway-transit) equilibrium dynamics that give rise to delay savings in a congested corridor. In the absence of major changes in the level of highway supply or transit service in the corridor, this measured relationship, or model, provides a formula-based performance measurement system in lieu of a survey-based approach. In addition to the obvious cost advantages, this approach provides FTA with (i) an efficient means of measuring and comparing transit performance in strategic corridors; and (ii) a consistent performance assessment tool for transfer to MPOs throughout the country.

Principal Findings Using the 1994 Data

The first phase of the pilot study consists of using the 1994 I-270 corridor convergence data and historical HPMS data to test the study methodology and to estimate the hours of delay saved due to transit in the corridor. This chapter presents an analysis of the 1994 convergence data which is critical to determine the convergence level and then use this level to estimate the metric for the years 1994, 1995, 1996, and 1997.

The Convergence Level

The starting point to estimate the "without transit" curve is to determine the convergence level based on the key findings from the 1994 travel data. Table A 1.7 shows a summary of the performance and service characteristics for the Washington-Gaithersburg I-270 corridor in 1994.

Table A 1.7 Performance and Service Characteristics in 1994

	Automobile	Metro Rail
Number of stops	N/A	13
Number of Streets and Highways	6	N/A
Tolls/Fares for a one way (in dollars)	$0.00	$3.15

The level of convergence for the 1994 Washington-Gaithersburg I-270 Corridor is based on the following key findings from the study:

- Average door-to-door travel times for auto and metro rail, are similar, 67.4 minutes by rail versus 71.9 minutes by auto (Table A 1.8).
- Travel time reliability, as represented by the standard deviation of average travel time, is greater for heavy rail mode compared to the auto mode (Table A 1.8).
- Commuters experienced longer travel times in the morning than the evening reflecting the different traffic dynamics of the inbound peak flow versus the outbound peak flow (Table A 1.9).
- Statistical analysis shows that the mean trip time by auto was at most 10 minutes longer with 95% confidence (Table A 1.10).
- The common segment travel time was greater for the auto mode than for the transit mode, 50.7 minutes versus 37.8 minutes. The difference of 12.9 minutes between the two modes is due to congestion on the highways (Table A 1.8).
- Access segment travel times indicate that auto commuters spent 8.4 minutes on average less outside the common segment than transit commuters (Table A 1.8).

Table A 1.8 Results for the Washington-Gaithersburg I-270 Corridor

	Automobile	Metro Rail
Total Travel Time		
Mean	71.9	67.4
Standard Deviation	14.7	8.0
Access Segment Travel Time		
Mean	21.2	29.6
Standard Deviation	8.8	6.1
Common Segment Travel Time		
Mean	50.7	37.8
Standard Deviation	13.2	5.0
Sample Size	38	34

Table A 1.9 Comparison of AM and PM Trip Times by Modes

	Auto	Metro Rail
Inbound AM Average Trip Time	78.7	66.8
Outbound PM Average Trip Time	65.1	68.0

Table A 1.10 Statistical Testing of Convergence Hypothesis

Difference in Mean Travel Times by Mode: (Auto- Metro Rail minutes)		4.5
Standard Error of the Difference of the Means (minutes):		2.8
Hypothesis	Significant at the	Significant at the
"The difference between the mean travel times by modes is at most..."	0.10 Level (90% Confidence)	0.05 Level (95% Confidence)
7 Minutes	NO	NO
8 Minutes	NO	NO
9 Minutes	YES	NO
10 Minutes	YES	YES
11 Minutes	YES	YES

Methodology Application on I-270 Corridor using 1994 Data

Data HLB obtained traffic volume data (HPMS data) from the regional MPO, Metropolitan Washington Council of Government (WASHCOG) and Maryland Department of Transportation. The ridership data were obtained from the Washington Metropolitan Area Transit Authority (WASHCOG). In addition, the 1994 door to door travel time survey results were used to derive the degree of convergence in the corridor.

Model The traffic volume and travel time data were used to populate the model, Equation 1 is estimated as follows:

$$\mathbf{T_{a1} = 51 / (1 + e^{-(-3.28 + -0.000121\ (V))}) + 29,} \qquad (1)$$

Similarly, Equation 2 is estimated based on auto travel volume, transit ridership data, and convergence level estimate from the survey.

$$\mathbf{T_{a2} = 29 \ * \ (1 + 2.68E\text{-}07\ (V^*)^{1.5})} \qquad (2)$$

The auto traffic volume in the absence of transit is determined by adding the auto volume in the presence of transit to the generated auto trips by transit riders. The generated is based on:

About 7% of person transit trips will be forgone (determined by the corridor convergence level).

The average vehicle occupancy (HOV and non-HOV) is 1.2 for cars and 40 for buses.

Car trips will make about 80% of trips.

Benefit Estimation To estimate the travel time saving (TTS) attributed to transit, the current traffic volume is inserted into Equation 1 and 2. An auto volume of 37,500 results into:

$$\mathbf{T_{a1} = 71.1,\ T_{a2} = 77.8, \text{ and . } TTS = T_{a2} - T_{a1} = 6.7}$$

That is on average, in I-270 corridor, transit saves about 6.7 minutes per auto trip (14.1 seconds per mile) during the peak period

Once the average travel time saving per vehicle is estimated, the savings are weighted to reflect the congestion level at each time of the day. App. Annex A shows the daily Average Traffic Volume distribution.

The benefits are calculated for three user groups:

1. Benefits to highway users (Club), these are the hours saved by the common segment user of the I-270 corridor (see Table A 1.11).
2. Benefits to Transit users (Market), these are the hours saved by the users of transit between Shady Grove and Farragut North station (see Table A 1.12).
3. Benefits to the highway network users within the corridor (spillover), these are the hours saved by users of parallel and adjacent highways to the common segment within the corridor (see Table A 1.13).

Table A 1.11 Club Benefits for I-270 Corridor using 1994 Data

	Distance (miles)	Avg Traffic Volume	Daily Savings (hours)
Common Segment			
K Street	0.1	13,975	4.59
Whitehurst Freeway	1	13,975	41.27
Canal Street	0.1	13,975	4.13
Clara Barton Parkway	3.3	13,975	136.17
Cabin John Parkway	1.5	13,975	61.90
I-495	4.17	202,650	1,386.25
I-270	14.12	181,750	5,893.81
Access Segment (on average)	4.3	13,975	197.16
Total	28.59		7,725.26

Table A 1.12 Market Benefits of I-270 Corridor using 1994 Data

Station	In-bound Trips	Out-bound Trips	Daily Savings (hours)
Shady Grove	8,321	8,315	1,300.38
Rockville	3,550	3,502	523.67
Twinbrook	3,855	3,822	540.08
White Flint	3,661	3,692	488.55
Grosvenor	3,650	3,492	446.61
Medical Center	3,927	3,924	460.26
Bethesda	7,625	7,817	844.93
Friendship Heights	8,520	8,582	868.92
Tenleytown-AU	5,210	5,406	497.89
Van Ness-UDC	6,422	6,052	536.28
Cleveland Park	4,204	4,125	325.53
Woodley Park-Zoo	7,309	7,215	510.88
Dupont Circle	20,411	20,725	1,286.19
Farragut North	23,364	21,150	1,217.83
Total			9,848

Table A 1.13 Spillover Benefits of I-270 Corridor using 1994 Data

Highways in the corridor	Distance (miles)	Avg Traffic Volume	Daily Savings (hours)
MD 355	12.62	61,250	1,902.02
MD 191	9.84	18,000	290.55
MD 187	5.32	125,600	1,863.41
MD 185	8.59	65,250	919.46
MD 190	5.86	44,000	634.45
MD 396	2.21	11,025	59.95
MD 188	3.25	10,700	57.05
Total			5,727

Table A 1.14 shows that the 1994 delay saving attributed to transit on the I-270 corridor is estimated at about $87.4 million. This can be translated to $3.05 million per rail mile.

Feeding the volume levels for 1994, 1995, 1996, and 1997, for the Washington-Gaithersburg I-270 corridor into equations (1) and (2), HLB estimated the hours of delay saved due to transit for each of the four years. Figure A 1.3 shows the “with-“ and “without transit” curves using *the 1994 convergence data* for the I-270 corridor.

Table A 1.14 Benefit Summary using 1994 Data

Benefit Category	Daily Savings		Yearly Savings
	In Hours	In Dollars	In Dollars
Market Benefits	9,848	$ 147,720	$ 36,929,998
Club Benefits	7,725	$ 115,879	$ 28,969,725
Spillover Benefits	5,727	$ 85,904	$ 21,475,877
Total	23,300	$ 349,502	$ 87,375,600

Table A 1.15 Summary Table of Delay Savings based on the 1994 convergence data

	Travel time in the corridor (in minutes)		Hours of delay saved due to transit		
	In presence of Transit	In absence of Transit	per trip during peak period (min)	All user-categories per day (hours)	Yearly Savings in Dollars
1994	71.1	77.8	6.7	23,300	$ 87,375,600
1995	72.3	79.1	6.8	23,950	$ 89,812,666
1996	73.6	80.6	7.0	24,664	$ 92,489,113
1997	74.9	82.0	7.1	25,415	$ 95,307,355

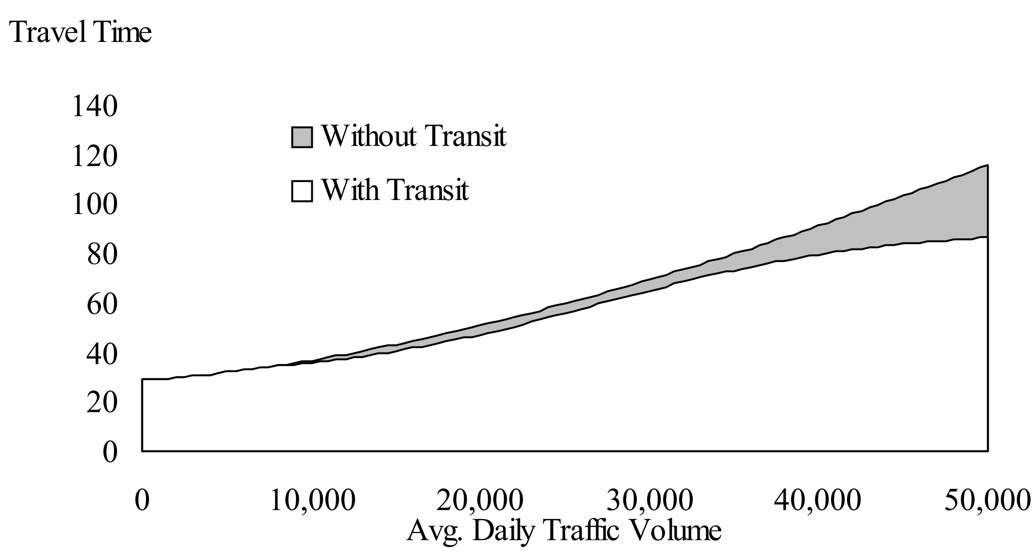


Figure A 1.3 Illustration of the "With-" and "Without Transit" Curves Using 1994 Convergence Data

The above results indicate a peak-period delay saving due to transit of about seven minutes. Using a travel time value of $15 per hour and an average of 250 working days per year, Table A 1.15 shows the peak delay saving due to the metro rail on I-270 corridor can be valued at $89.8 million in 1995 and about $95 in 1997. The door to door travel times for 1995, 1996, and 1997 were not collected on site but estimated using Equation 1. Because the model parameters were estimated based on historical HPMS data, a decrease in door to door travel time due to recent infrastructure improvements—opening of HOV lanes—is not reflected in the results shown in Table A 1.15. Therefore, the above results may overestimate the results for the years after the opening of the HOV lanes.

Regarding the methodology accuracy, HLB does not discern any anomalous results, indicating that the methodological framework is operating as expected. In fact, the methodology report states that in *the absence of major infrastructure improvement,* the structural parameters of the estimated equations are stable. Therefore, the trip volume in the corridor along with the ridership level can be inserted into these equations to estimate the delay savings due to transit. It is only in the presence of major changes in the level of highway supply or transit service that the behavioral equations underlying mode choice will change and need to be re-estimated.

An Update of the I-270 Corridor Equilibrium Study

This section presents the results from the 1998 door-to-door travel survey. The chapter also shows the model estimation results using the new data and concludes with an interpretation of the effect of the convergence level on the estimated metric. Table A 1.16 presents the performance and service characteristics during the 1998 door to door travel survey.

Table A 1.16 Performance and Service Characteristics in 1998

	Automobile	Metro Rail
Number of stops	N/A	13
Number of Streets and Highways	6	N/A
Tolls/Fares for a one way (in dollars)	$0.00	$3.25

Pilot Update of the I-270 Corridor Equilibrium Study

The 1994 Washington-Gaithersburg I-270 corridor results presented in Table A 1.11, Table A 1.12, and Table A 1.13 can be compared with pilot I-270 results for 1998 in matching Table A 1.21, Table A 1.22, and Table A 1.23. A comparison of Table A 1.10 and Table A 1.15 indicate that the convergence hypothesis remains statistically valid for a door to door trip time difference (auto versus metro rail as main mode) of *at most* 10-11 minutes. The average trip time difference measured in 1998 of 5.7 minutes remains very close to the 4.5 minute difference in 1994. Annex A 1.2 provides the 1998 survey findings by route in the I-270 corridor.

The key findings from the 1998 travel time for Washington-Gaithersburg I-270 Corridor are:

- Average door-to-door travel times for auto and metro rail, are still similar, 59.9 minutes by rail versus 65.6 minutes by auto (Table A 1.17).
- Travel time reliability, as represented by the standard deviation of average travel time, is again greater for rail mode compared to the auto mode (Table A 1.17).

- Auto commuters experienced longer travel time in the morning than in the evening reflecting the different traffic dynamics of the inbound peak flow versus the outbound peak flow, rail commuters did not experience any significant difference in travel time between morning and evening trips (Table A 1.14).
- Statistical analysis shows that the mean trip time by auto was at most 10 minutes longer with 95% confidence, similar results were obtained from 1994 trip data (Table A 1.15).
- The common segment travel time was greater for the auto mode than for the transit mode, 43.4 minutes versus 36.1 minutes. The difference of 7.3 minutes between the two modes is due to congestion on the highways (Table A 1.13).
- Access segment travel times indicate that auto commuters spent about 2 minutes on average less outside the common segment than transit commuters (Table A 1.13).

Table A 1.17 Travel Time Results

	Automobile	Metro Rail
Total Travel Time		
Mean	65.6	59.9
Standard Deviation	7.1	6.0
Access Segment Travel Time		
Mean	22.2	23.8
Standard Deviation	5.6	6.5
Common Segment Travel Time		
Mean	43.4	36.1
Standard Deviation	8.6	6.5
Sample Size	30	30

Table A 1.18 Comparison of AM and PM Trip Times by Modes

	Auto	Metro Rail
Inbound AM Average Trip Time	66.7	59.7
Outbound PM Average Trip Time	64.6	60.1

Table A 1.19 Statistical Testing of Convergence Hypothesis

Difference in Mean Travel Times by Mode (Auto - Metro Rail minutes):		5.7
Standard Error of the Difference of the Means (minutes):		2.2
Hypothesis: "The difference between the mean travel times by mode is less than…"	Significant at the Level (90% Confidence)	Significant at the 0.05 Level (95% Confidence)
7 Minutes	NO	NO
8 Minutes	NO	NO
9 Minutes	NO	NO
10 Minutes	YES	YES
11 Minutes	YES	YES

Methodology Application on I-270 Corridor

Data HLB obtained traffic volume data (HPMS data) from the regional MPO, Metropolitan Washington Council of Government (WASHCOG) and Maryland Department of Transportation. The ridership data were obtained from the Washington Metropolitan Area Transit Authority (WASHCOG). In addition, door to door travel time survey was conducted to derive the degree of convergence in the corridor.

Model The traffic volume and travel time data were used to populate the model, Equation 1 is estimated as follows:

$$\mathbf{T_{a1} = (90 - 50) / (1 + e^{-(-7.41 + 0.000144\,(V))}) + 50} \qquad \mathbf{(1)}$$

When V is equal to 0, the travel time is equal the travel time at free flow speed (50 minutes). For an auto traffic volume of 49,500 between Gaithersburg and Downtown DC (based on WASHCOG 1998 O-D tables), the travel time is equal to 66.95 minutes.

Similarly, Equation 2 is estimated based on auto travel volume, transit ridership data, and convergence level estimate from the survey.

$$\mathbf{T_{a2} = 50 * (1 + 7.94E\text{-}08\,(V^*)^{1.44})} \qquad \mathbf{(2)}$$

Table A 1.20 shows an example of the data used to estimate Equation 1 and 2. Volume 1 and Travel Time 1 on the table shows the auto volume and travel time in the presence of transit while Volume 2 and Travel time 2 shows the estimated volume and travel time in the absence of transit.

Table A 1.20 Example of Data used to estimate the equations

	Daily Savings		Yearly Savings
Benefit Category	In Hours	In Dollars	In Dollars
Market	10,095	$ 151,421	$ 37,855,246
Club	8,196	$ 122,945	$ 30,736,165
Spillover	5,860	$ 87,898	$ 21,974,568
Total	24,151	$ 362,264	$ 90,565,978

The auto traffic volume in the absence of transit is determined by adding the auto volume in the presence of transit to the generated auto trips by transit riders. The generated results are based on:

- About 10% of person transit trips will be forgone (determined by the corridor convergence level).
- The average vehicle occupancy (HOV and non-HOV) is 1.2 for cars and 40 for buses.
- Car trips will make about 80% of trips.
- Benefit Estimation

To estimate the travel time saving (TTS) attributed to transit, the current traffic volume is inserted into Equation 1 and 2. An auto volume of 37,500 results into:

$$\mathbf{T_{a1} = 66.95,\ \ T_{a2} = 73.53,\ and\ .\ TTS = T_{a2} - T_{a1} = 6.58}$$

That is on average, in I-270 corridor, transit saves about 6.58 minutes per auto trip (15 seconds per mile) during the peak period

Once the average travel time saving per vehicle is estimated, the savings are weighted to reflect the congestion level at each time of the day. The benefits are calculated for three user groups:

- Benefits to highway users (Club), these are the hours saved by the common segment user of the I-270 corridor (seeTable A 1.21).
- Benefits to Transit users (Market), these are the hours saved by the users of transit between Shady Grove and Farragut North station (see Table A 1.22).
- Benefits to the highway network users within the corridor (spillover), these are the hours saved by users of parallel and adjacent highways to the common segment within the corridor (see Table A 1.23).

Table A 1.21 Club Benefits for I-270 Corridor

	Distance (miles)	Avg Traffic Volume	Daily Savings (hours)
Common Segment			
K Street	0.1	16,850	5.43
Whitehurst Freeway	1	16,850	48.86
Canal Street	0.1	16,850	4.89
Clara Barton Parkway	3.3	16,850	161.25
Cabin John Parkway	1.5	16,850	73.29
I-495	4.17	219,650	1,475.63
I-270	14.12	194,475	6,193.50
Access Segment (on average)	4.3	16,850	233.46
Total	28.59		8,196.31

Table A 1.22 Market Benefits for I-270 Corridor

Station	In-bound Trips	Out-bound Trips	Daily Savings (hours)
Shady Grove	9,377	9,368	1,438.99
Rockville	3,696	3,644	535.29
Twinbrook	3,547	3,513	487.78
White Flint	3,905	3,935	511.57
Grosvenor	3,522	3,404	425.35
Medical Center	4,131	4,133	475.80
Bethesda	8,056	8,385	883.48
Friendship Heights	8,617	8,784	868.28
Tenleytown-AU	5,985	6,183	560.46
Van Ness-UDC	6,692	6,280	547.70
Cleveland Park	4,548	4,480	346.52
Woodley Park-Zoo	5,892	5,648	398.65
Dupont Circle	20,109	20,939	1,260.45
Farragut North	25,302	25,107	1,354.41
Total			10,095

Table A 1.23 Spillover Benefits for I-270 Corridor

Highways in the Corridor	Distance (miles)	Avg Traffic Volume	Daily Savings (hours)
MD 355	12.62	63,550	1,938.10
MD 191	9.84	19,050	302.00
MD 187	5.32	128,950	1,878.85
MD 185	8.59	68,625	949.70
MD 190	5.86	47,575	673.72
MD 396	2.21	11,075	59.15
MD 188	3.25	11,150	58.38
Total			5,860

Table A 1.24 Benefit Summary

	Daily Savings		Yearly Savings
Benefit Category	In Hours	In Dollars	In Dollars
Market	10,095	$ 151,421	$ 37,855,246
Club	8,196	$ 122,945	$ 30,736,165
Spillover	5,860	$ 87,898	$ 21,974,568
Total	24,151	$ 362,264	$ 90,565,978

Table A 1.24 shows that the 1998 delay saving attributed to transit on the I-270 corridor is estimated at about $90.6 million. This can be translated to $3.2 million per rail mile.

The convergence level is calculated as the percentage change between auto and metro rail travel times.

For 1994 : D = (71.9 - 67.4) / 71.9 = 6.26%, and

For 1998: D = (65.6 - 59.9) / 65.6 = 8.68%.

Based on the study methodology, the convergence level directly impacts the hours of delay saved. This impact is illustrated by a shift in the "with-" and "without transit" curves when the equations are re-estimated.

The methodology implies that in the absence of major infrastructure improvements or strong growth in volume of traffic the performance metric will remain stable. So, it should suffice to gather corridor travel time—degree of convergence—once every several years. In the case of major infrastructure improvement or a change in the transit service, however, door to door travel time data should be collected to estimate an accurate performance metric.

Annex A 1.1 Time of Day Trip Distribution for the I-270 Corridor

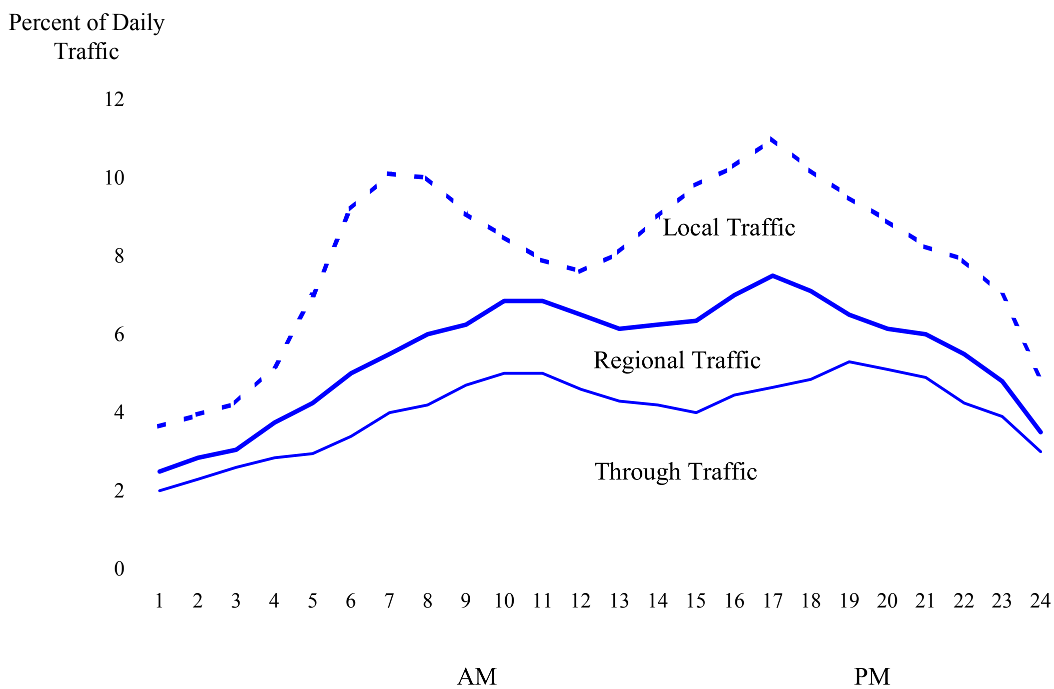
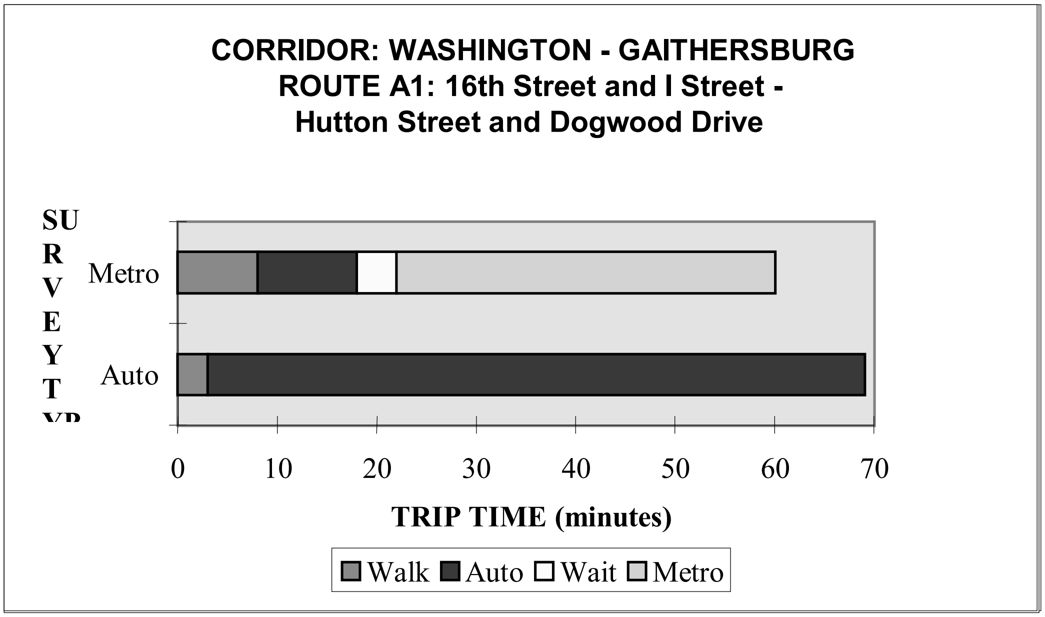
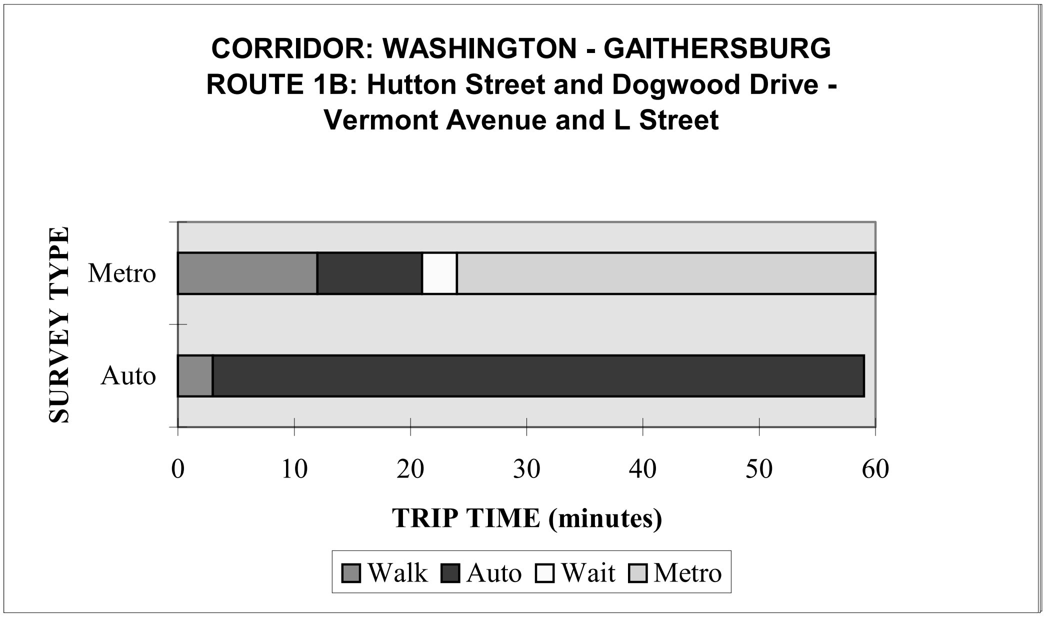


Figure A 1.4 Typical Traffic by Time of Day on a Major Roadway in the I-270 Region

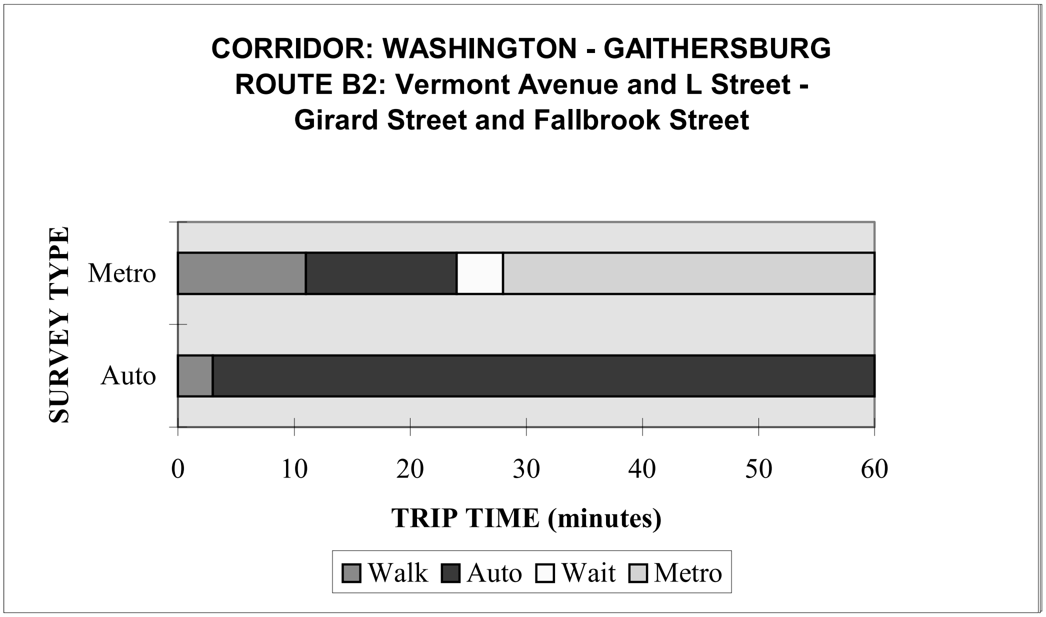
Annex A 1.2 The 1998 survey findings by route in the I-270 corridor.



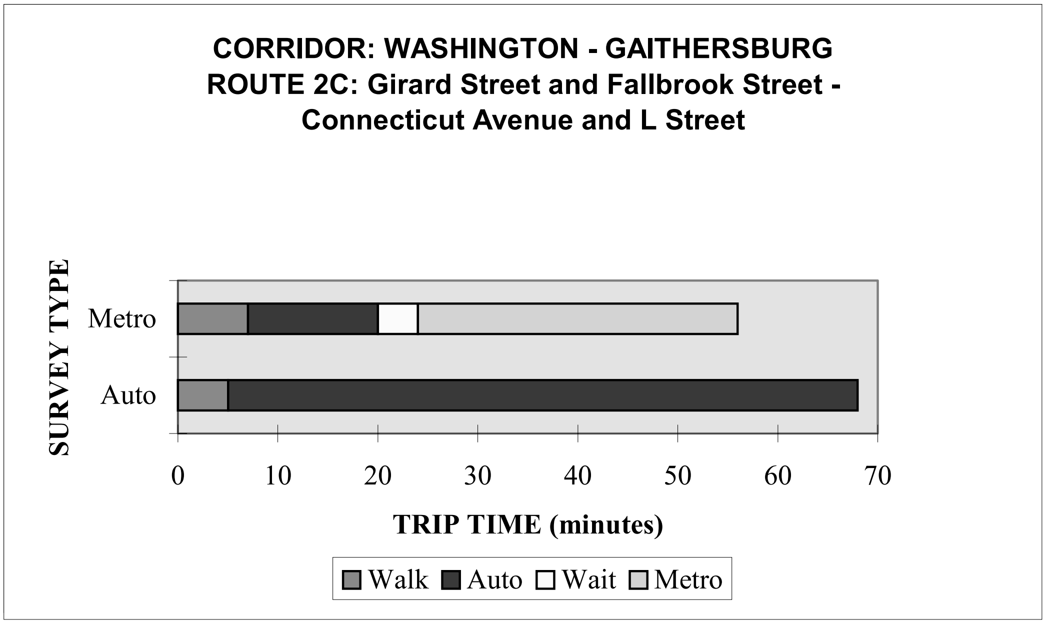
CORRIDOR: WASHINGTON - GAITHERSBURG SUMMARY TABLE FOR ROUTE A1: 16th Street and I Street - Hutton Street and Dogwood Drive		
	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	69	60
In Common Segment	41	38
Outside Common Segment	28	22
Wait Time	0	4
Walk Time	3	8
DISTANCE (miles)		
Direct Distance	19.2	19.2
Route Distance	28.6	23.6
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	24.9	23.6
In Common Segment	35.6	32.2
Outside Common Segment	9.2	8.7



CORRIDOR: WASHINGTON - GAITHERSBURG SUMMARY TABLE FOR ROUTE 1B: Hutton Street and Dogwood Drive - Vermont Avenue and L Street		
	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	59	60
In Common Segment	30	36
Outside Common Segment	29	24
Wait Time	0	3
Walk Time	3	12
DISTANCE (miles)		
Direct Distance	18.8	18.8
Route Distance	28.6	23.8
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	29.1	23.8
In Common Segment	48.6	34.0
Outside Common Segment	8.9	8.5

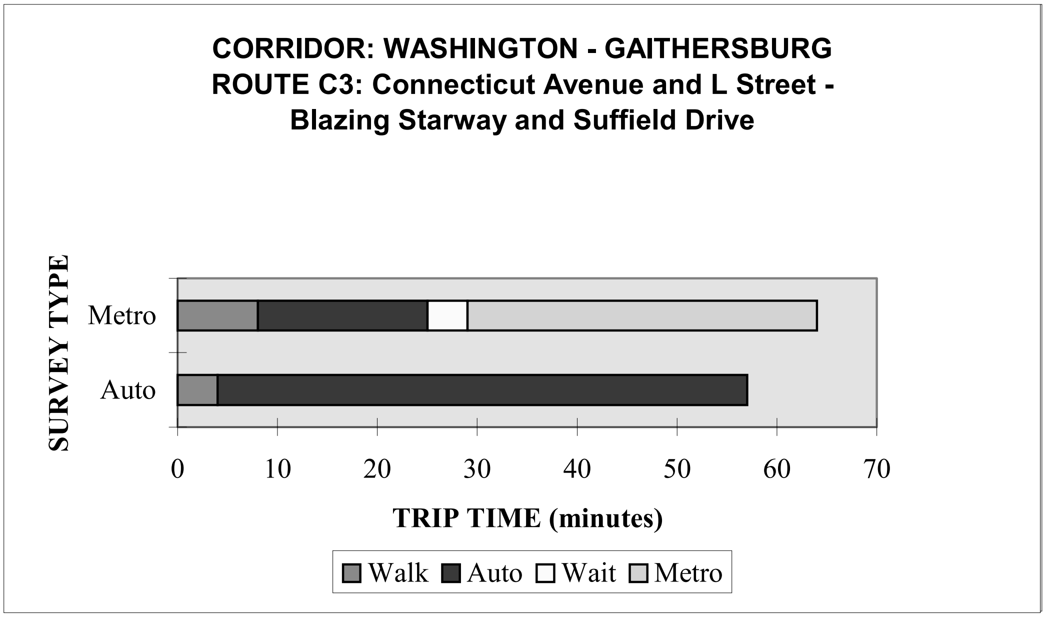


CORRIDOR: WASHINGTON - GAITHERSBURG SUMMARY TABLE FOR ROUTE B2: Vermont Avenue and L Street - Girard Street and Fallbrook Street	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	60	60
In Common Segment	35	32
Outside Common Segment	25	28
Wait Time	0	4
Walk Time	3	11
DISTANCE (miles)		
Direct Distance	19.0	19.0
Route Distance	28.6	24.4
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	28.6	24.4
In Common Segment	41.7	38.3
Outside Common Segment	10.3	8.6

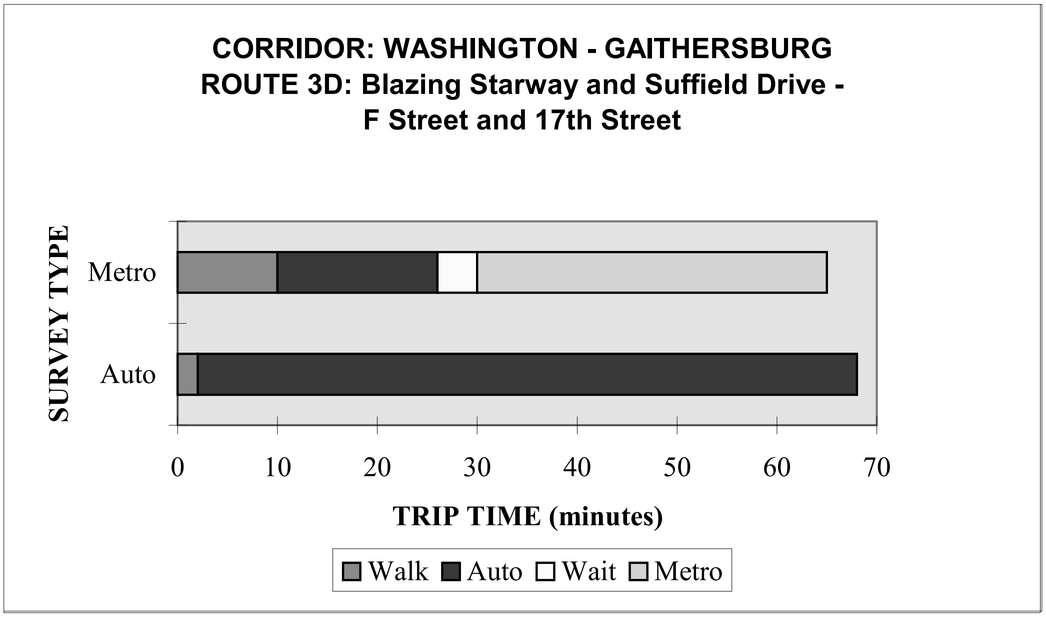


CORRIDOR: WASHINGTON - GAITHERSBURG
SUMMARY TABLE FOR
ROUTE 2C:
Girard Street and Fallbrook Street - Connecticut Avenue and L Street

	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	68	56
In Common Segment	49	45
Outside Common Segment	19	11
Wait Time	0	4
Walk Time	5	7
DISTANCE (miles)		
Direct Distance	17.9	17.9
Route Distance	28.2	24.2
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	24.9	25.9
In Common Segment	29.8	27.2
Outside Common Segment	12.3	20.7

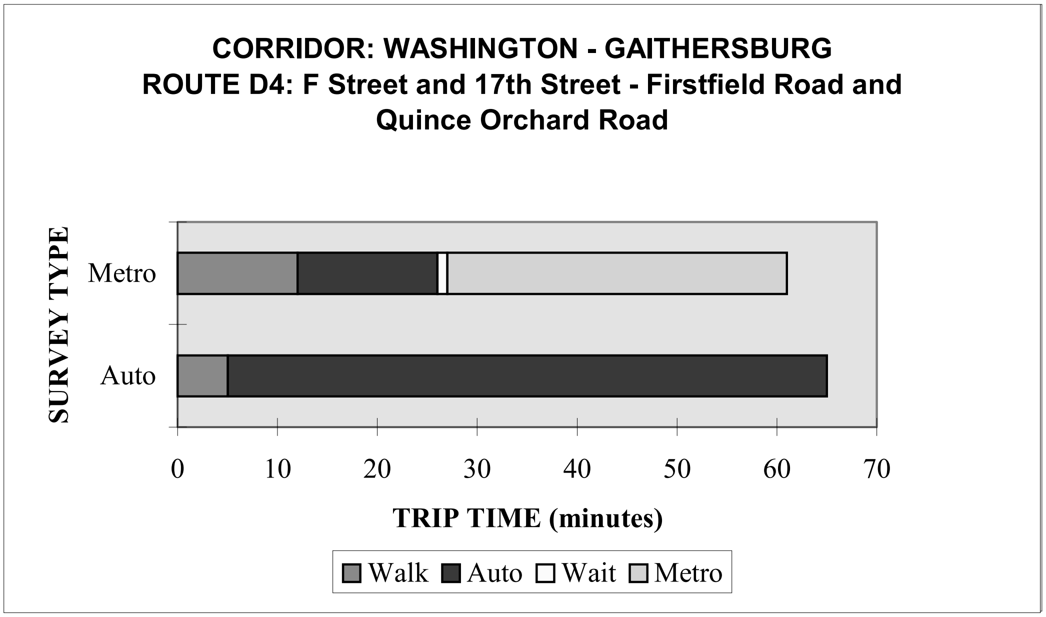


CORRIDOR: WASHINGTON - GAITHERSBURG SUMMARY TABLE FOR ROUTE C3: Connecticut Avenue and L Street - Blazing Starway and Suffield Drive	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	57	64
In Common Segment	35	35
Outside Common Segment	22	29
Wait Time	0	4
Walk Time	4	8
DISTANCE (miles)		
Direct Distance	18.5	18.5
Route Distance	27.6	25.0
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	29.1	23.4
In Common Segment	41.7	35.0
Outside Common Segment	9.0	9.5

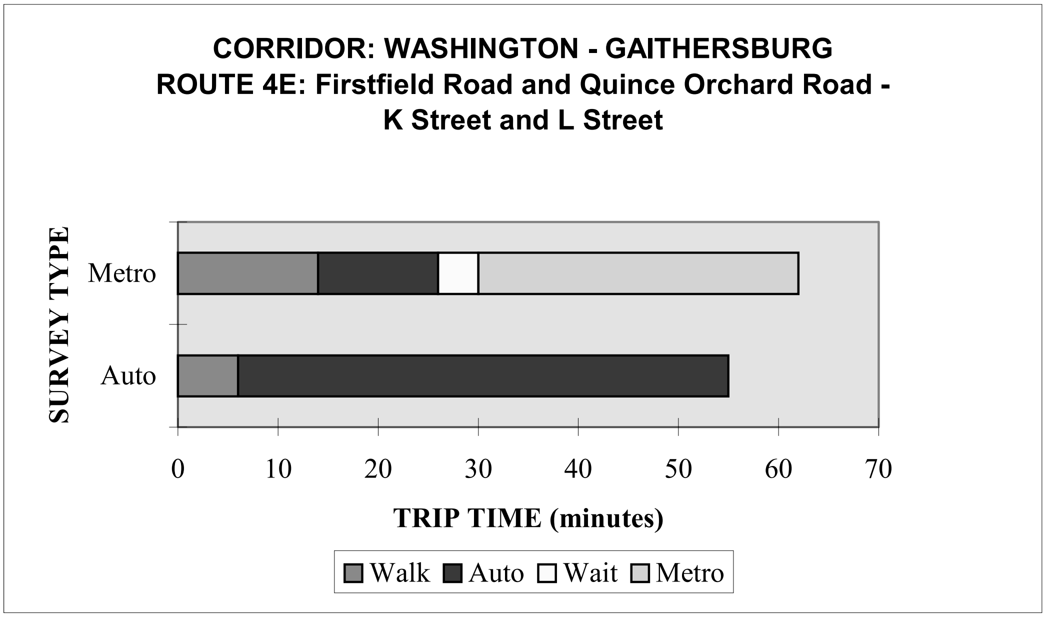


CORRIDOR: WASHINGTON - GAITHERSBURG
SUMMARY TABLE FOR
ROUTE 3D:
Blazing Starway and Suffield Drive - F Street and 17th Street

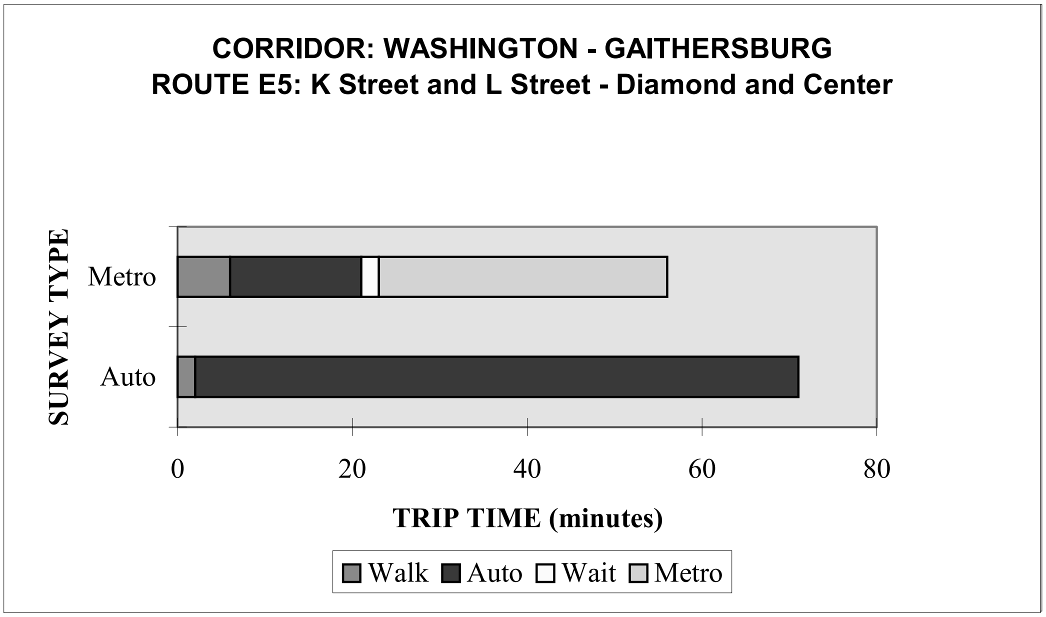
	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	68	65
In Common Segment	48	35
Outside Common Segment	20	30
Wait Time	0	4
Walk Time	2	10
DISTANCE (miles)		
Direct Distance	18.0	18.0
Route Distance	27.7	25.2
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	24.4	23.3
In Common Segment	30.4	35.0
Outside Common Segment	10.2	9.6



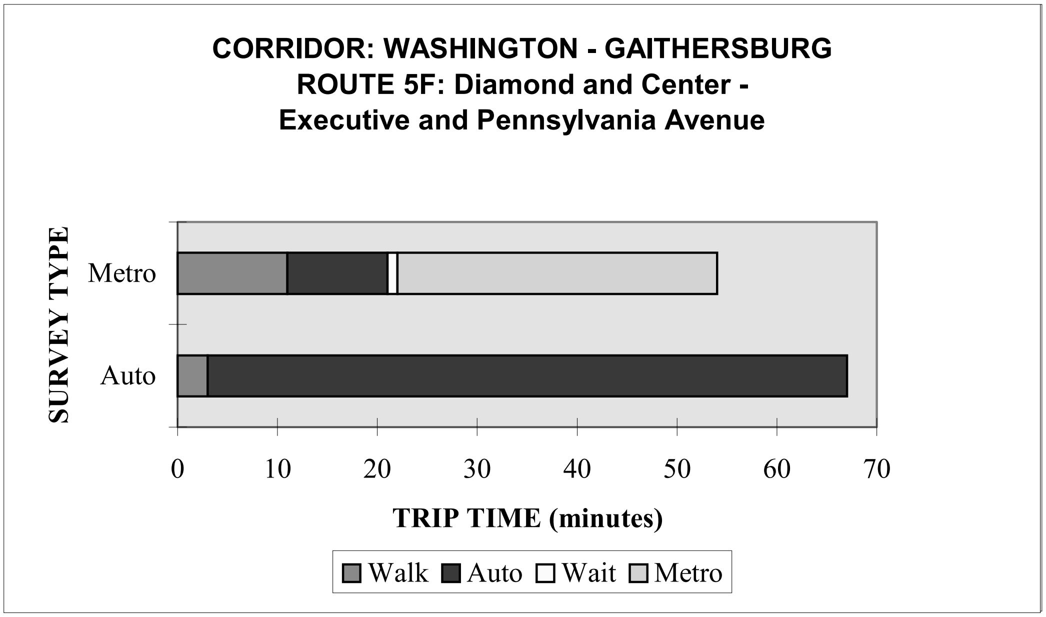
CORRIDOR: WASHINGTON - GAITHERSBURG SUMMARY TABLE FOR ROUTE D4: F Street and 17th Street - Firstfield Road and Quince Orchard Road		
	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	65	61
In Common Segment	34	34
Outside Common Segment	31	27
Wait Time	0	1
Walk Time	5	12
DISTANCE (miles)		
Direct Distance	17.8	17.8
Route Distance	28.9	26.2
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	26.7	25.8
In Common Segment	42.9	36.0
Outside Common Segment	8.9	12.9



CORRIDOR: WASHINGTON - GAITHERSBURG SUMMARY TABLE FOR ROUTE 4E: Firstfield Road and Quince Orchard Road - K Street and L Street	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	55	62
In Common Segment	39	32
Outside Common Segment	16	30
Wait Time	0	4
Walk Time	6	14
DISTANCE (miles)		
Direct Distance	18.1	18.1
Route Distance	29.5	26.1
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	32.2	25.3
In Common Segment	37.4	38.3
Outside Common Segment	19.5	11.4

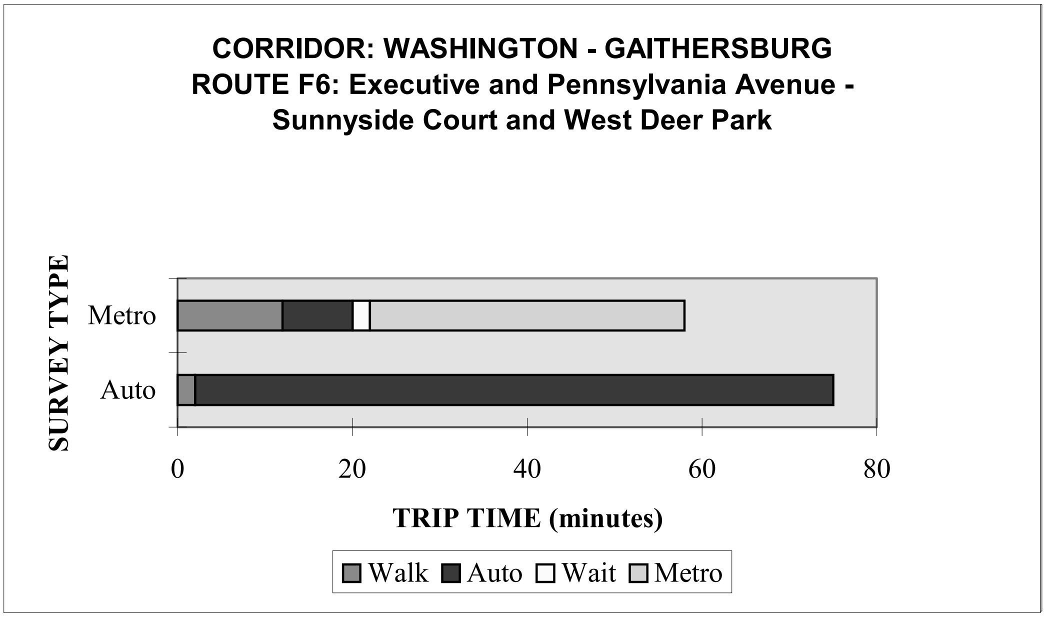


CORRIDOR: WASHINGTON - GAITHERSBURG SUMMARY TABLE FOR ROUTE E5: K Street and L Street - Diamond and Center	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	71	56
In Common Segment	53	33
Outside Common Segment	18	23
Wait Time	0	2
Walk Time	2	6
DISTANCE (miles)		
Direct Distance	18.3	18.3
Route Distance	28.8	23.6
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	24.3	25.3
In Common Segment	27.5	37.1
Outside Common Segment	15.0	8.3



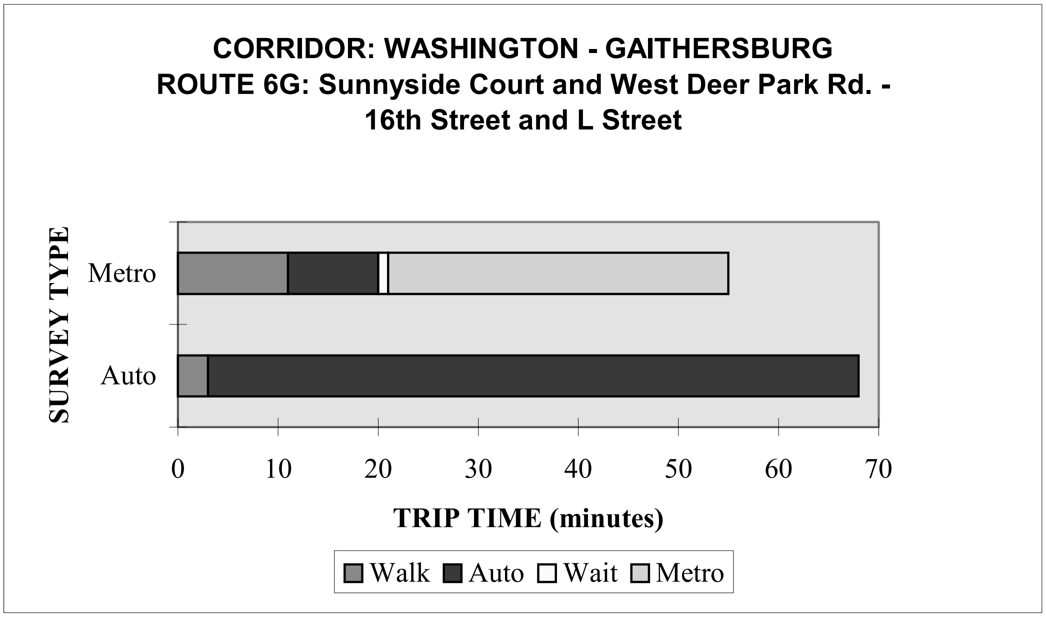
CORRIDOR: WASHINGTON - GAITHERSBURG
SUMMARY TABLE FOR
ROUTE 5F:
Diamond and Center - Executive and Pennsylvania Avenue

	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	67	54
In Common Segment	50	32
Outside Common Segment	17	22
Wait Time	0	1
Walk Time	3	11
DISTANCE (miles)		
Direct Distance	18.9	18.9
Route Distance	28.6	24.0
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	25.6	26.7
In Common Segment	29.2	38.3
Outside Common Segment	15.2	9.8



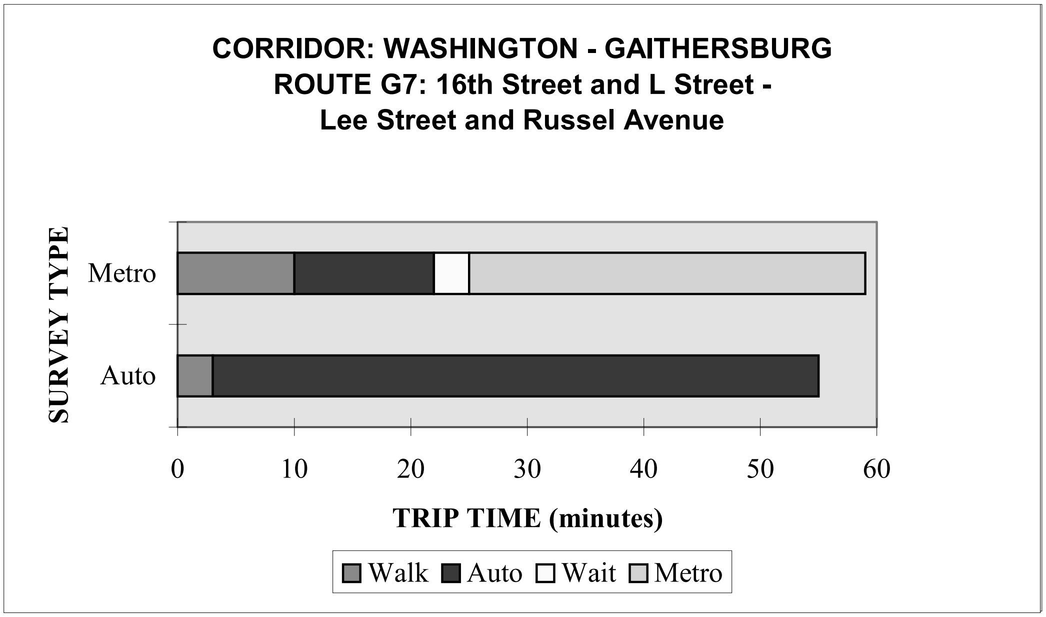
CORRIDOR: WASHINGTON - GAITHERSBURG
SUMMARY TABLE FOR
ROUTE F6:
Executive and Pennsylvania Avenue - Sunnyside Court and West Deer Park Rd.

	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	75	58
In Common Segment	60	36
Outside Common Segment	15	22
Wait Time	0	2
Walk Time	2	12
DISTANCE (miles)		
Direct Distance	18.5	18.5
Route Distance	28.6	22.9
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	22.9	23.7
In Common Segment	24.3	34.0
Outside Common Segment	17.2	6.8

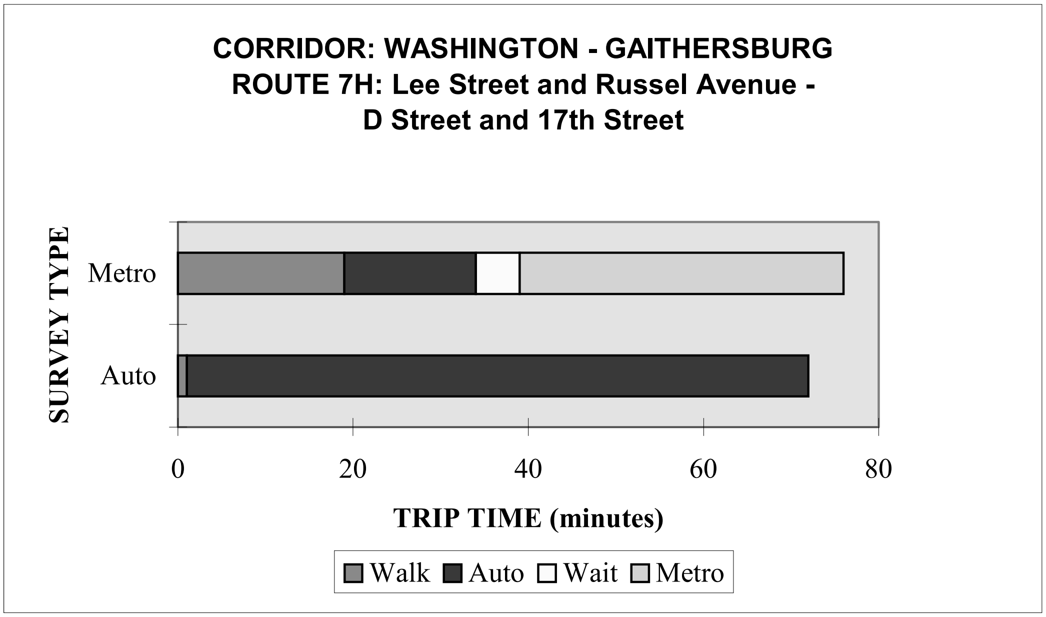


CORRIDOR: WASHINGTON - GAITHERSBURG
SUMMARY TABLE FOR
ROUTE 6G:
Sunnyside Court and West Deer Park Rd. - 16th Street and L Street

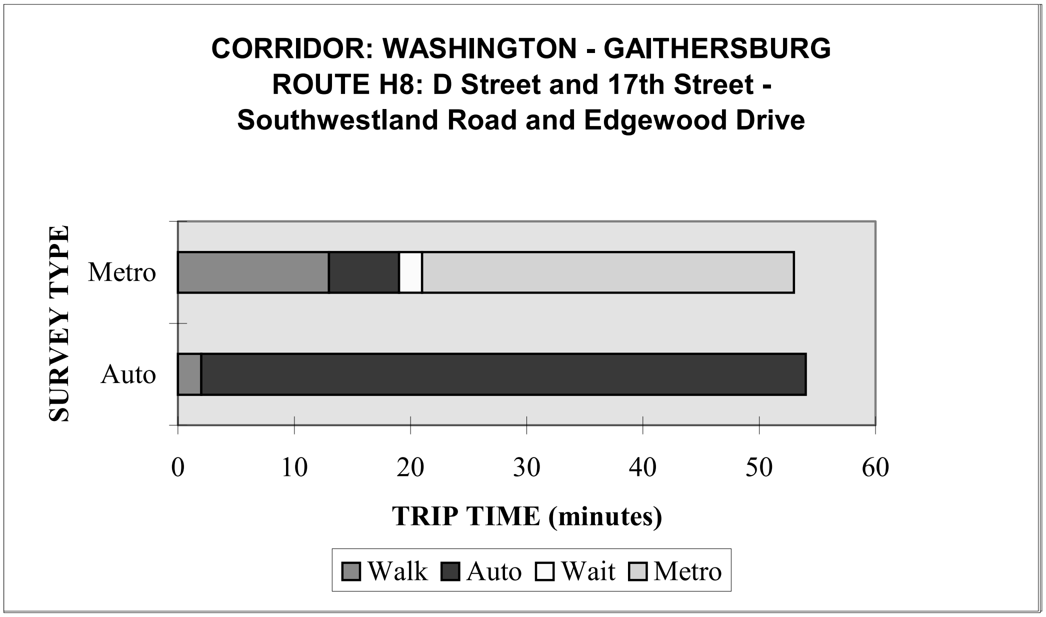
	SURVEY TYPE	
	Auto	Metro
TIME (minutes)		
Trip	68	55
In Common Segment	51	34
Outside Common Segment	17	21
Wait Time	0	1
Walk Time	3	11
DISTANCE (miles)		
Direct Distance	19.0	19.0
Route Distance	28.1	23.0
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	24.8	25.1
In Common Segment	28.6	36.0
Outside Common Segment	13.4	7.4



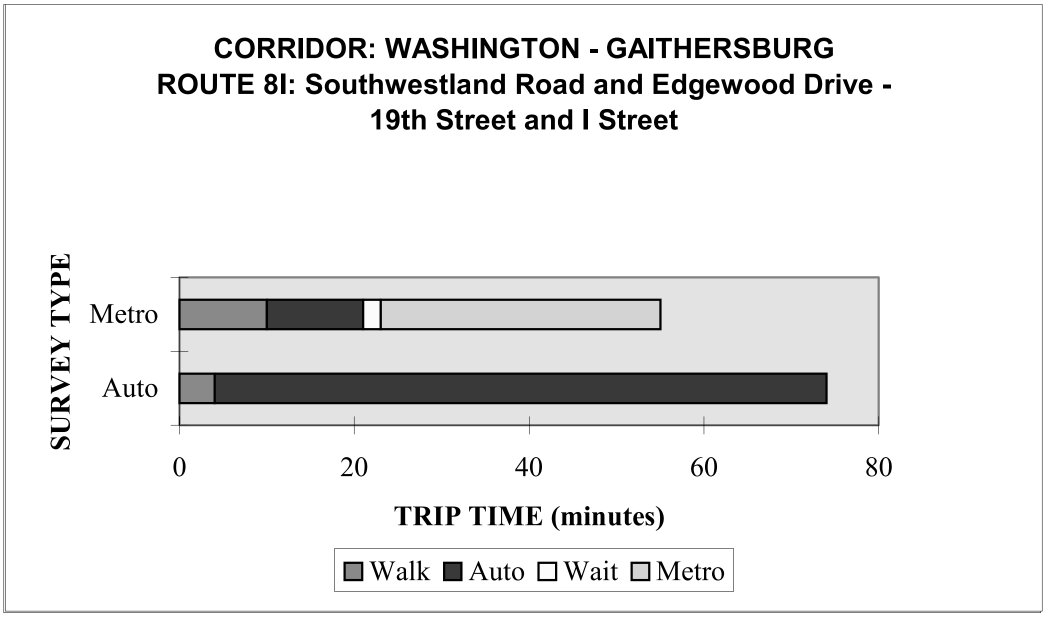
CORRIDOR: WASHINGTON - GAITHERSBURG SUMMARY TABLE FOR ROUTE G7: 16th Street and L Street - Lee Street and Russel Avenue	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	55	59
In Common Segment	36	34
Outside Common Segment	19	25
Wait Time	0	3
Walk Time	3	10
DISTANCE (miles)		
Direct Distance	19.1	19.1
Route Distance	28.7	24.2
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	31.3	24.6
In Common Segment	40.5	36.0
Outside Common Segment	13.9	9.1



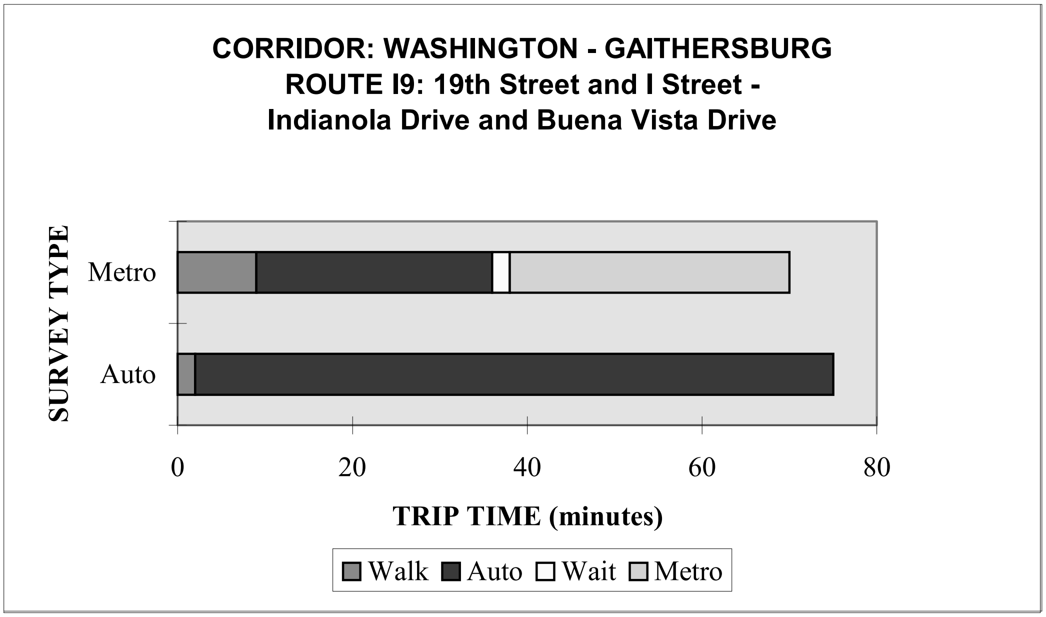
CORRIDOR: WASHINGTON - GAITHERSBURG SUMMARY TABLE FOR ROUTE 7H: Lee Street and Russel Avenue - D Street and 17th Street	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	72	76
In Common Segment	52	37
Outside Common Segment	20	39
Wait Time	0	5
Walk Time	1	19
DISTANCE (miles)		
Direct Distance	18.6	18.6
Route Distance	28.4	24.4
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	23.7	19.3
In Common Segment	28.0	33.1
Outside Common Segment	12.3	6.2



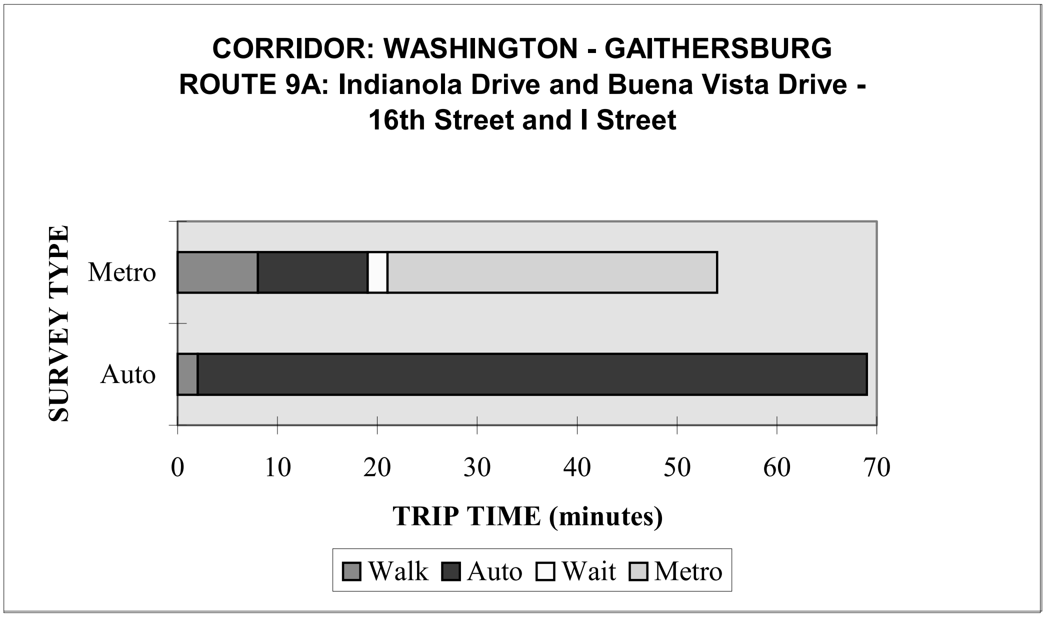
CORRIDOR: WASHINGTON - GAITHERSBURG SUMMARY TABLE FOR ROUTE H8: D Street and 17th Street - Southwestland Road and Edgewood Drive	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	54	53
In Common Segment	33	32
Outside Common Segment	21	21
Wait Time	0	2
Walk Time	2	13
DISTANCE (miles)		
Direct Distance	19.1	19.1
Route Distance	26.9	22.7
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	29.9	25.7
In Common Segment	44.2	38.3
Outside Common Segment	7.4	6.6



CORRIDOR: WASHINGTON - GAITHERSBURG SUMMARY TABLE FOR ROUTE 8I: Southwestland Road and Edgewood Drive - 19th Street and I Street		
	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	74	55
In Common Segment	50	32
Outside Common Segment	24	23
Wait Time	0	2
Walk Time	4	10
DISTANCE (miles)		
Direct Distance	18.3	18.3
Route Distance	26.5	22.6
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	21.5	24.7
In Common Segment	29.2	38.3
Outside Common Segment	5.5	5.7



CORRIDOR: WASHINGTON - GAITHERSBURG SUMMARY TABLE FOR ROUTE I9: 19th Street and I Street - Indianola Drive and Buena Vista Drive		
	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	75	70
In Common Segment	40	59
Outside Common Segment	35	11
Wait Time	0	2
Walk Time	2	9
DISTANCE (miles)		
Direct Distance	18.0	18.0
Route Distance	27.1	21.5
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	21.7	18.4
In Common Segment	36.5	20.7
Outside Common Segment	4.8	6.0



CORRIDOR: WASHINGTON - GAITHERSBURG
SUMMARY TABLE FOR
ROUTE 9A:
Indianola Drive and Buena Vista Drive - 16th Street and I Street

	SURVEY TYPE	
TIME (minutes)	Auto	Metro
Trip	69	54
In Common Segment	45	33
Outside Common Segment	24	21
Wait Time	0	2
Walk Time	2	8
DISTANCE (miles)		
Direct Distance	18.5	18.5
Route Distance	27.7	21.4
Common Segment Distance	24.3	20.4
SPEED (mph)		
Trip	24.1	23.8
In Common Segment	32.4	37.1
Outside Common Segment	8.5	2.9