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STATE HIGHWAY ADMINISTRATION

RESEARCH REPORT

CONCURRENT FLOW LANES – PHASE III

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16. Abstract This report describes efforts taken to develop and calibrate VISSIM models of existing concurrent flow lane designs along I-270 and portions of I-495. It also presents details of VISSIM models developed to replicate a proposed design alternative involving electronic toll lanes along a portion of I-270, as well as analysis of the alternative.		
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EXECUTIVE SUMMARY

This report describes efforts taken to develop and calibrate VISSIM models of existing concurrent flow lane designs of north- and southbound lanes of I-270 from the interchange at I-70 to interchanges on I-495 at Connecticut Avenue in Maryland and Georgetown Pike in Virginia. The report describes the data employed within the modeling and calibration efforts, including the input data and the data used for calibration. Efforts taken to calibrate and evaluate the existing conditions models are presented. The models were calibrated against surveyed segment travel times and evaluated against main lane volumes and segment densities. Results of the calibration and post-calibration evaluation confirm VISSIM's ability to replicate real-world traffic operations along freeways with concurrent flow lanes.

The study also evaluated the potential benefits of a proposed ETL managed lane facility design for forecast year 2030 along the I-270 freeway between interchanges at I-370 and I-70. The report describes VISSIM models that were developed to replicate this segment in both south- and northbound directions for a total of 46 miles. Parameters identified in the calibration effort were adopted in running the alternative models. Traffic performance in terms of average travel time, total travel delay, emissions and fuel consumption under the proposed managed lane design was evaluated and compared with that of the existing facility design given 2010 and predicted 2030 traffic demand levels. Simulation run results predict that traffic performance in terms of the studied measures will significantly degrade under 2030 demand estimates given no facility upgrade. Construction of ETLs is expected to lead to improved roadway performance in terms of the same metrics in the southbound direction. In the northbound direction, however, such improvements are not predicted. This appears to be due to a likely bottleneck at one of the off-ramps that leads to significantly degraded performance of the GP lanes.

The simulation models developed in this effort provide a platform for considering policy and proposed congestion management programs for addressing both recurrent and non-recurrent congestion in the I-270 corridor. They enable quantification of savings in, for example, travel delay and fuel consumption. Moreover, they provide a platform for quantifying potential revenue that can be gained through the operation of tolled lanes.

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Chapter 1 Introduction

This report describes outcomes and efforts taken in the third phase of a multi-phase project whose ultimate objectives are the development and application of a simulation model for the analysis of concurrent flow lanes.

Phase I of this project sought to develop a comprehensive understanding of the current state-of-the-art in modeling and analysis of non−barrier separated electronic/high occupancy toll (HOT) lane and other concurrent flow lane operations as reported in (Miller-Hooks et al., 2008). As part of the initial effort, information was gathered through interviews conducted with project managers of existing and proposed HOT lane facilities, modelers and other domain experts and review of related reports and literature. Details of models employed, and analytical tools used, to evaluate the impact of proposed HOT lanes on traffic operations and potential revenue; supplemental analysis tools; lane configurations; tolling strategies; High Occupancy Vehicle (HOV) restrictions; types of separation; how weaving is addressed; and design alternatives for ingress and egress between the HOT and general purpose lanes were provided. Knowledge pertaining to model calibration and validation was gleaned from the interview and literature review processes. Potential data sources for calibrating developed models were also identified. Finally, a proof-of-concept was developed to illustrate how details associated with violation modeling can be handled in the selected modeling framework, the VISSIM simulation platform, which was proposed for use in this and additional subsequent phases of this research effort. The VISSIM micro-simulation platform was chosen over other traffic simulators, because this platform had been successfully employed in modeling the impact of proposed HOT lane facilities on traffic operations in several studies conducted across the country as described in (Miller-Hooks et al., 2008). While nearly all of these models treated the HOT lane facility as a separate link, effectively modeling a barrier separated facility, preliminary work within the platform indicated that this platform could also be successfully used to model non-barrier separated facilities.

The primary purpose of phase II of this research effort was to ascertain whether or not the chosen simulation software platform, the VISSIM simulation platform, and modeling methodologies provide a suitable framework for modeling and analyzing traffic operations, including the specific details associated with modeling concurrent flow lanes with designated access points, along significant portions of the Maryland freeways. While the intended use of these lanes is for non-intrusive (barrierless) tolling, the model is also useful for studying the performance of HOV lane operations. Phase II culminated in a fully calibrated simulation model and supporting modeling techniques necessary to replicate vehicular behavior in the presence of both continuous access HOV lanes and limited access managed lane facilities. The modeling techniques were applied to the southbound lanes of a 7-mile segment of I-270 within the State of Maryland (between the interchanges with I-370 and the I-270 Spurs). Results of runs of the developed and calibrated existing conditions simulation model show, through a comparison of mean travel times by roadway segment, that the chosen VISSIM simulation platform using developed modeling techniques is a suitable tool for modeling the I-270 roadway segment with concurrent flow lane operations. In fact, once calibrated, no significant statistical difference was found between mean segment travel times produced by the simulation and those recorded in a traffic study on the actual roadway facility for all segments of the study area. Given this ability to match real-world operations using one set of parameters for multiple segments, it was anticipated that the results of the calibration and general modeling techniques would be directly useful in this additional phase of simulation-based development involving a more extensive portion of the I-270 corridor. Results from the second phase of this effort also indicate that proposed managed lane alternative designs in the area of the 7-mile study roadway segment have significant potential for improving roadway performance even given increased traffic demand in future years. Moreover, the model was able to identify possible limitations in access design.

In this third phase of the study, modeling techniques and results from the prior calibration effort conducted in Phase II have been exploited in developing simulation models of existing concurrent flow lane designs of north- and southbound lanes of I-270 from the interchange at I-70 to interchanges on I-495 at Connecticut Avenue in Maryland and Georgetown Pike in Virginia. Each model replicating a direction (either southbound or northbound) involves 41 miles of roadway length. The study area is depicted in Figure 1-1. Morning peak hours (6:00 a.m. to 9:00 a.m.) were replicated for the southbound direction and evening peak hours (3:00 p.m. to 7:00 p.m.) were replicated for the northbound direction. These are referred to as SB-AM and NB-PM, respectively, throughout. Findings from simulating the existing network, including the modeling techniques and parameters chosen, were applied to construct a proposed managed lane design of I-270 from I-70 to I-370 interchanges.

The simulation models developed in this effort provide a platform for considering policy and proposed congestion management programs for addressing both recurrent and non-recurrent congestion. They enable quantification of savings in, for example, travel delay and fuel consumption. Moreover, they provide a platform for quantifying potential revenue that can be gained through the operation of tolled lanes.

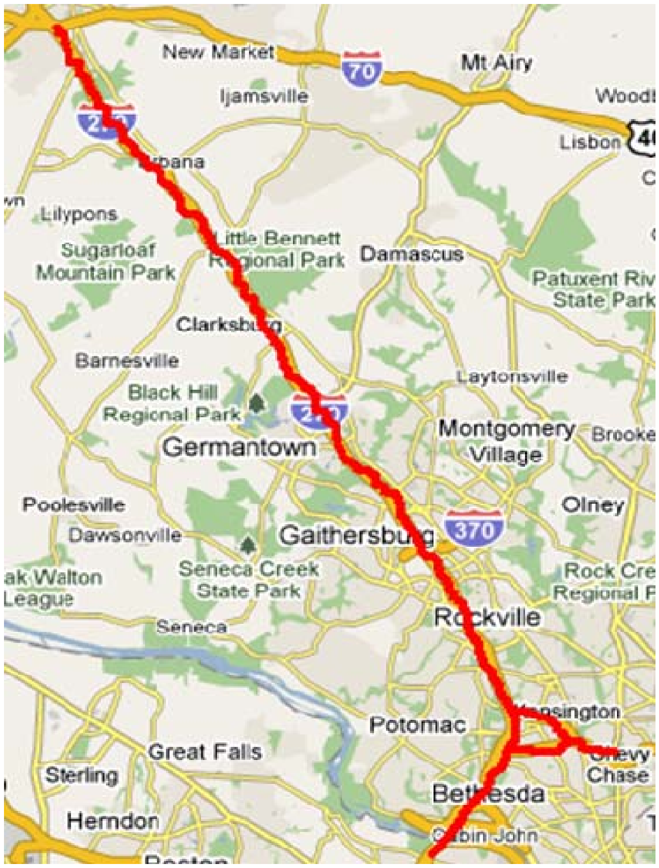


Figure 1-1. Study Area: SB-AM Lanes of I-270 from I-70 to the Spur

Chapter 2 describes the data employed within the modeling and calibration efforts including the input data and the data used for calibration. The developed simulation models for the existing concurrent flow lane design, efforts taken to calibrate the existing conditions models, and results and findings from the assessment of the calibration effort are given in Chapter 3. Details of the proposed design alternative and its evaluation are provided in Chapter 4. In Chapter 5, findings from the study are synthesized.

Chapter 2 Data Collection and Analysis

Input data related to roadway geometry, traffic volume, vehicle composition, and vehicle occupancy are required for the development of the existing conditions and proposed alternative VISSIM models of the study area. Data pertaining to travel time, traffic volume, and segment density are needed for the calibration of the existing conditions model. Details associated with the preparation of these required input and calibration data are given in this section.

2.1 Input Data

2.1.1 Roadway Geometry

Geometry of the study roadway area, including characteristics of the interchanges, and general purpose (GP), HOV and collector-distributor (CD) lanes, were extracted from maps through GoogleMaps. A scale of 1:100 meters was employed for this purpose. The study roadway includes 26 interchanges connecting I-270 and local roads. Roads from which the on- and off-ramps connected to the I-270 are listed in Table 2-1 from north to south. The distance from I-70 to the Spur is 29.9 miles, from the start of the Northern Spur to the Connecticut Avenue exit on I-495 is 4.4 miles, from the start of the Southern Spur to the Georgetown Pike exit of I-495 is 6.8 miles.

The existing facility hosts a single HOV lane in both the SB-AM and NB-PM directions as depicted in Figure 2-1. For the SB-AM direction, the HOV lane starts approximately 0.7 miles north of I-370 and reaches to approximately 0.8 miles south of MD 187 within the northern Spur and 0.6 miles south of Democracy Boulevard within the southern Spur. In the NB-PM direction, the HOV lane emanates from approximately one mile north of MD 190 (River Road) and runs the entirety of I-270 north to 1.5 miles south of MD 121.

CD lanes are barrier separated from the GP lanes and exist at both directions of I-270 from the Spur as shown in the figure. In the southbound direction, the CD lanes start after I-370 and runs through approximately 1 mile prior to reaching the Spur. In the northbound direction, the CD lanes start at 0.5 miles before Montrose Road and run north to MD 117.

Table 2-1. Connection Information of I-270 Study Area

NO.	Local Road Name	SB-AM		NB-PM	
		On-Ramp	Off-Ramp	On-Ramp	Off-Ramp
1	I-70	2	0	0	1
2	Buckeystown Pike (MD 85)	2	2	2	2
3	Fingerbroard Rd (MD 80)	1	1	1	1
4	Old Hundred Rd (MD 109)	1	1	1	1
5	Clarkburg Rd (MD 121)	1	1	1	1
6	Father Hurley Rd(MD 27)	2	1	2	1
7	Germantown Rd (MD 118)	2	1	1	2
8	Middlebrook Rd	1	0	0	2
9	Montgomery Village Ave (MD 124)	1	1	2	1
10	W. Diamond Ave (MD 117)	1	0	0	1
11	I-370	1	1	1	2
12	Shady Grove Rd	2	1	2	1
13	W Montgomery Ave (MD 28)	2	1	2	2
14	Falls Rd (MD 189)	1	1	1	1
15	Montrose Rd	2	2	2	2
I-270 Spur					
Western					
16	Democracy Blvd	1	1	2	1
17	Beltway 495	1	0	0	1
18	MD 190 (River Road)	1	2	2	1
19	Cabin John Pkwy	1	0	1	0
20	Clara Barton Pkwy	1	1	2	0
21	George Washington Pkwy	1	1	1	1
22	Georgetown Pike (VA-193)	1	1	1	1
Eastern					
23	Old Georgetown Rd (MD 187)	1	1	1	1
24	Beltway 495	1	1	1	1
25	Rockville Pike (MD 355)	2	1	1	1
26	Connecticut Ave (MD 185)	1	1	1	0

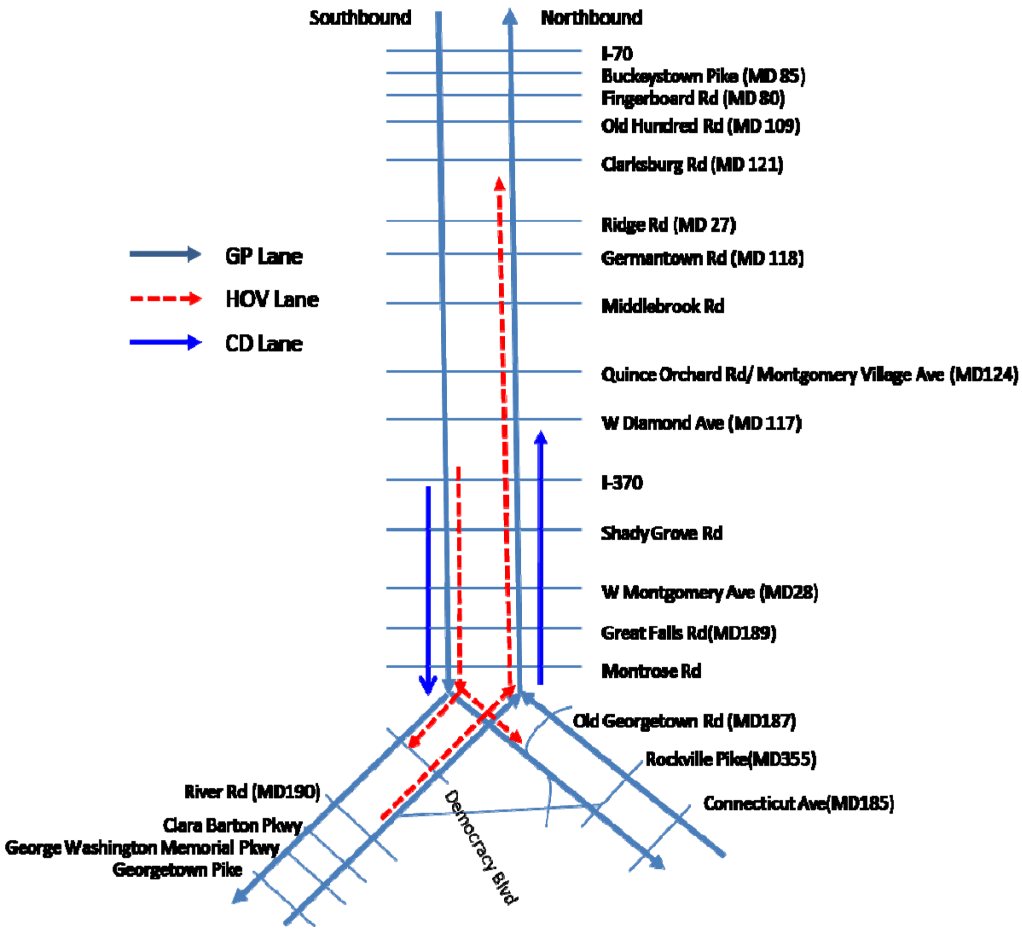
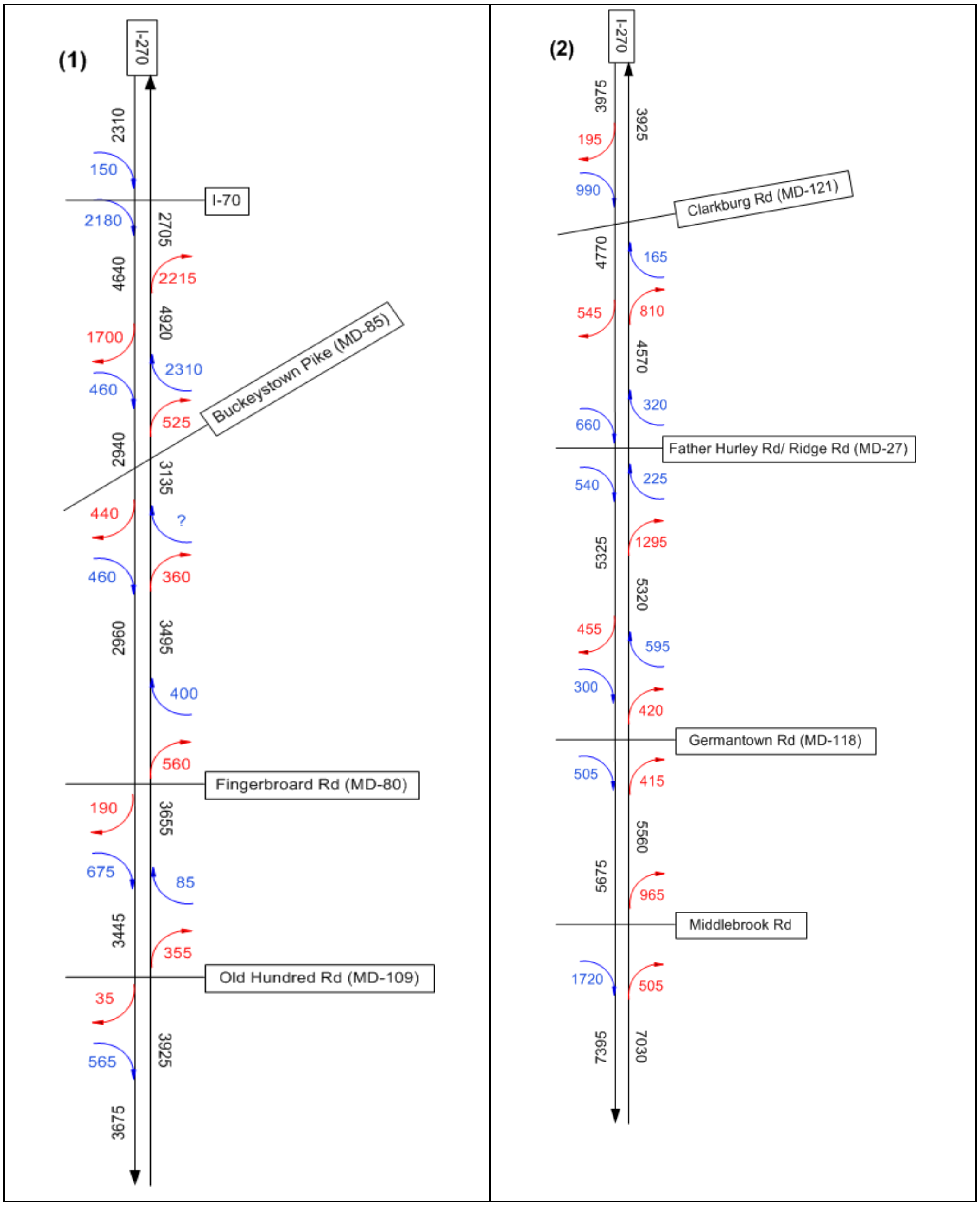


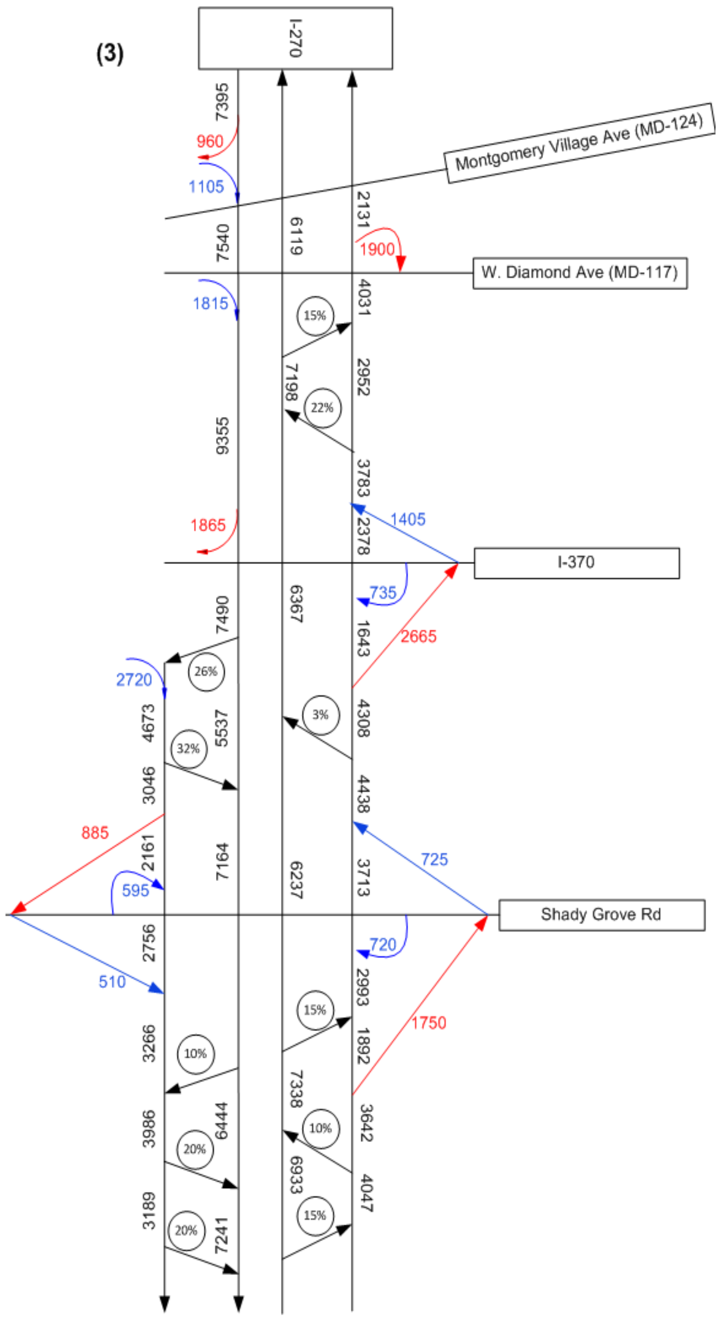
Figure 2-1. Lane Type Configurations along I-270 and Connecting 495 Beltway

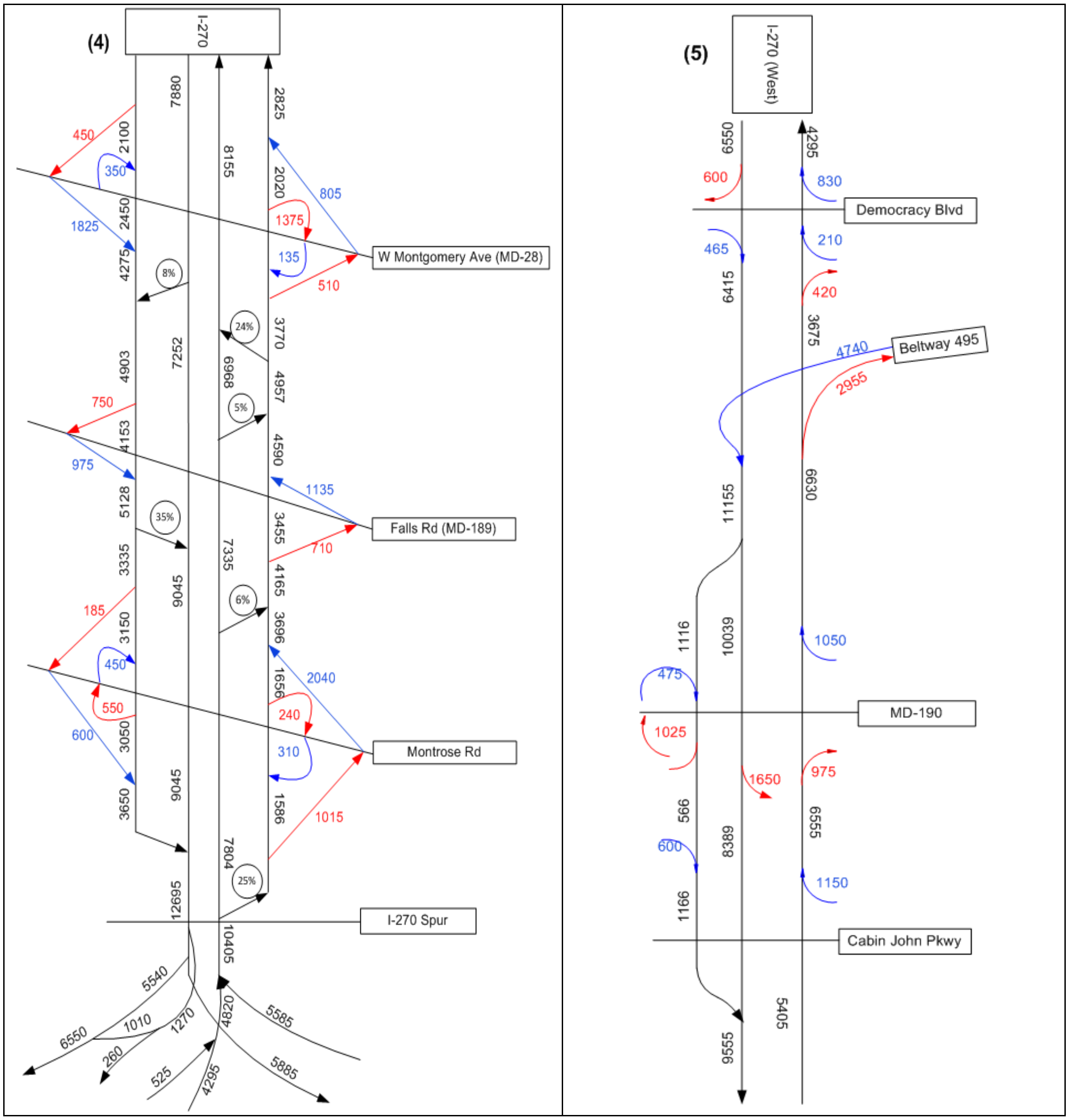
2.1.2 Input Volume and Turning Proportion

The input volume for the existing conditions model was obtained from 2010 Existing ADT Volumes and Western Mobility Study 2005 Volumes provided by the Maryland State Highway Administration (SHA). The turning proportion data was obtained from the "GP, CD, Slip Ramp Distributions" file provided by SHA. Volume wiring diagrams were drawn to depict the provided data as given in the Figure 2-2.


(1)
I-270
2310
150
I-70
2180
2705
4640
2215
4920
1700
2310
Buckeystown Pike (MD-85)
460
525
2940
3135
440
?
460
360
2960
3495
400
560
Fingerbroard Rd (MD-80)
190
3655
675
85
3445
355
Old Hundred Rd (MD-109)
35
565
3925
3675
(2)
I-270
3975
3925
195
990
Clarkburg Rd (MD-121)
4770
165
545
810
4570
320
660
Father Hurley Rd/ Ridge Rd (MD-27)
540
225
5325
1295
5320
455
595
300
420
Germantown Rd (MD-118)
505
415
5560
5675
965
Middlebrook Rd
1720
505
7395
7030

(3)


I-270
Montgomery Village Ave (MD-124)
W. Diamond Ave (MD-117)
I-370
Shady Grove Rd
7395
960
1105
7540
6119
2131
1900
1815
4031
15%
7198
2952
22%
9355
3783
1865
2378
1405
735
7490
6367
1643
2665
2720
26%
4673
5537
4308
3%
32%
3046
4438
885
2161
7164
6237
3713
725
595
2756
720
510
2993
15%
1750
3266
10%
1892
7338
3986
6444
20%
10%
3642
6933
3189
20%
7241
15%
4047


(4)
I-270
W Montgomery Ave (MD-28)
Falls Rd (MD-189)
Montrose Rd
I-270 Spur
(5)
I-270 (West)
Democracy Blvd
Beltway 495
MD-190
Cabin John Pkwy

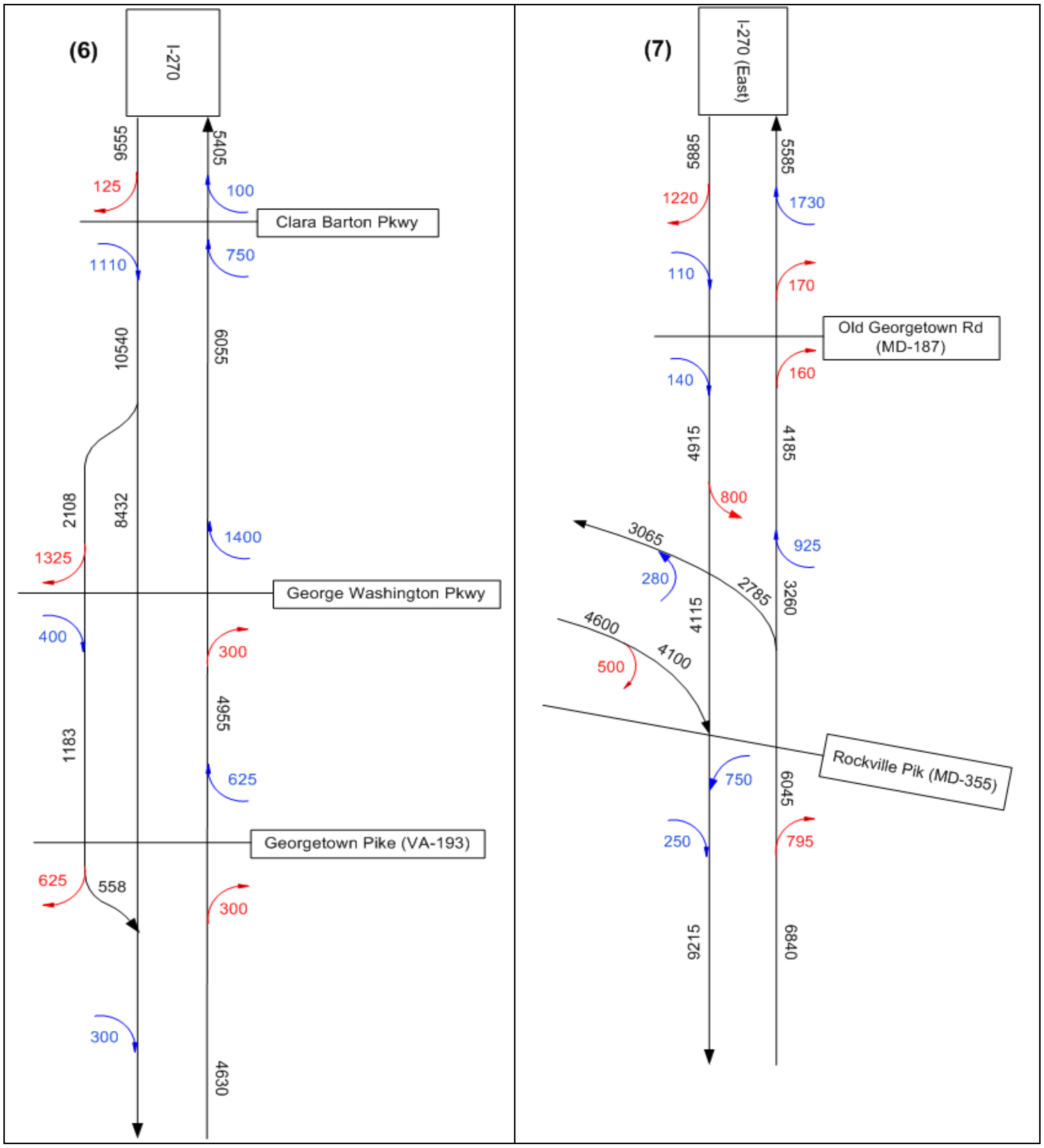


Figure 2-2. Wiring Diagram of Input Volume and Turning Proportion

2.1.3 Vehicle Occupancy and Composition

Vehicle occupancy, i.e. the number of occupants riding in each vehicle, is a significant characteristic in terms of describing a vehicle's type in the context of this managed lane study. A vehicle will be permitted to use the HOV lane in the existing conditions model during the study period only if that vehicle contains two or more occupants.

Average morning peak-hour hourly vehicle occupancy data employed within this study was based on data obtained from the database of Internet Traffic Monitoring System (I-TMS website, accessed in 2010). The occupancy data between 3:00 p.m and 7:00 p.m were used for the NB-PM peak hours, while 6:00 a.m. and 9:00 a.m. occupancy data were used for the SB-AM peak hours. All occupancy data used within the study were collected in 2008. The occupancy data were obtained from six different survey stations. The locations of vehicle occupancy survey stations are provided in Figure 2-3. Classifications employed within the vehicle occupancy data were used in computing traffic composition.

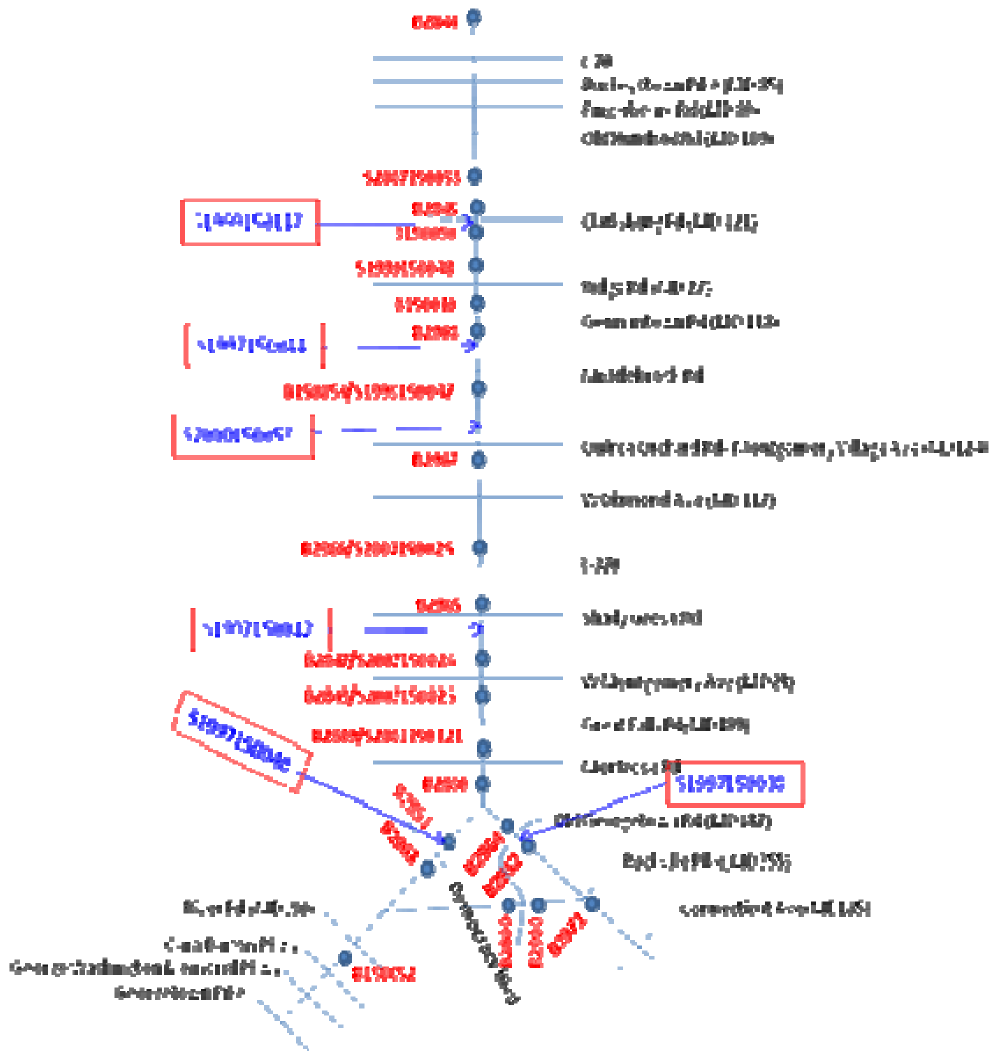


Figure 2-3. Vehicle Occupancy and Composition Survey Station Locations

Vehicles were categorized as one of several types: personal cars with a single occupant (the driver), personal cars with a driver and one or more passengers, buses (assumed to carry 20 passengers), and trucks. Each lane was counted separately and the average per lane hourly occupancies were computed. The relevant average peak-hour number of vehicles per lane per hour by occupancy category is shown in Table 2-2.

Table 2-2. Average Hourly Vehicle Occupancy during Peak Hours in 2008

Lane	Vehicle Type			
	1*	2+**	Buses	Trucks
S1999150147 - IS 270 south of MD 121				
LANE 1 NORTH-GP	1091	43	4	53
LANE 2 NORTH-GP	1451	48	2	34
LANE 3 NORTH-GP	357	539	6	2
LANE 4 SOUTH-GP	1402	253	2	2

Lane	Vehicle Type			
	1*	2+**	Buses	Trucks
LANE 5 SOUTH-GP	1131	79	5	56
LANE 6 SOUTH-GP	1162	116	6	75
S1997150044 - IS 270 SOUTH OF MD 118				
LANE 1 NORTH-GP	469	43	12	8
LANE 2 NORTH-GP	1108	116	2	163
LANE 3 NORTH-GP	1256	39	1	29
LANE 4 NORTH-HOV	257	530	29	26
LANE 5 SOUTH-GP	1383	159	3	3
LANE 6 SOUTH-GP	1269	122	3	93
LANE 7 SOUTH-GP	1372	50	9	101
LANE 8 SOUTH-GP	252	23	4	10
S2000150057 - IS 270 SOUTH OF MIDDLEBROOK RD				
LANE 1 NORTH-GP	197	49	2	4
LANE 2 NORTH-GP	1108	163	4	11
LANE 3 NORTH-GP	977	48	3	47
LANE 4 NORTH-GP	1522	20	1	33
LANE 5 NORTH-HOV	175	650	15	0
LANE 6 SOUTH-GP	1459	35	3	89
LANE 7 SOUTH-GP	1372	42	5	82
LANE 8 SOUTH-GP	931	55	12	35
LANE 9 SOUTH-GP	1218	207	4	6
S1997150042 - IS 270 SOUTH OF SHADY GROVE RD				
LANE 1 NORTH-CD	1001	237	9	45
LANE 2 NORTH-CD	836	157	6	19
LANE 3 NORTH-GP	950	99	5	11
LANE 4 NORTH-GP	1027	113	4	35
LANE 5 NORTH-GP	1060	167	3	54
LANE 6 NORTH-GP	1544	52	2	26
LANE 7 NORTH-HOV	337	677	10	6
LANE 8 SOUTH-HOV	69	802	15	3
LANE 9 SOUTH-GP	1486	27	1	37
LANE 10 SOUTH-GP	1111	51	2	52
LANE 11 SOUTH-GP	1234	84	0	36
LANE 12 SOUTH-CD	1384	130	3	46
LANE 13 SOUTH-CD	1161	115	6	29
S1997150040 IS 270Y NORTH OF DEMOCRACY BLVD				
LANE 1 NORTH-GP	377	9	1	2
LANE 2 NORTH-GP	1284	137	3	48
LANE 3 NORTH-GP	1496	65	1	23
LANE 4 NORTH-HOV	374	614	5	2
LANE 5 SOUTH-HOV	293	344	6	2
LANE 6 SOUTH-GP	2116	88	2	27
LANE 7 SOUTH-GP	1733	41	1	99
LANE 8 SOUTH-GP	628	13	1	19
S1997150038 - IS 270 SOUTH OF MD 187				
LANE 1 NORTH-GP	108	18	1	1
LANE 2 NORTH-GP	829	33	2	22
LANE 3 NORTH-GP	1283	18	2	49
LANE 4 NORTH-HOV	115	501	9	0
LANE 5 SOUTH-HOV	427	406	14	3
LANE 6 SOUTH-GP	1840	18	1	42
LANE 7 SOUTH-GP	926	38	4	71
LANE 8 SOUTH-GP	76	8	4	1

* Passenger cars or vans with occupancy equals to one.

** Passenger cars or vans with occupancy higher than one.

The fraction within each category (i.e. the number of vehicles within each category as a fraction of the total number of vehicles in the roadway segment) is presented in Table 2-3. Note that it was assumed that this fraction is constant over the entire segment.

Table 2-3. Fraction within each Vehicle Occupancy Category in 2008

Location	Direction	Total	1*		2+*		Buses		Trucks	
S1999150147	North	3629	2900	79.91%	629	17.34%	12	0.32%	88	2.43%
	South	4288	3695	86.16%	448	10.46%	12	0.29%	133	3.09%
S1997150044	North	4085	3089	75.62%	727	17.80%	43	1.06%	226	5.52%
	South	4856	4276	88.06%	354	7.29%	19	0.39%	207	4.26%
S2000150057	North	5028	3979	79.13%	930	18.49%	24	0.48%	95	1.89%
	South	5554	4980	89.67%	339	6.10%	24	0.43%	211	3.81%
S1997150042	North	8485	6753	79.58%	1500	17.68%	39	0.45%	194	2.29%
	South	7884	6445	81.75%	1209	15.33%	28	0.36%	202	2.56%
S1997150040	North	4438	3531	79.55%	824	18.56%	9	0.20%	75	1.69%
	South	5411	4769	88.14%	486	8.98%	10	0.18%	147	2.71%
S1997150038	North	2989	2335	78.12%	569	19.03%	14	0.48%	71	2.38%
	South	3878	3268	84.29%	470	12.12%	23	0.60%	116	2.99%

* Passenger cars or vans with occupancy of one.

** Passenger cars or vans with occupancy higher than one.

Additional survey data (provided by SHA) obtained from 23 survey stations shown in Table 2-4 were available for use in this study. The location of survey stations are shown in Figure 2-3. Traffic counts by vehicle class were recorded at one hour intervals. The following classes were considered.

Class 1 – Motorcycles (MC);
Class 2 – Passenger Cars;
Class 3 – Light Trucks;
Class 4 – Buses;
Classes 5-9 – Single-Trailer Trucks; and
Classes 10-13 – Multi-Trailer Trucks.

The fraction of vehicles falling within each category was obtained by dividing the number of vehicles of a given class by the total number of vehicles counted. For consistency with other sources of input data, all were taken from 2009. Table 2-4 shows the average vehicle composition fractions computed from this second data source for each station.

Table 2-4. Vehicle Composition in 2009

Station*	Location	Direction	Car**	Bus	Truck***
B2844	I-270-.10 MI S OF FREDERICK CO/L	NB-PM	89.69%	0.86%	9.45%
		SB-AM	93.15%	0.55%	6.30%
S2007150053	I-270 between MD 121 & MD 109	NB-PM	92.19%	0.86%	6.95%
		SB-AM	95.89%	0.48%	3.62%
B2845	IS270-.50 MI N OF MD 121	NB-PM	90.23%	0.92%	8.85%
		SB-AM	94.09%	0.47%	5.45%
B150050	IS270-.40 MI S OF MD 121 (ATR0004)	NB-PM	89.19%	1.13%	9.67%
		SB-AM	92.47%	0.57%	6.95%
S1999150048	IS 270 -.10 MI SOUTH OF STRUC#15040(LITTLE SENECA CREEK)(ATR#04)	NB-PM	89.62%	0.68%	9.70%
		SB-AM	92.85%	0.39%	6.76%
B150010	IS270-.40 MI N OF MD 118	NB-PM	89.16%	1.02%	9.82%
		SB-AM	91.92%	0.43%	7.65%
B2968	IS270-.10 MI S OF MD 118	NB-PM	88.82%	1.19%	9.99%
		SB-AM	92.81%	0.37%	6.82%
B150053	I-270-.50 MI S OF MIDDLEBROOK RD (ATR0060)	NB-PM	89.96%	0.93%	9.12%
		SB-AM	93.32%	0.51%	6.18%
B2967	I-270-.10 MI S OF MD 124	NB-PM	90.67%	1.17%	8.16%
		SB-AM	94.03%	0.48%	5.49%
B2966	I-270-.10 MI N OF I-370	NB-PM	89.36%	1.61%	9.03%
		SB-AM	93.59%	0.56%	5.86%
B2965	I-270-.10 MI N OF SHADY GROVE RD	NB-PM	90.92%	1.15%	7.92%
		SB-AM	92.97%	0.61%	6.43%
B2847	I-270-.50 MI N OF MD 28	NB-PM	92.25%	0.92%	6.82%
		SB-AM	93.17%	0.60%	6.23%
B2848	I-270-.10 MI S OF MD 28	NB-PM	92.33%	0.81%	6.86%
		SB-AM	92.33%	0.56%	7.12%
B2849	I-270-.20 MI N OF MD 927 (MONTROSE RD)	NB-PM	92.83%	0.79%	6.38%
		SB-AM	93.59%	0.63%	5.78%
B2850	I-270-.10 MI N OF TUCKERMAN LA	NB-PM	92.66%	0.89%	6.45%
		SB-AM	93.42%	0.57%	6.01%
B2851	I-270Y-.50 MI N OF DEMOCRACY BLVD	NB-PM	96.80%	0.62%	2.58%
		SB-AM	96.35%	0.64%	3.01%
B2963	I-270Y-.10 MI S OF DEMOCRACY BLVD	NB-PM	96.60%	0.44%	2.96%
		SB-AM	96.95%	0.42%	2.63%
B150052	I-495-.10 MI E OF STRUC #15105(PERSIMMON TREE RD) (ATR0040)	NB-PM	94.49%	0.48%	5.03%
		SB-AM	93.14%	0.92%	5.94%
B2964	I-270-.30 MI N OF MD 187B	NB-PM	91.01%	1.21%	7.79%
		SB-AM	93.99%	0.46%	5.55%
B2852	I-270-.10 MI S OF MD 187	NB-PM	93.53%	0.71%	5.76%
		SB-AM	93.64%	0.58%	5.78%
B2971	I-495-.20 MI E OF MD 355	NB-PM	92.10%	0.84%	7.06%
		SB-AM	91.87%	0.98%	7.14%
B2900	I-495-.30 MI E OF MD 187	NB-PM	93.30%	0.58%	6.12%
		SB-AM	93.67%	0.71%	5.62%
B2899	I-495-.50 MI W OF MD 187	NB-PM	93.71%	0.60%	5.69%
		SB-AM	92.05%	0.98%	6.97%

* Refer to Figure 2-3 for station numbering.

**Cars include Classes 1-3

** Trucks include Classes 5-9

2.2 Data for calibration

In this study, travel time, traffic volume and segment density were employed in calibrating and assessing the model. Specifically, parameters of the model were chosen so as to minimize the difference in travel time estimates by roadway segment with actual travel times collected over a period of time. Once selected, model forecasts in terms of traffic volume and segment density were compared with actual values taken from the field to assess the model forecasting quality with respect to other measures not employed in the parameter selection process.

2.2.1 Travel Time

Segment travel times surveyed by probe vehicles traveling along GP and HOV lanes during the peak periods were provided by SHA. The study roadway is segmented into 19 and seven segments for the GP and HOV lanes, respectively, in the southbound direction and 19 and 16 segments for the GP and HOV lanes, respectively, in the northbound direction. Segments extend between interchanges.

Twelve and nine survey travel times were provided from live runs completed during the morning peak hours over multiple days in April 2004 along the southbound lanes over GP and HOV lane segments, respectively. Ten survey travel times were provided for both GP and HOV lane segments of the northbound direction made during evening peak hours over multiple days in April 2004 and May 2007.

Details associated with roadway segmenting and travel time survey data are provided in Appendix 2-1.

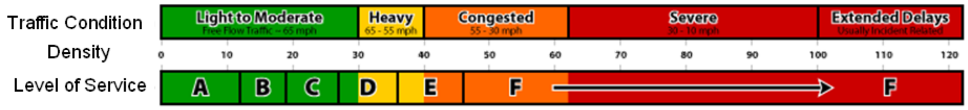
2.2.2 Traffic Volume

Traffic volumes along the main road of I-270 were obtained from the Volume Count Detail Report archived in the database of the Internet Traffic Monitoring System (I-TMS) on the SHA website (I-TMS website, accessed in 2010). This data (i.e. traffic volume) reflects raw count vehicle values at each survey location. Specifically, reports from 20 collection locations in 2009 were utilized in this study. Each report details the survey station ID, location, survey date and hourly volume counts. The morning peak hours in the southbound direction and evening peak hours in the northbound direction were extracted from each report and summarized as provided in Appendix 2-2.

Input volume and turning portion data described in Section 2.1.2 were also used in assessing the simulation model to ensure that input and output from the simulation network are consistent with the survey data.

2.2.3 Segment Density

Density data given in units of pcplpm (i.e. passenger car per lane per mile) employed in assessing the model were represented using the Traffic Quality Rating system. This data was provided by SHA and Skycomp, Inc. and is repeated in Appendix 2-3. This data was surveyed during morning and evening peak hours for the SB-AM and NB-PM lanes, respectively, in the spring of 2008. Red, orange, yellow and green, along with corresponding level of service (LOS) indices from A to E, are used to depict service levels, as shown in Figure 2-4 (HCM 2000 and Skycomp, Inc. website, accessed in 2010). The density data were categorized by lane type and segment, with 17, 10, and 4 segments in the SB-AM direction and 17, 14, and 5 segments in the NB-PM direction for GP, HOV and CD lanes, respectively. This segmenting scheme differs from that used in analyzing travel times discussed in Section 2.2.1.



Density (pcplpm)	LOS	Traffic description
0 to 11	A	Very light traffic
12 to 18	B	Light traffic
19 to 26	C	Moderate traffic
27 to 35	D	Moderate to heavy traffic without significant slowing
36 to 45	E	Heavy traffic with minor slowing
>45	F	Congested traffic involving slowing and stopping

Figure 2-4. Representation of Density in LOS Coloring and Density Value

Chapter 3 Modeling and Calibration for Existing Design

In this chapter, development and calibration of the I-270 facility covering the entirety of I-270 from interchange I-70 to interchanges on I-495 at Connecticut Avenue in Maryland and Georgetown Pike in Virginia under the existing concurrent flow lane design, referred to herein as the Existing Network, are described. In Section 3.1., Existing Network model development and error elimination are discussed. This is followed by description of calibration efforts with respect to travel time in Section 3.2. Evaluation of the final chosen parameters using performance measures of traffic volume and density are given in Section 3.3.

3.1 Modeling of Existing System

The Existing Network was modeled using tools available within the VISSIM micro-simulation software product (version 5.2). Link elements with appropriate property settings (e.g. length and lane configuration) were employed to represent roadway geometry in the study area using the GoogleMap developed in Section 2.1.1 as a guide. Input Volume and Split/Turning Proportion as shown in Section 2.1.2 were set at each on-ramp using Link Input and at each off-ramp using Route Decision functions, respectively. Traffic Composition, Vehicle Class and Vehicle Type properties in the simulation network were set according to survey findings described in Section 2.1.3.

Once the Existing Network was developed, initial simulation runs were conducted. These initial runs applied modeling techniques developed in Phase II of this study, including O-D modeling using Route Decision and Direction Decision, and techniques to foster smooth lane-changing behavior between lanes or at exits and entrances (Miller-Hooks et al., 2009). After completing the initial runs, the error reports (i.e. files with ".err" extension produced during the runs) were investigated and actions were taken to eliminate the identified errors. Large numbers of vehicles were identified as missing vehicles. That is, during a simulation run they either disappeared from the network, typically as a result of an incorrect setting in a Route Decision, or did not enter the network, typically as a consequence of spillback. It was noted that such errors were more frequent when many vehicles were generated during the warm-up period, i.e. the simulation period designed to replicate traffic operations just prior to the actual simulation period.

To address these two types of errors, several actions were taken. First, two actions were considered to deal with vehicles that disappeared from the network.

(1) Extend the length of the Route Decision to ensure that vehicles exiting or entering the simulation network facility will have enough time and distance to change lanes before a lane is dropped as a function of its geometric design.

(2) Adjust the "Lane Change Distance" parameter, which defines the distance at which vehicles will begin lane-changing maneuvers, associated with each Connector covered by a relevant Route Decision. This action is to ensure that vehicles are able to recognize the exit or entrance prior to arriving at the connectors.

Second, two actions were considered to reduce the number of vehicles that cannot enter the network during the simulation period.

(1) Set the Input Volumes during the warm-up period (0-1800 seconds) using a stepwise

input profile over time for selected on-ramps where traffic queues are observed from animations as illustrated in Figure 3-1. Note that input volumes to ramps for which this stepwise setting were not applied may be higher during the warm-up period than during simulation hour.

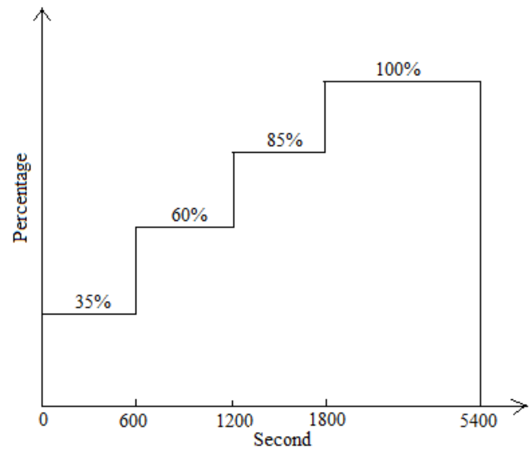


Figure 3-1. Stepwise Input Profile in Warm-up and Simulation Periods

(2) Remove the bottlenecks downstream of the Input Links by adjusting the Safety Distance Reduced Factor parameter for the Link. Typically, a bottleneck occurs at merge sections, where a vehicle might show unrealistically conservative merging behavior to the main lanes. For example, a vehicle might wait for a gap of a length that occurs infrequently. This task requires repeated observation of simulation animation to identify locations at which such bottlenecks arise as a consequence of this behavior.

3.2 Calibration of Existing Network

Parameters of the VISSIM simulation software must be set so that traffic measures from the simulation best match actual measurements taken from the field. The process of determining the optimal set of parameters for the existing conditions model so as to minimize such error is known as calibration. In the prior phase of this study, a 7-mile stretch of I-270 was modeled and a parameter set was identified from a similar calibration effort. As a first step in the calibration efforts taken in this third phase, the parameter set identified in Phase II was applied on the Existing Network. While the model was found to replicate existing conditions reasonably well on the Existing Network using the Phase II parameter settings, additional experiments produced an improved parameter set. In Section 3.2.1, key tasks and performance measures for identifying the improved parameter set are discussed. Results from the experiments are given in Section 3.2.2.

3.2.1 Calibration Tasks

The following tasks were conducted.

(1) Identified parameter sets for test runs.

The five selected parameters from Phase II study were considered in this calibration effort:

headway time (CC1), ‘Following’ Variation (CC2), ‘Following’ Thresholds (CC4&5), Safety Distance Reduced Factor (SDRF) and Look Back Distance (LBD). Their definitions, default values, ranges of these parameters and the final set used in Phase II study are list in Table 3-1. In addition to the set found in the Phase II study, 32 additional sets, called design points, were tested based on the factorial design also designed in the Phase II study (Appendix 3-1).

Table 3-1. Parameters Selected for Calibration

Parameter	Definition	Default Value	Range	Phase II
CC1	Headway time: *higher value, more cautious driver*	0.9 second	0.2-1.5 second	0.9
CC2	Following variation: *desired safety following distance*	4 meters	1.5-20 meters (16.40-65.62 ft)	12 meters =39.37 ft
CC4&5	Lower & Upper following threshold	0.35 mph	0.1-2.0	2
SDRF	Safety distance reduced factor: *effects safety distance during lane changing*	0.6	0.1-0.9	0.4
LBD	Look back distance: *defines the distance at which vehicles will begin to attempt to change lanes*	200 meters	50-1000 meter	492.13 ft

Note: the sign of Lower following threshold (CC4) is ‘-’ and the sign of Upper following threshold (CC5) is ‘+’.

(2) Conduct simulation runs using identified parameter sets and collect results

Five simulation runs were conducted for each identified parameter set, each with different randomly selected seed values. Each run of the VISSIM model entailed 5,400 seconds of simulation time, the first 1,800 seconds of which was considered as the warm-up period. Hourly averages of segment travel times based on the 3,600 seconds of simulation run time were collected for comparison with field survey data.

To obtain segment travel time data from the simulation, numerous simulation detectors (i.e. Collection Points in the VISSIM software) were deployed in the Existing Network. Detector locations were set such that the segments used in the simulation for collecting travel time data are consistent with the segments used in developing the survey data as described in Section 2.2. Travel time results were further classified by lane type (GP or HOV) and segment.

(3) Compare survey field data with simulation output

To assess how well a chosen parameter set performed, a measure of mean squared error (MSE) suggested in Dowling et al. (2004) is employed. The calculation of MSE, which measures the difference between the simulation result and field data in each segment *i*, is given in equation (1).

$$MSE_i^p = \frac{1}{R}\sum_{r=1}^{R}(STT_i^P - AATT_i)^2 \qquad (1),$$

where

i : Segment index;

p : Parameter set index;

R : Number of runs;

MSE_i^p : Mean square error value for parameter set *p* in segment *i*;

STT_i^p : Simulated travel time of parameter set *p* in segment *i*; and

$AATT_i$: Average actual travel time in segment *i*.

The performance measure was applied repeatedly to each roadway segment and the average over all segments was calculated using equation (2). A lower value of the *AMSE* is preferable.

$$AMSE^p = \frac{1}{N}\sum_{i=1}^{N} MSE_i^p \qquad (2),$$

where

N : Total number of segments on the entire roadway and

$AMSE^p$: Average MSE for parameter set *p*.

Additionally, t-tests were conducted for each segment to determine whether or not there is a significant statistical difference between simulation and survey mean travel times.

(4) Fine-tuning
After identifying the preferred parameter set from the design points, the values of each parameter within the set were fine-tuned to achieve improved results. The process used insights gleaned from the factorial design, sensitivity analysis and expert advice (provided during the Phase II study) in tuning the values. Additionally, observation of the simulation animation and adjustment of parameter values was made in identifying a final preferred parameter set.

3.2.2 Choosing the Final Parameter Set

33 candidate parameter sets were employed in simulation runs, one set as recommended from experiments conducted in Phase II of this study (referred to herein as the Phase II parameter set) and the remaining 32 chosen based on the related factorial design presented in (Miller-Hooks et al., 2009). How well the simulation estimates average segment travel time in both SB-AM and NB-PM lanes as a function of the tested parameter set (i.e. the design point) was assessed. The *AMSE* of each design point for SB-AM and NB-PM of the Existing Network are reported in Tables 3-2 and 3-3, respectively. For the phase II parameter set, the

AMSE values are 3632.7 and 3783.9 in SB-AM and NB-PM directions, respectively.

Table 3-2. SB-AM Factorial Design Results

Design Point	AMSE	Design Point	AMSE
1	3380.1	17	3484.2
2	3287.8	18	3278.2
3	4953.0	19	2950.1
4	3708.2	20	5072.6
5	5048.1	21	3674.3
6	3939.1	22	3272.1
7	5881.5	23	3628.1
8	13750.7	24	9831.2
9	3102.6	25	3271.9
10	3257.5	26	3672.4
11	4210.9	27	3940.9
12	6352.5	28	6590.4
13	5076.7	29	3267.3
14	3150.6	30	3751.0
15	3705.3	31	4802.5
16	3959.1	32	8179.9

Table 3-3. NB-PM Factorial Design Results

Design Point	AMSE	Design Point	AMSE
1	2028.5	17	1958.9
2	2134.4	18	2292.2
3	2832.1	19	2266.9
4	2943.9	20	2884.7
5	2087.4	21	2026.9
6	2845.5	22	2104.2
7	2896.8	23	3222.7
8	2895.7	24	3076.7
9	2179.5	25	2177.2
10	2301.5	26	2306.1
11	2690.3	27	2686.1
12	2879.8	28	3010.9
13	2134.6	29	2149.1
14	2252.4	30	12402.2
15	2920.5	31	8248.5
16	2707.2	32	10301.7

The minimum *AMSE* occurs using design point 19 for the SB-AM direction and design point 17 for the NB-PM direction. The *AMSE* associated with these design points is lower than that achieved through the use of the Phase II parameter set.

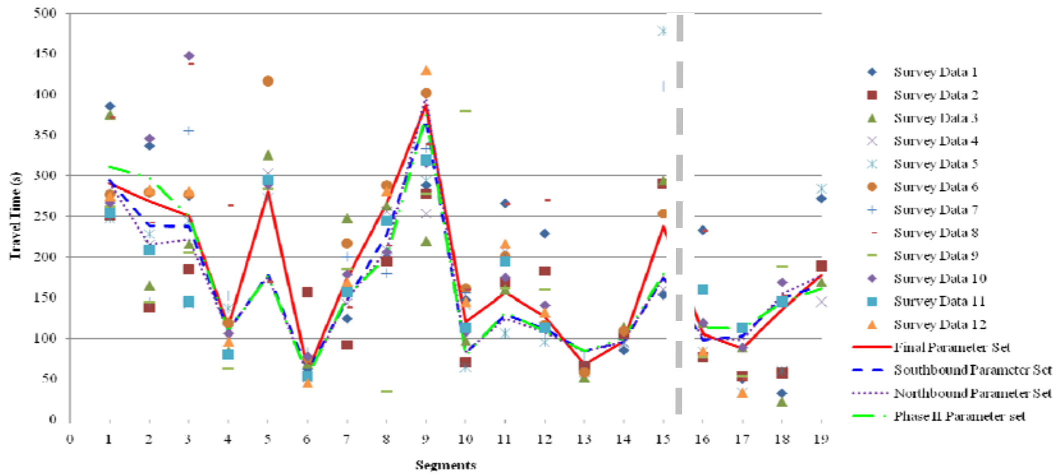
Once the parameter sets were identified, approximately 200 additional experiments were conducted in an effort to fine-tune the parameters. This process involved adjustments to the input volumes associated with the warm-up period, as discussed in Section 3.1, the SDRF at certain on-ramps, and LBD at select merging areas so as to produce reasonable driving behavior. A similar attempt to fine-tune the Phase II parameter set was made. Results associated with runs using the Phase II parameters before fine-tuning for the southbound direction are given in Appendix 3-2 to allow the reader to discern the value of fine tuning.

A common parameter set for use in simulating both SB-AM and NB-PM traffic was identified through additional experiments and observations of the simulation animation. These additional experiments were based off of design points 19 and 17. Individual parameters were adjusted over numerous simulation trials, holding all other parameter settings constant. The *AMSE* measure was considered and simulation animation was studied in an effort to identify values of the *AMSE* measure that improved for both SB-AM and NB-PM directions. Additional fine-tuning work was completed.

Parameter values for the final (best) common parameter set, parameter sets 19 and 17 identified for SB-AM and NB-PM directions, respectively, and the parameter set identified in the Phase II study are listed in Table 3-4. Numbers shown in the table are those that were used most often in the model. The LBD setting in the final set is increased from 492 feet suggested in Phase II to 3,280 feet to allow vehicles attempting to change lanes sufficient reaction time. Results of the simulation runs employing these four parameter sets are provided in Figures 3-2 to 3-5 and are compared with the field survey data as described in Section 2.2. The associated *AMSE* for these runs are given in Table 3-5.

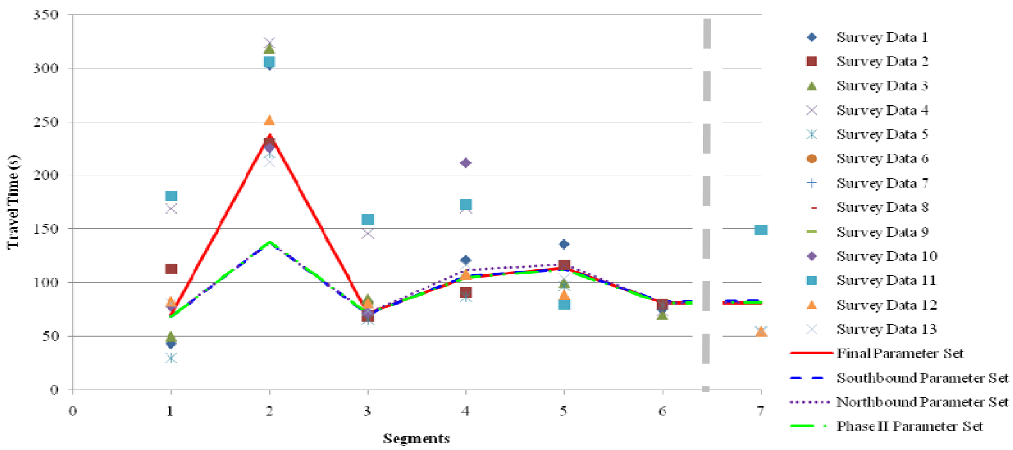
Table 3-4. Tested Parameters

Parameter	Phase II	Phase III		
		SB-AM Best	NB-PM Best	Final Set
CC1	0.9	0.9	0.9	0.9
CC2(ft)	39.37	65.62	13.12	39.37
CC4&5	2	0.1	0.1	0.1
SDRF	0.4	0.1	0.1	0.1
LBD	492.13 ft	3280.83	3280.83	3280.83



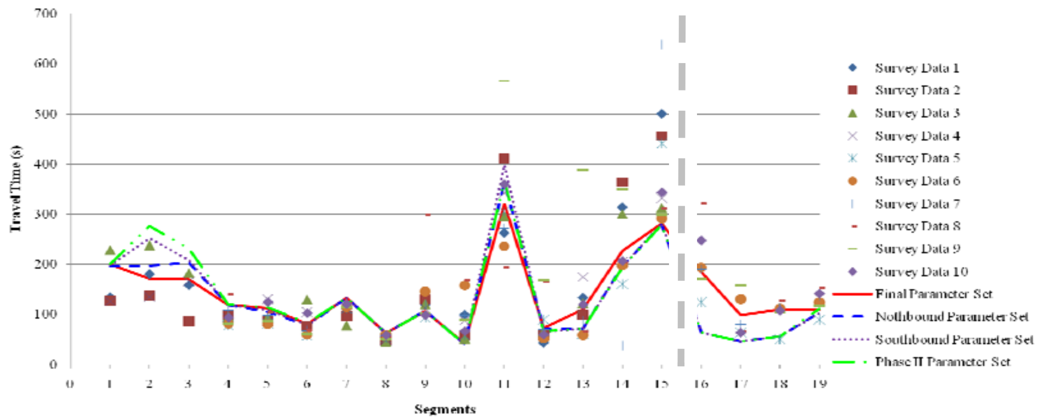
1	MD-109 to MD-121	5	Middlebrook to MD-124	9	ShaddyGrove to MD-28	13	Spur to MD-187	17	Democracy to Begin 495
2	MD-121 to MD-27	6	MD-124 to MD-117	10	MD-28 to MD-189	14	MD-187 to MD-355/I-495 Split	18	Begin I-495 to MD-190
3	MD-27 to MD-118	7	MD-117 to MD-370	11	MD-189 to Montrose Rd	15	355/495 Split to MD-185	19	MD-190 to Clara Barton Pkwy
4	MD-118 to Middlebrook	8	MD-370 to Shaddy Grove	12	Montrose Rd to Spur	16	I-270 Spur to Democracy		

Figure 3-2. SB-AM GP Lane Travel Time Comparison



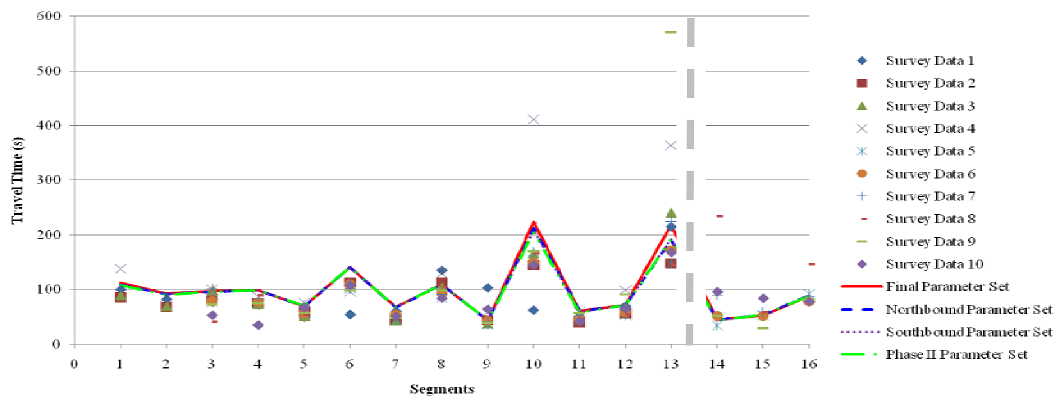
1	MD-370 to Shady Grove(HOV)	5	Montrose Rd to Spur (HOV)
2	Shady Grove to MD-28(HOV)	6	Spur to MD-187 (HOV)
3	MD-28 to MD-189 (HOV)	7	I-270 Spur to Democracy(HOV)
4	MD-189 to Montrose Rd (HOV)		

Figure 3-3. SB-AM HOV Lane Travel Time Comparison



1	MD-185 to Begin I-270	5	Montrose Rd to MD-189	9	I-370 to MD-117	13	MD-118 to MD-27	17	Begin HOV to Begin I-270
2	Begin I-270 to MD-187	6	MD-189 to MD-28	10	MD-117 to MD-124	14	MD-27 to MD-121	18	Begin I-270 to Democracy
3	MD-187 to Spur	7	MD-28 to ShadyGrove	11	MD-124 to Middlebrook	15	MD-121 to MD-109	19	Democracy to Spur
4	Spur to Montrose Rd	8	ShadyGrove to I-370	12	Middlebrook to MD-118	16	MD-190 to Begin HOV		

Figure 3-4. NB-PM GP Lane Travel Time Comparison



1	Begin I-270 to MD-187(HOV)	5	MD-189 to MD-28 (HOV)	9	MD-117 to MD-124 (HOV)	13	MD-27 to MD-121 (HOV)
2	MD-187 to Spur(HOV)	6	MD-28 to ShadyGrove (HOV)	10	MD-124 to Middlebrook (HOV)	14	Begin HOV to Begin I-270 (HOV)
3	Spur to Montrose Rd (HOV)	7	ShadyGrove to I-370 (HOV)	11	Middlebrook to MD-118 (HOV)	15	Begin I-270 to Democracy (HOV)
4	Montrose Rd to MD-189(HOV)	8	I-370 to MD-117 (HOV)	12	MD-118 to MD-27 (HOV)	16	Democracy to Spur (HOV)

Figure 3-5. NB-PM HOV Lane Travel Time Comparison

Table 3-5. Performance Measure (*AMSE*) by Using Different Parameter Sets

Direction	SB-AM		NB-PM	
Road type	GP	HOV	GP	HOV
Phase II	3632.7	2601.0	3783.9	582.4
SB-AM	3069.9	2625.0	3672.7	597.5
NB-PM	3812.1	2594.3	3087.8	618.3
Common	1553.7	382.2	1381.8	673.6

One will note from Table 3-5 that the common parameter set outperforms both the SB-AM and NB-PM parameter sets (19 and 17, respectively) along GP and SB-AM HOV lanes based on the *AMSE* values. This is because these latter parameter sets, while fine-tuned, were derived directly from the factorial design. Insights gleaned from the two chosen sets were applied to identify the improved common parameter set. Thus, this common set is not only best for both directions when considered together, but is also best for each direction when considered separately.

Mean segment travel times obtained from the simulation results were compared with mean segment travel times obtained from the field. A comparison of mean travel times for small sample size (i.e. a t-test) was completed to test the null hypothesis of equal population means given simulated and field survey samples. Results of the analysis are given in Tables 3-6 through 3-9.

Table 3-6. Statistical Analysis of Simulation Results for SB-AM GP Lanes

Segment		SB-AM GP Lanes			
		t (0.025,v)	v	T	If -t<T<t, accepted
1	MD 109 to MD 121	2.198	11.1236	-0.0327	Accepted
2	MD 121 to MD 27	2.149	13.7003	1.23975	Accepted
3	MD 27 to MD 118	2.193	11.3863	-0.3707	Accepted
4	MD 118 to Middlebrook	2.248	9.42527	-0.1175	Accepted
5	Middlebrook to MD 124	2.290	8.35386	-0.4908	Accepted
6	MD 124 to MD 117	2.133	14.8584	-0.7928	Accepted
7	MD 117 to MD 370	2.232	9.88978	0.28295	Accepted
8	MD 370 to Shaddy Grove	2.349	7.2711	1.45151	Accepted
9	ShaddyGrove to MD 28	2.141	14.2819	2.65902	Rejected
10	MD 28 to MD 189	2.176	12.1678	-0.6773	Accepted
11	MD 189 to Montrose Rd	2.154	13.3917	-1.7185	Accepted
12	Montrose Rd to Spur	2.200	11.0258	-0.8566	Accepted
13	Spur to MD 187	2.300	8.14447	1.078	Accepted
14	MD 187 to MD 355/I-495 Split	2.417	6.36941	-0.8063	Accepted
15	355/495 Split to MD 185	2.282	8.54822	-0.935	Accepted
16	I-270 Spur to Democracy	2.210	10.6605	-1.0739	Accepted
17	Democracy to Begin 495	2.162	12.8832	1.35271	Accepted
18	Begin I-495 to MD 190	2.316	7.83293	1.04472	Accepted
19	MD 190 to Clara Barton Pkwy	2.662	4.55672	-1.1799	Accepted

Table 3-7. Statistical Analysis of Simulation Results for SB-AM HOV Lane

Segment		SB-AM HOV Lane			
		t (0.025,v)	v	T	If -t<T<t, accepted
1	MD 370 to Shaddy Grove(HOV)	2.302	8.09681	-0.8987	Accepted
2	ShaddyGrove to MD 28(HOV)	2.305	8.02383	-1.3061	Accepted
3	MD 28 to MD 189 (HOV)	2.306	8.00487	-1.3505	Accepted
4	MD 189 to Montrose Rd (HOV)	2.296	8.22397	-1.3784	Accepted
5	Montrose Rd to Spur (HOV)	2.311	7.91425	1.09222	Accepted
6	Spur to MD 187 (HOV)	2.770	4.03043	3.19517	Rejected
7	I-270 Spur to Democracy(HOV)	2.776	4.00004	-0.47	Accepted

Table 3-8. Statistical Analysis of Simulation Results for NB-PM GP Lanes

Segment		NB-PM GP Lanes			
		t (0.025,v)	v	T	If -t<T<t, accepted
1	MD 185 to Begin I-270	3.102	3.19715	2.01843	Accepted
2	Begin I-270 to MD 187	2.607	4.82637	-0.059	Accepted
3	MD 187 to Spur	2.460	5.89795	0.83476	Accepted
4	Spur to Montrose Rd	2.341	7.40428	2.33576	Rejected
5	Montrose Rd to MD 189	2.165	12.7408	1.73982	Accepted
6	MD 189 to MD 28	2.193	11.3617	0.14647	Accepted
7	MD 28 to ShadyGrove	2.259	9.08019	3.64058	Rejected
8	ShadyGrove to I-370	2.261	9.02702	4.4221	Rejected
9	I-370 to MD 117	2.262	9.00192	-1.1021	Accepted
10	MD 117 to MD 124	2.260	9.05804	-2.7813	Rejected
11	MD 124 to Middlebrook	2.208	10.7513	-0.088	Accepted
12	Middlebrook to MD 118	2.232	9.8858	-0.4668	Accepted
13	MD 118 to MD 27	2.253	9.25978	-0.4728	Accepted
14	MD 27 to MD 121	2.160	12.9989	-0.1668	Accepted
15	MD 121 to MD 109	2.261	9.02441	-2.1509	Accepted
16	MD 190 to Begin HOV	2.571	5.00002	-0.7727	Accepted
17	Begin HOV to Begin I-270	2.483	5.70633	0.28179	Accepted
18	Begin I-270 to Democracy	2.539	5.25414	0.64402	Accepted
19	Democracy to Spur	2.268	8.8736	-1.5075	Accepted

Table 3-9. Statistical Analysis of Simulation Results for NB-PM HOV Lane

Segment		NB-PM HOV Lane			
		t (0.025,v)	v	T	If -t<T<t, accepted
1	Begin I-270 to MD 187(HOV)	2.988	3.47767	0.77526	Accepted
2	MD 187 to Spur(HOV)	2.980	3.49756	3.63061	Rejected
3	Spur to Montrose Rd (HOV)	2.250	9.34467	2.0682	Accepted
4	Montrose Rd to MD 189(HOV)	2.260	9.0514	3.49748	Rejected
5	MD 189 to MD 28 (HOV)	2.257	9.14193	3.08549	Rejected
6	MD 28 to ShadyGrove (HOV)	2.260	9.06474	5.25539	Rejected
7	ShadyGrove to I-370 (HOV)	2.252	9.30052	7.97429	Rejected
8	I-370 to MD 117 (HOV)	2.262	9.00542	0.69329	Accepted
9	MD 117 to MD 124 (HOV)	2.262	9.00198	-0.8213	Accepted
10	MD 124 to Middlebrook (HOV)	2.161	12.9715	1.18112	Accepted
11	Middlebrook to MD 118 (HOV)	2.236	9.75842	3.45278	Rejected
12	MD 118 to MD 27 (HOV)	2.262	9.01067	0.5162	Accepted
13	MD 27 to MD 121 (HOV)	2.229	9.98337	-0.3537	Accepted
14	Begin HOV to Begin I-270 (HOV)	2.570	5.00524	-1.4685	Accepted
15	Begin I-270 to Democracy (HOV)	2.570	5.00467	-0.3561	Accepted
16	Democracy to Spur (HOV)	2.570	5.00842	-0.5287	Accepted

The t-test indicates that the mean segment travel times obtained from the simulation using the final set of calibrated parameters are not statistically different from mean segment travel times obtained through field observations for those segments in which an "Accepted" test result is provided in the table. These results assume a confidence level of 95%. It is also worth considering the fact that the same parameter values were employed in all segments; that is, the parameters were not chosen so as to produce only locally good results. Results of the t-tests show that for the SB-AM GP and HOV lanes, there are only two segments in which difference between the simulated and surveyed travel times are statistically significant at a 95% confidence interval. Thus, the calibration can be considered quite successful for this direction. A statistical difference in mean travel times is, however, noted in quite a number of segments for the NB-PM direction. Specifically, this occurs in four of the 19 GP lane segments and six of the 16 HOV lane segments. This appears to be due to the low variance in survey travel times along the HOV lanes. One will note from Figure 3-5 that the simulated travel times appear to be reasonable for these segments.

3.3 Evaluation by Volume and Density

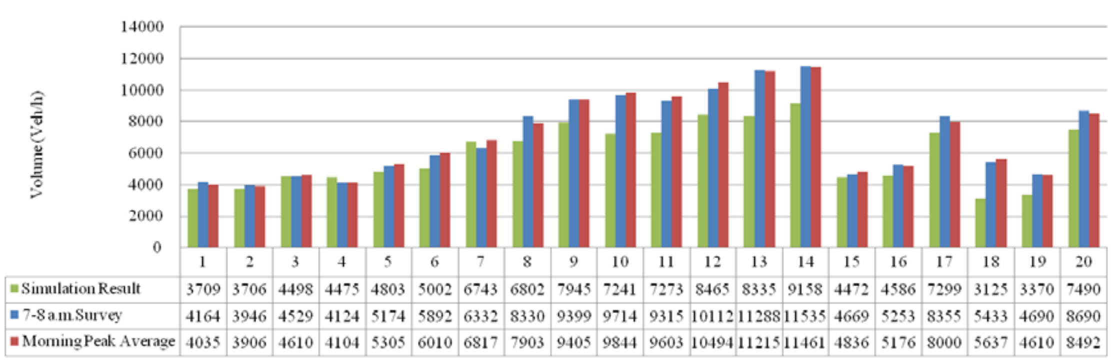
Simulation performance pertaining to traffic volume and segment density were calculated and compared with the corresponding field data to further evaluate the common parameter set. Section 3.3.1 shows simulation results in terms of traffic volume along the main lanes of the Existing Network. Additionally, the simulated input and output volumes at the on- and off-ramps, respectively, are presented in Section 3.3.2. Results pertaining to segment density within various lane types are discussed in Section 3.3.3.

3.3.1 Main Lane Traffic Volume

Simulation traffic volumes on the main lanes are compared with the survey data at each collection point as described in Section 2.2. Figures 3-7 and 3-8 compare these simulated and survey traffic volumes for the SB-AM and NB-PM directions, respectively. The collection point codes are listed in Table 3-10. Figure 2-3 of Chapter 2 shows the location of these points by code on the network map.

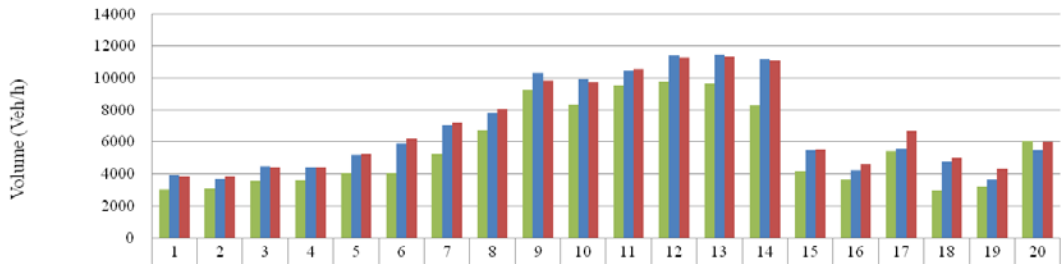
Table 3-10. Traffic Volume Collection Points

Order	1	2	3	4	5	6	7	8	9	10
Code	S2007150053	B2845	B150050	S1999150048	B150010	B2968	B150053	B2967	B2966	B2965
Order	11	12	13	14	15	16	17	18	19	20
Code	B2847	B2848	B2849	B2850	B2851	B2963	B150052	B2964	B2852	B2971



Note : * "7-8 a.m. survey" values depict raw count traffic data along the main lanes
** "Morning peak average" takes the average value of raw count traffic data between 6 and 9 a.m.

Figure 3-6. SB-AM Main Lane Traffic Volumes



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Simulation Result	3046	3071	3569	3594	4038	4047	5244	6740	9261	8334	9547	9808	9635	8286	4179	3625	5406	2997	3230	6036
5-6 p.m. Survey	3919	3711	4456	4410	5204	5912	7052	7816	10322	9943	10446	11419	11475	11178	5486	4227	5589	4747	3662	5477
Evening Peak Average	3861	3819	4433	4414	5236	6175	7210	8049	9831	9756	10561	11260	11341	11090	5499	4603	6649	4970	4337	6016

Note: * "5-6 p.m. survey" values depict raw count traffic data along the main lanes
** "Evening peak average" refers the average value of raw count traffic data during 3 and 7 p.m.

Figure 3-7. NB-PM Main Lane Traffic Volumes

Figures 3-6 and 3-7 show that the simulated traffic volumes at different locations along the main lanes of the Existing Network are consistent with the survey data in most collection points. At certain points at which there is higher traffic volumes the corresponding simulated traffic volumes are consistently lower than the survey volumes. The average error is approximately 8% for both directions.

3.3.2 Input and Output Volume

Figures 3-8 through 3-11 compare traffic input and output volumes in the on- and off-ramps, respectively, for both SB-AM and NB-PM directions. The codes associated with each on- and off-ramp data collection point are given in Appendix 3-3. These codes are used on the x-axes of the figures to identify the locations.

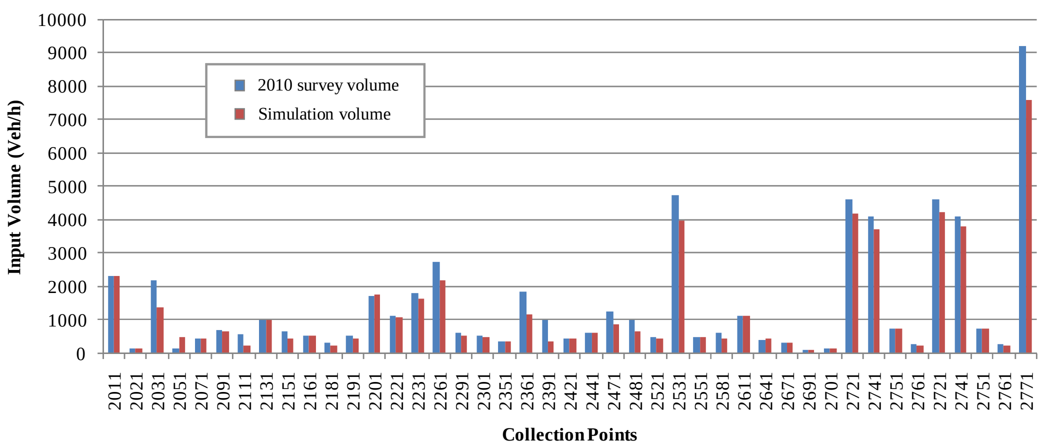


Figure 3-8. SB-AM On-Ramp (Input) Volume Comparison

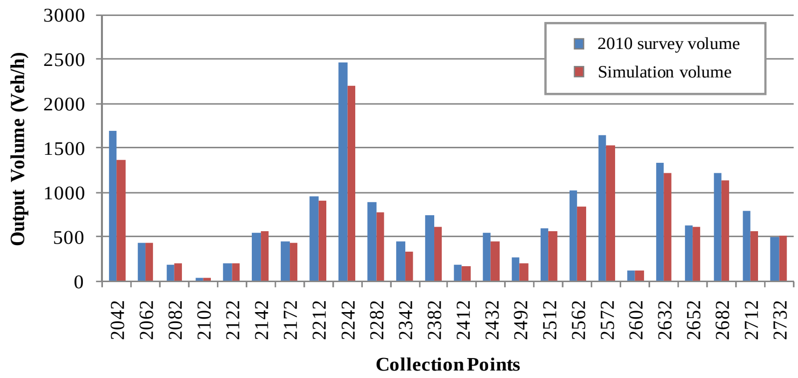


Figure 3-9. SB-AM Off-Ramp (Output) Volume Comparison

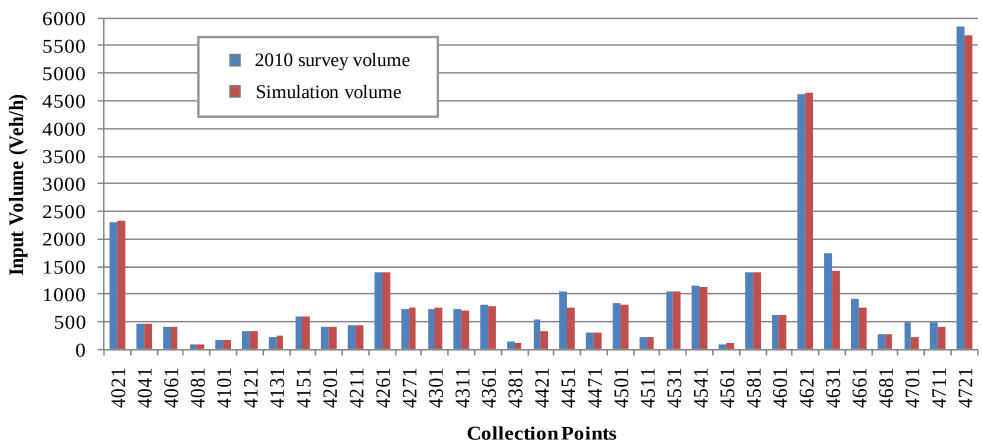


Figure 3-10. NB-PM On-Ramp (Input) Volume Comparison

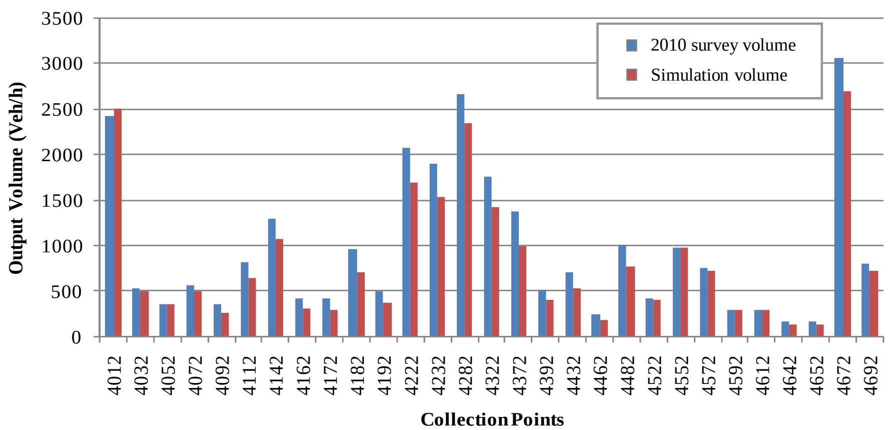
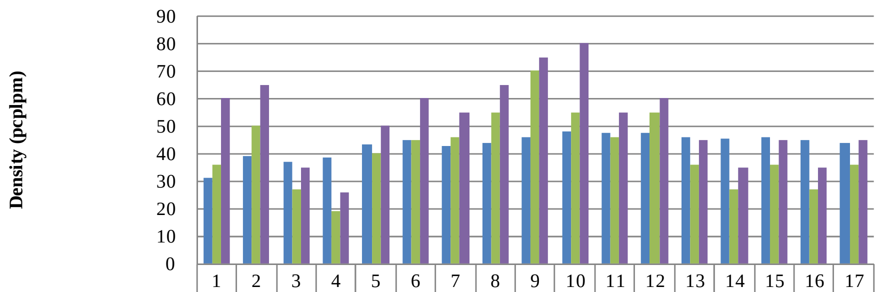


Figure 3-11. NB-PM Off-Ramp (Output) Volume Comparison

The general patterns for the on- and off-ramp volumes as estimated through simulation follow the surveyed volume patterns very closely. At those locations where there is significant differences in the actual volumes, the simulation tends to underestimate the volumes. It is hypothesized that this is due to spillback, which prevents some vehicles from entering the network. The average errors related to the input and output volumes are both less than 10%.

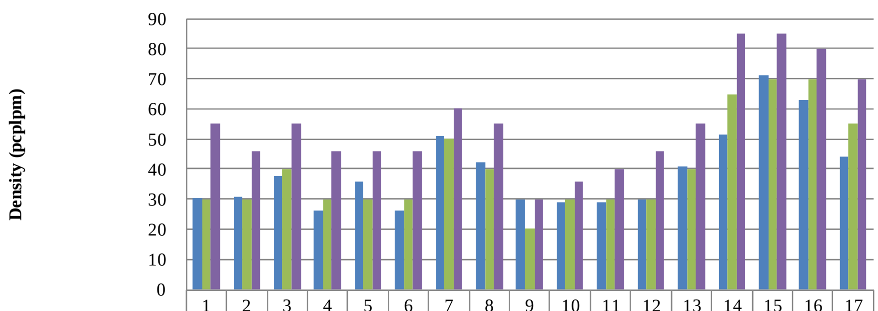
3.3.3 Segment Density

Average simulation density was calculated for each surveyed segment and the results were compared with survey data. Figures 3-12, 3-13 and 3-14 compare average segment density on GP, HOV and CD lanes, respectively, in SB-AM and NB-PM directions. More information on the surveyed densities can be found in Section 2.2.3 as well as the detail of segment locations.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Simulation Result	31	39	37	39	43	45	43	44	46	48	47	48	46	46	46	45	44
Survey Lowerbound	36	50	27	19	40	45	46	55	70	55	46	55	36	27	36	27	36
Survey Upperbound	60	65	35	26	50	60	55	65	75	80	55	60	45	35	45	35	45

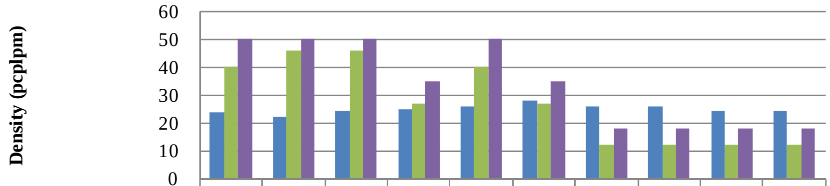
SB-AM Segments



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Simulation Result	31	31	38	26	36	26	51	42	30	29	29	30	41	51	71	63	44
Survey Lowerbound	30	30	40	30	30	30	50	40	20	30	30	30	40	65	70	70	55
Survey Upperbound	55	46	55	46	46	46	60	55	30	36	40	46	55	85	85	80	70

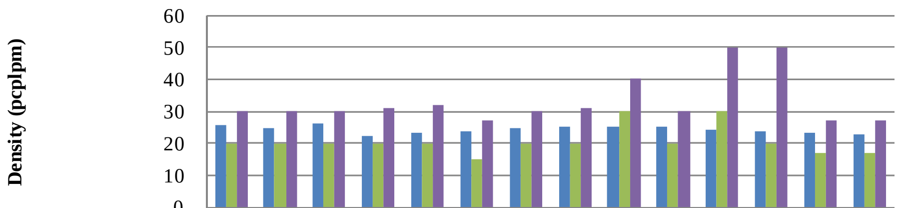
NB-PM Segments

Figure 3-12. GP Lane Density Comparison



	8	9	10	11	12	13	14	15	16	17
Simulationn Result	24	22	24	25	26	28	26	26	25	24
Survey Lowerbound	40	46	46	27	40	27	12	12	12	12
Survey Upperbound	50	50	50	35	50	35	18	18	18	18

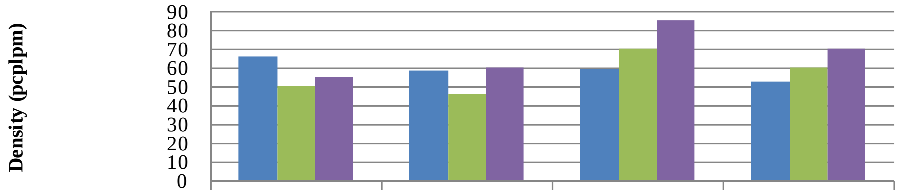
SB-AM Segments



	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Simulation Result	25	25	26	22	23	24	25	25	25	25	24	24	23	23
Survey Lowerbound	20	20	20	20	20	15	20	20	30	20	30	20	17	17
Survey Upperbound	30	30	30	31	32	27	30	31	40	30	50	50	27	27

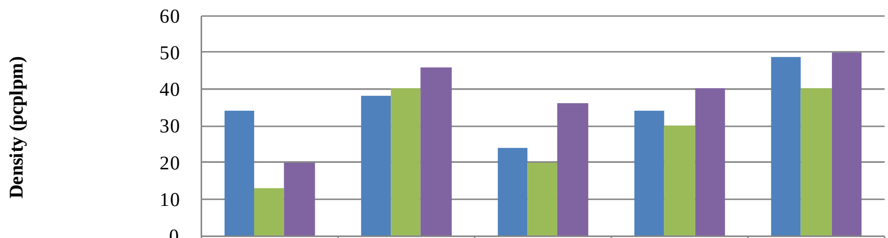
NB-PM Segments

Figure 3-13. HOV Lane Density Comparison



	9	10	11	12
Simulation Result	66	59	60	52
Survey Lowerbound	50	46	70	60
Survey Upperbound	55	60	85	70

SB-AM Segments



	8	9	10	11	12
Simulation Result	34	38	24	34	49
Survey Lowerbound	13	40	20	30	40
Survey Upperbound	20	46	36	40	50

NB-PM Segments

Figure 3-14. CD Lane Density Comparison

Segment density is often used as a measure of level of service. Thus, it is convenient to use LOS to evaluate the facility performance. Borrowing from such concepts and density data as discussed in Section 2.2.3, the calculated average density was re-categorized into three categories listed in Table 3-11.

Table 3-11. Categories for Density

Category	Description	LOS	Dens. Range	Color
1	Uncongested	A to part of E	0-39	
2	Congested	E to part of F	40-64	
3	Severe	F	>65	

Table 3-12 presents a comparison between the simulated and surveyed LOS values as defined in Table 3-11.

Table 3-12. Comparing Simulated and Surveyed Densities

Seg	Name	GP				HOV				CD			
		Survey Data			Simulation	Survey Data			imulatio	Survey Data			Simulation
		6:00 - 7:00	7:00 - 8:00	8:00 - 9:00		6:00 - 7:00	7:00 - 8:00	8:00 - 9:00		6:00 - 7:00	7:00 - 8:00	8:00 - 9:00	
Southbound													
1	MD-85 to MD-80	E	F(46)	E	31								
2	MD-80 to MD-109	F(60)	F(65)	F(50)	39								
3	MD-109 to MD-121	D	D	D	37								
4	MD-121 to MD-120	C	C	E	39								
5	MD-120 to MD-118	D	E	F(60)	43								
6	MD-118 to Middlebrook	D	F(55)	F(60)	45								
7	Middlebrook MD-124	D	F(46)	F(55)	43								
8	MD-124 to I-370	D	F(55)	F(65)	44	D	E	E	24				
9	I-370 to Shady Grove Rd	D	F(75)	F(75)	46	C	F(46)	D	22	A	F(55)	F(50)	66
10	Shady Grove Rd to MD-28	D	F(55)	F(80)	48	C	F(46)	F(46)	24	C	F(46)	F(60)	59
11	MD-28 to MD-189	D	F(46)	F(55)	47	B	D	D	25	C	F(70)	F(85)	60
12	MD-189 to Montrose Rd	D	F(60)	F(55)	48	C	E	D	26	C	F(60)	F(60)	52
13	Montrose Rd to I-270 Spur	D	E	E	46	C	D	D	28				
14	I-270 Spur to Democracy Blvd	E	D	D	46	B	B	A	26				
15	Democracy Blvd to I-495	E	E	D	46	B	B	B	26				
16	I-270 Western Spur to MD-187	C	D	E	45	B	B	A	25				
17	MD-187 to I-495	D	E	F(60)	44	B	B	E	24				
	Northbound												
1	MD-85 to MD-80	F(55)	D	C	31								
2	MD-80 to MD-109	E	D	C	31								
3	MD-109 to MD-121	F	E	C	38								
4	MD-121 to MD-120	E	E	B	26	C	B	C	25				
5	MD-120 to MD-118	F(46)	E	B	36	C	A	C	25				
6	MD-118 to Middlebrook	F(46)	E	C	26	C	C	C	26				
7	Middlebrook MD-124	F(60)	F(50)	C	51	D	C	C	22				
8	MD-124 to I-370	E	F(55)	C	42	C	C	C	23	B	B	B	34
9	I-370 to Shady Grove Rd	C	D	C	30	B	B	C	24	E	F(46)	D	38
10	Shady Grove Rd to MD-28	D	D	D	29	C	C	D	25	D	C	B	24
11	MD-28 to MD-189	E	D	D	29	C	C	C	25	E	E	D	34
12	MD-189 to Montrose Rd	E	E	D	30	D	D	D	25	E	E	D	49
13	Montrose Rd to I-270 Spur	F(55)	F(55)	E	41	C	C	D	25				
14	I-270 Spur to Democracy Blvd	F(85)	F(75)	F(65)	51	D	C	F(50)	24				
15	Democracy Blvd to I-495	F(70)	F(80)	F(50)	71	C	B	F(50)	24				
16	I-270 Western Spur to MD-187	F(80)	F(70)	D	63	B	C	D	23				
17	MD-187 to I-495	F(55)	F(70)	D	44	B	C	C	23				

Chapter 4 Alternative Network

4.1 Alternative Network Development

An alternative design for I-270 from I-370 to I-70 in both SB-AM and NB-PM directions, referred to herein as the Alternative Network, is studied herein. The design for the southern portion of the Alternative Network, between I-370 and MD 109, was extracted from CORSIM simulation files provided by SHA. The northern portions of the Alternative Network, from MD 109 to I-70, were proposed as part of the I-270/US15 Multi-Modal Corridor Study, referred to as "Express Toll Lanes Alternatives 6A/B, 7A/B," maps for which were provided by SHA. Details associated with both the southern and northern portions of the Alternative Network are given in Figure 4-1. The Alternative Network incorporates an Electronic Toll Lane (ETL) in portions. Interchanges shown in red in the figure indicate that major revisions are planned.

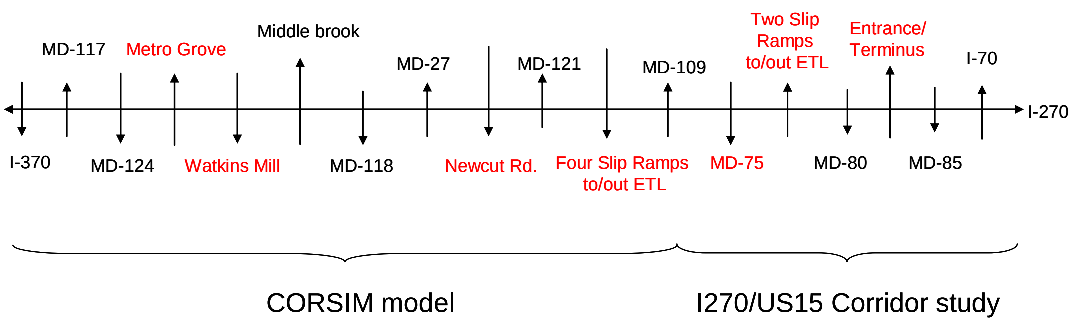


Figure 4-1. Conceptual Locations of Interchanges and Network Designs in the Alternative Network

The Alternative Network can be described by its differences from the corresponding Existing Network as enumerated next.

1. Barrier separation between GP and CD lanes in the Existing Network is removed.
2. Two ETLs are added in both south- and NB-PM directions, replacing a small portion of the HOV lane in the NB-PM direction from the Existing Network.
3. Barrier separation is placed between ETL and GP lanes in all locations except at access points.
4. Three proposed interchanges were modeled, including:
   (1) Watkins Mill Road interchange,
   (2) Newcut Road interchange, and
   (3) MD 75 interchange.
5. Revised interchange designs:
   (1) MD 80, and
   (2) MD 85.
6. Six slip ramps between GP and ETL lanes for both NB-PM and SB-AM lanes of I-270 are modeled.
7. ETL on- and off-ramps at Metro Grove are added, and
8. An ETL entrance and a terminus for SB-AM and NB-PM directions, respectively, near the battlefield in Germantown are modeled.

The developed Alternative Network was assessed through preliminary simulation runs. Modeling techniques for removing bottlenecks and improving inflow through treatment of the warm-up period were employed to improve the behavior of the models. The final parameter set defined through the calibration effort, together with settings of vehicle classification and traffic composition used in the Existing Network were applied.

4.2 Input Volumes for Alternative Network

Input volumes at each on-ramp, as well as turning proportion at each off-ramp and slip-ramp between GP and ETL lanes of the Alternative Network, were provided by SHA for the segment between MD 109 and I-70, and extracted from the CORSIM files for the segment between I-370 and MD 109, as shown in Appendix 4-1. The total input volumes employed in the Alternative Network for the one hour simulation period were 24,126 and 25,030 vehicles for the SB-AM and NB-PM directions, respectively, representing traffic demand in year 2030. The Alternative Network is referred as Alternative 2030.

4.3 Existing Network Input Volumes for Comparison

Two networks covering the same segment of I-270 as the Alternative 2030 were developed: Existing 2010 and No Build 2030. The Existing 2010 network covers I-270 from I-370 to I-70 with input volumes set according to surveyed data used in the Existing Network as described in Chapter 2. This network is identical to the Existing Network for the roadway segment it covers. Total input volumes for the SB-AM and NB-PM directions of Existing 2010 were 17,155 and 13,245 vehicles, respectively, for the one hour simulation run period. No Build 2030 is identical to Existing 2010 in all respects except settings associated with input volumes and turning proportions. A wiring diagram is provided in Appendix 4-2 that depicts the settings used in the No Build 2030 network model given inputs (i.e. the 2030 No Build Forecasts Volume) from SHA. Total input volumes for the SB-AM and NB-PM directions of No Build 2030 were 23,350 and 21,075 vehicles, respectively, for the one hour simulation period.

4.4 Compare System Performance

SB-AM and NB-PM directions of the Alternative 2030, Existing 2010 and No Build 2030 models were each run five times, once for a different selected seed value. One run of the VISSIM model for a given network and seed involves 5,400 seconds of simulation time, the first 1,800 seconds of which was considered as the warm-up period. Average results when provided are hourly averages based on the 3,600 seconds of simulation run time from each of the five runs. A total of 30 simulation runs (i.e. three network × two directions × five seeds) were conducted. Each run required approximately 10 minutes on a Dell Precision T7500 personal computer with a 3.20 gigahertz quad core processor, and 12 gigabytes of RAM, running a 64 bit Windows 7 operating system.

4.4.1 Travel Time Analysis

Average travel times were computed for the GP and ETL lanes in Alternative 2030 over the entire model roadway segment, a 23.7 mile stretch. These travel times are compared with average travel times over the same roadway length estimated from runs of the Existing 2010 and No Build 2030.

Table 4-1. Travel Time Results

Network	Alternative 2030				Existing 2010		No Build 2030	
Direction	South		North		South	North	South	North
Lane type	GP	ETL	GP	ETL	GP	GP	GP	GP
Average travel time	28.2	23.8	32.6	25.5	35.8	30.7	35.5	33.7

* travel time unit: minute

As observed from Table 4-1, travel times in the ETL facility (in Alternative 2030) are expected to be approximately 16% and 22% lower than in the GP lanes in the SB-AM and NB-PM directions, respectively. In a comparison between travel times in GP lanes of Alternative 2030, Existing 2010 and No Build 2030, Alternative 2030 requires the least time, i.e. 28.2 minutes on average, to traverse its length in the SB-AM direction, which is considerably shorter than the estimated 35-minute average travel time predicted for Existing 2010 and No Build 2030. Note that the No Build 2030 input volume and turning proportion are different from the settings in Existing 2010 network given 2030 forecasts. Results from additional simulation runs with 2030 input volumes while keeping turning proportion settings unchanged (i.e. same settings as in Existing 2010) predict an average travel time of 41.3 minutes in the SB-AM direction of the No Build 2030 network. In the NB-PM direction, Alternative 2030 is expected to lead to a 6.2% increase in travel time as compared with that of Existing 2010. This increase appears to be a consequence of a bottleneck at the off-ramp of MD 117. This bottleneck is likely due to a relatively large turning proportion setting to the off-ramp traffic at the MD 117 interchange of Alternative 2030. The lane configuration at this interchange involves four lanes along the main road heading northbound and one lane for the off-ramp to MD 117. These lanes take 58.7% and 41.3% of the approaching traffic, respectively. The bottleneck forms as a result of traffic waiting to get off at the ramp. NB-PM runs of Alternative 2030 and No Build 2030 models produce comparable average travel time estimates, at 32.6 and 33.7 minutes, respectively, despite their differences.

4.4.2 Network-wide Travel Delay, Emissions and Fuel Consumption

Network-wide total travel delay (in hours), fuel consumption (in gallons) and resulting emissions by weight were estimated for each of the runs. Average fuel consumption and emissions rates provided in Table 4-2 (taken from (EPA, 2010)) for passenger cars and light duty trucks were used to estimate emissions produced during the simulation hour over the network. The emissions rates are a function of miles traveled. To obtain the total vehicle miles travelled (VMT) for the purpose of estimating emissions, total fuel consumed over the simulation period as output by VISSIM is divided by the fuel consumption rates of passenger cars, accounting for 95% of the traffic volume, and light duty trucks, accounting for 5% of the traffic volume. Table 4-3 summaries network-wide performance results averaged over the five runs corresponding to five seed values. Note that VISSIM contains a tool for estimating emissions; however, there is little documentation and it appears that significant calibration work is required to produce meaningful results.

Table 4-2. Passenger Car and Light Truck Emission Rates (EPA Website)

Component	HC	CO	NO	CO2	Fuel Consumption
Passenger car Value (unit)	2.8(g)	20.9(g)	1.39(g)	0.916(pound)	0.0465(gallon)
Light Truck Value (unit)	3.51(g)	27.7 (g)	1.81(g)	1.15(pound)	0.0581 (gallon)

Table 4-3. Network-wide Measures

Network	Alternative 2030		Existing 2010		No Build 2030	
Direction	SB-AM	NB-PM	SB-AM	NB-PM	SB-AM	NB-PM
Total travel delay (hours)	388.4	1,230.5	970.7	1,053.9	1,377.9	2,341.0
Fuel Consumption (gallons)	489.6	586.5	545.3	497.0	611.7	726.3
HC (pounds)	64.9	77.8	72.3	65.9	81.1	96.3
CO (pounds)	486.5	582.8	541.9	493.9	607.8	721.7
NO (pounds)	32.3	38.7	36.0	32.8	40.4	47.9
CO_2 (pounds)	9,647.4	11,556.8	10,745.0	9,793.3	12,053.2	14,311.5

* 5% and 95% traffic compositions are assumed for passenger car and light truck in computing the emissions.

Given Existing 2010 results as a baseline, and increases in input volumes associated with Alternative 2030 and No Build 2030, results of the simulation runs indicate a 60% improvement in total travel delay for Alternative 2030 and a 41% deterioration in performance for No Build 2030 in the SB-AM direction. In the NB-PM direction, deterioration in performance by 17% and 122% for Alternative 2030 and No Build 2030, respectively, is expected. The performance deterioration for Alternative 2030 in the NB-PM direction appears to be the result of the bottleneck that forms at the MD 117 interchange.

In the SB-AM direction, a 10% decrease in fuel consumption and resulting emissions is predicted for Alternative 2030, while a 12% increase is expected for No Build 2030. In the NB-PM direction, increase in fuel consumption and emissions by 18% and 46% for Alternative 2030 and No Build 2030, respectively, is expected.

Chapter 5 Conclusions and Findings

In this study, the VISSIM micro-simulation platform was employed to model the entirety of I-270 under the existing geometric design. The model covers a total of 82 miles from I-70 to the interchanges at Connecticut Avenue (MD 185) in Maryland and Georgetown Pike (VA-193) in Virginia of the I-495 Capitol Beltway in both SB-AM and NB-PM directions. The purpose of the model is to replicate peak period traffic operations, morning peak in the SB-AM direction and evening peak in the NB-PM direction. The model required input in the form of roadway geometry, on- and off-ramp volumes, vehicle classification and vehicle occupancy along GP, HOV, and CD lanes. The model was calibrated against surveyed segment travel times and evaluated against main lane volumes and segment densities. Results of the calibration and post-calibration evaluation confirm VISSIM's ability to replicate real-world traffic operations along freeways with concurrent flow lanes.

This study also evaluated the potential benefits of a proposed ETL managed lane facility design for forecast year 2030 along the I-270 freeway between interchanges at I-370 and I-70. VISSIM models were developed to replicate this segment in both SB-AM and NB-PM directions for a total of 46 miles. This simulation model adopted the parameter set identified in the calibration effort. Traffic performance in terms of average travel time, total travel delay, emissions and fuel consumption under the proposed managed lane design was evaluated and compared with that of the existing facility design given 2010 and predicted 2030 traffic demand levels. Simulation run results predicts that traffic performance, in terms of average travel time, total delay, fuel consumption and emissions, will significantly degrade under 2030 demand estimates given no facility upgrade. Construction of ETLs is expected to lead to improved roadway performance in terms of the same metrics in the SB-AM direction. In the NB-PM direction, however, such improvements are not predicted. This appears to be due to a likely bottleneck at one of the off-ramps that leads to significantly degraded performance of the GP lanes.

It is anticipated that the developed models will have significant utility for future simulation studies in the region. Insights gleaned from the calibration effort, along with the identified set of parameters, are expected to provide useful input for VISSIM simulation models of freeways more broadly.

References

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Appendix 2-1: Travel Time for Calibration

Southbound Direction A.M. Peak Travel Time:

I-270 (A.M. Peak Direction - Southbound)													
		Run Date:	01-Apr-04	Run Date:	20-Apr-04	Run Date:	21-Apr-04	Run Date:	22-Apr-04	Run Date:	27-Apr-04	Run Date:	28-Apr-04
		Start Time:	6:30:00	Start Time:	7:00:00	Start Time:	7:00:00	Start Time:	7:00:00	Start Time:	7:45:00	Start Time:	7:30:00
Landmarks	Mile	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)
Md. 109	0.00	6:30:00	6:30:00	7:00:00	7:00:00	7:00:00	7:00:00	7:00:00	7:00:00	7:45:00	7:45:00	7:30:00	7:30:00
Hyattstown scales	1.50	6:33:09	6:33:12	7:01:35	7:01:57	7:03:37	7:03:37	7:01:27	7:01:39	7:46:33	7:46:44	7:31:52	7:32:09
Md. 121	3.90	6:36:16	6:36:35	7:03:59	7:04:22	7:06:18	7:06:12	7:04:17	7:04:11	7:49:10	7:49:04	7:34:35	7:34:39
Md. 27 (Father Hurley Blvd.)	6.50	6:41:49	6:42:15	7:06:11	7:06:45	7:09:08	7:08:52	7:08:01	7:07:37	7:53:11	7:52:40	7:39:08	7:39:25
Md. 118 (Germantown Rd.)	7.50	6:45:59	6:47:15	7:08:59	7:10:07	7:12:31	7:12:41	7:10:21	7:10:02	7:56:59	7:57:01	7:43:44	7:44:03
Middlebrook Rd.	8.30	6:48:11	-	7:10:23	-	7:13:46	7:14:14	7:11:36	7:11:26	7:59:06	7:59:28	7:45:23	7:46:21
Md. 124 (Quince Orchard Rd.)	10.80	6:53:09	6:54:14	7:14:55	7:16:05	7:19:25	7:19:26	7:16:44	7:16:24	8:03:47	8:03:52	7:52:10	7:53:27
Md. 117 (Clopper Rd.)	11.50	6:54:13	6:55:13	7:15:44	7:20:28	7:20:38	7:20:30	7:17:33	7:17:18	8:04:40	8:04:52	7:53:29	7:54:37
Begin HOV													
I-370 (Sam Eig Hwy.)	13.00	6:55:36	6:57:17	7:17:46	7:22:00	7:24:48	7:24:38	7:20:01	7:19:41	8:06:30	8:07:31	7:55:32	7:58:14
Shady Grove Rd.	13.90	6:56:19	7:00:36	7:19:39	7:25:15	7:25:38	7:29:01	7:22:50	7:23:57	8:07:00	8:11:00	7:56:51	8:03:02
Md. 28 (W. Montgomery Ave.	15.90	7:01:22	7:05:24	7:23:29	7:29:52	7:30:57	7:32:41	7:28:14	7:28:10	8:10:41	8:15:54	8:01:02	8:09:44
Md. 189 (Falls Rd.)	16.80	7:02:44	7:07:51	7:24:38	7:31:02	7:32:22	7:34:18	7:30:40	7:30:31	8:11:47	8:16:58	8:02:25	8:12:25
Montrose Rd.	18.20	7:04:45	7:12:17	7:26:09	7:33:51	7:34:10	7:36:58	7:33:30	7:33:58	8:13:14	8:18:44	8:04:12	8:15:46
Tuckerman Lane (I-270 "split"	19.60	7:07:01	7:16:06	7:28:06	7:36:54	7:35:50	7:38:53	7:35:26	7:35:52	8:14:51	8:20:19	8:05:44	8:17:42
Md. 187 (Old Georgetown Rd.	20.80	7:08:16	7:17:07	7:29:26	7:38:00	7:37:00	7:39:45	7:36:40	7:36:58	8:16:10	8:21:17	8:06:54	8:18:40
End HOV	21.80	7:09:10	7:21:19	7:30:22	7:39:23	7:38:22	7:41:23	7:37:42	7:38:12	8:17:29	8:22:29	8:07:52	8:20:01
Md. 355/I-495 "split"	22.20	7:09:39	7:18:34	7:30:44	7:39:45	7:39:07	7:41:39	7:38:02	7:38:32	8:18:09	8:22:52	8:08:11	8:20:29
Exit 33 to Connecticut Ave.	24.10	7:12:10	7:21:09	7:36:42	7:44:35	7:41:36	7:46:33	7:40:35	7:41:12	8:24:01	8:30:50	8:12:11	8:24:42

I-270 Spur (A.M. Peak Direction - Southbound)													
		Run Date:	01-Apr-04	Run Date:	20-Apr-04	Run Date:	21-Apr-04	Run Date:	22-Apr-04	Run Date:	27-Apr-04	Run Date:	28-Apr-04
		Start Time:	6:30:00	Start Time:	7:00:00	Start Time:	7:00:00	Start Time:	7:00:00	Start Time:	7:45:00	Start Time:	7:30:00
Landmarks	Mile	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)
Md. 109	0.00	-	6:30:00	-	7:00:00	7:35:00	7:35:00	7:00:00	7:00:00	7:30:00	7:30:00	7:30:00	-
Hyattstown scales	1.50	-	6:32:46	-	7:02:00	7:36:46	7:36:56	7:01:49	7:01:34	7:32:06	7:32:09	7:31:48	-
Md. 121	3.90	-	6:36:12	-	7:04:22	7:39:15	7:39:27	7:04:19	7:04:14	7:34:33	7:34:35	7:34:35	-
Md. 27 (Father Hurley Blvd.)	6.60	-	6:40:14	-	7:06:46	7:44:21	7:45:13	7:08:11	7:07:42	7:39:11	7:39:18	7:37:03	-
Md. 118 (Germantown Rd.)	7.60	-	6:47:31	-	7:10:12	7:51:20	7:52:41	7:10:02	7:10:07	7:43:50	7:43:59	7:42:49	-
Middlebrook Rd.	8.30	-	6:51:54	-	7:11:14	7:53:01	7:54:27	7:11:45	7:11:27	7:45:25	7:45:35	7:45:06	-
Md. 124 (Quince Orchard Rd.)	10.80	-	6:54:43	-	7:15:58	7:57:50	7:59:16	7:17:43	7:16:22	7:52:11	7:54:25	7:49:42	-
Md. 117 (Clopper Rd.)	11.50	-	6:55:52	-	7:16:56	7:58:49	8:00:34	7:18:03	7:17:15	7:53:40	7:55:10	7:50:45	-
Begin Concurrent-flow HOV		-		-									-
I-370 (Sam Eig Hwy.)	13.00	-	6:58:10	-	7:20:02	8:00:46	8:03:33	7:19:55	7:19:51	7:55:28	7:57:59	7:52:34	-
Shady Grove Rd.	13.90	-	7:01:44	-	7:20:37	8:02:04	8:06:59	7:22:56	7:23:56	7:56:51	8:02:40	7:53:55	-
Md. 28 (W. Montgomery Ave.	15.90	-	7:07:22	-	7:25:15	8:05:50	8:12:15	7:28:02	7:29:15	8:01:03	8:09:50	7:57:28	-
Md. 189 (Falls Rd.)	16.80	-	7:10:02	-	7:31:34	8:07:02	8:14:03	7:30:41	7:31:07	8:02:24	8:12:15	7:58:42	-
Montrose Rd.	18.20	-	7:14:27	-	7:34:15	8:10:34	8:16:58	7:33:34	7:34:22	8:04:12	8:15:51	8:00:39	-
Tuckerman Lane (I-270 "split"	19.60	-	7:18:57	-	7:36:55	-	8:19:19	7:34:54	7:36:15	8:05:41	8:18:03	8:02:23	-
Democracy Blvd.	20.70	-	7:22:50	-	7:38:12	-	8:21:18	7:37:23	7:38:55	8:06:36	8:19:27	8:03:17	-
End HOV		-		-		-							-
End I-270 spur - begin I-495	21.60	-	7:22:40	-	7:39:05	-	8:22:47	7:38:09	7:40:48	8:06:49	8:20:00	8:04:46	-
Md. 191 (Bradley Blvd.)	21.70	-	7:24:12	-	7:40:02	-	8:23:09	7:39:00	7:40:57	8:07:01	8:21:00	8:04:55	-
Md. 190 (River Road)	23.00	-	7:28:12	-	7:42:14	-	8:25:36	7:40:56	7:43:13	8:13:28	8:24:44	8:13:16	-
Exit 41 to Clara Barton Parkway	24.70	-	-	-	-	-	-	-	-	-	-	-	-
Exit to Carderock	25.70	-	-	-	-	-	-	-	-	-	-	-	-

Northbound Direction P.M. Peak Travel Time:

I-270 (P.M. Peak Direction - Northbound)									
		Run Date:	01-May-07	Run Date:	02-May-07	Run Date:	03-May-07	Run Date:	01-May-07
		Start Time:	16:30:00	Start Time:	16:00:00	Start Time:	16:00:00	Start Time:	16:00:00
Landmarks	Mile	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)
Enter I-495 from Md. 185 (Connecticut Avenue)	0.00	16:30:00	16:30:00	16:00:00	16:00:00	16:00:00	16:00:00	16:00:00	16:00:00
Begin I-270 concurrent-flow HOV lane	2.10	16:33:03	16:32:15	16:02:15	16:02:07	16:02:36	16:03:49	16:02:07	16:02:06
Md. 187 (Old Georgetown Rd.)	3.60	16:34:43	16:35:16	16:03:41	16:04:25	16:04:06	16:07:47	16:04:25	16:04:21
Tuckerman Lane (I-270 "split")	4.80	16:36:05	16:37:55	16:04:49	16:05:52	16:05:16	16:10:50	16:05:52	16:07:07
Montrose Rd.	6.20	16:37:27	16:39:21	16:06:09	16:07:32	16:06:55	16:12:26	16:07:32	16:08:38
Md. 189 (Falls Rd.)	7.60	16:38:39	16:40:47	16:07:25	16:08:59	16:08:09	16:13:59	16:08:59	16:10:49
Md. 28 (W. Montgomery Ave.)	8.60	16:39:28	16:41:49	16:08:25	16:10:16	16:09:01	16:16:09	16:10:16	16:12:34
Shady Grove Rd.	10.50	16:40:22	16:43:40	16:10:18	16:11:52	16:10:48	16:17:27	16:11:52	16:14:27
I-370 (Sam Eig Hwy.)	11.40	16:41:22	16:44:32	16:11:01	16:12:39	16:11:32	16:18:12	16:12:39	16:15:15
Md. 117 (Clopper Rd.)	12.90	16:43:37	16:46:32	16:12:54	16:14:49	16:13:17	16:20:13	16:14:49	16:17:08
Md. 124 (Quince Orchard Rd.)	13.50	16:45:20	16:48:12	16:13:38	16:15:48	16:13:55	16:21:05	16:15:48	16:18:36
Middlebrook Rd.	16.00	16:46:22	16:52:35	16:16:03	16:22:39	16:16:41	16:26:01	16:22:39	16:24:18
Md. 118 (Germantown Rd.)	16.80	16:47:06	16:53:19	16:16:43	16:23:38	16:17:37	16:27:07	16:23:38	16:25:15
Md. 27 (Father Hurley Blvd.)	17.80	16:48:15	16:55:33	16:17:39	16:25:17	16:18:44	16:29:10	16:25:17	16:28:10
Md. 121	20.50	16:51:50	17:00:47	16:20:07	16:31:21	16:22:44	16:34:11	16:31:21	16:31:35
(End concurrent-flow HOV lane)									
Hyattstown scales	22.90	16:55:34	17:07:48	16:25:05	16:34:52	16:26:37	16:37:36	16:34:52	16:35:12
Md. 109	24.80	16:59:16	17:09:07	16:26:19	16:38:57	16:28:16	16:39:24	16:38:57	16:37:07

I-270 Spur (P.M. Peak Direction - Northbound)														
		Run Date:	20-Apr-04	Run Date:	21-Apr-04	Run Date:	22-Apr-04	Run Date:	27-Apr-04	Run Date:	29-Apr-04	Run Date:	28-Apr-04
		Start Time:	16:00:00	Start Time:	16:15:00	Start Time:	16:30:00	Start Time:	16:30:00	Start Time:	16:30:00	Start Time:	16:30:00
Landmarks	Mile	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)	(HOV)	(Non-HOV)
Enter Clara Barton Parkway from Carderock	0.00	16:00:00	16:00:00	16:15:00	16:15:00	16:30:00	16:30:00	16:30:00	16:30:00	16:30:00	16:30:00	16:30:00	16:30:00
Md. 190 (River Road)	3.00	16:00:00	16:00:00	16:15:00	16:15:00	16:30:00	16:30:00	16:30:00	16:30:00	16:30:00	16:30:00	16:30:00	16:30:00
Begin concurrent-flow HOV	4.00	16:03:57	16:02:04	16:16:36	16:18:14	16:31:49	16:33:10	16:30:55	16:35:21	16:33:10	16:32:50	16:32:41	16:34:08
Md. 191 (Bradley Blvd.)	4.30	16:04:16	16:02:45	16:17:02	16:19:50	16:33:01	16:33:57	16:34:28	16:36:00	16:33:46	16:34:40	16:33:10	16:44:38
Begin I-270 Spur	4.60	16:04:31	16:03:08	16:17:28	16:20:25	16:33:19	16:34:30	16:34:49	16:36:27	16:34:02	16:35:28	16:34:17	16:35:12
Democracy Blvd.	5.30	16:05:24	16:03:58	16:18:20	16:22:17	16:34:18	16:36:22	16:35:48	16:38:35	16:34:32	16:37:12	16:35:41	16:37:00
Tuckerman Lane (I-270 "split")	6.50	16:06:56	16:05:28	16:19:38	16:24:21	16:35:45	16:38:40	16:38:15	16:41:09	16:43:59	16:39:10	16:36:59	16:39:22
Montrose Rd.	7.90	16:08:12	16:06:46	16:20:57	16:25:43	16:37:27	16:40:28	16:38:56	16:43:29	16:37:06	16:40:31	16:49:12	16:40:56
Md. 189 (Falls Rd.)	9.20	16:09:27	16:08:08	16:22:14	16:27:04	16:38:51	16:42:06	16:40:25	16:45:13	16:38:21	16:41:58	16:38:27	16:43:01
Md. 28 (W. Montgomery Ave.)	10.20	16:10:22	16:09:06	16:23:10	16:28:04	16:39:49	16:43:14	16:41:19	16:46:21	16:39:18	16:42:59	16:39:34	16:44:44
Shady Grove Rd.	12.10	16:12:04	16:10:57	16:24:59	16:29:59	16:41:30	16:45:16	16:43:08	16:48:23	16:40:57	16:44:53	16:41:22	16:46:45
I-370 (Sam Eig Hwy.)	13.00	16:12:48	16:11:50	16:25:53	16:30:59	16:42:20	16:46:13	16:43:57	16:49:19	16:41:45	16:45:44	16:42:13	16:47:44
Md. 117 (Clopper Rd.)	14.60	16:14:13	16:13:23	16:27:26	16:33:25	16:43:51	16:48:13	16:45:42	16:54:18	16:43:23	16:47:27	16:43:37	16:49:23
Md. 124 (Quince Orchard Rd.)	15.20	16:14:49	16:14:21	16:28:09	16:36:03	16:44:33	16:49:51	16:46:23	16:57:07	16:44:02	16:48:55	16:44:41	16:50:30
Middlebrook Rd.	17.70	16:17:24	16:19:26	16:30:38	16:39:59	16:47:22	16:54:23	16:49:10	17:00:20	16:46:52	16:58:21	16:47:06	16:56:30
Md. 118 (Germantown Rd.)	18.40	16:18:07	16:20:56	16:31:23	16:40:51	16:48:14	16:55:33	16:49:56	17:03:06	16:47:49	17:01:09	16:47:48	16:57:30
Md. 27 (Father Hurley Blvd.)	19.50	16:19:00	16:21:58	16:32:21	16:41:50	16:49:21	16:57:00	16:50:50	17:04:13	16:49:20	17:07:38	16:48:53	16:59:30
Md. 121	22.10	16:21:27	16:24:39	16:35:13	16:45:08	16:53:06	16:57:38	16:53:15	17:07:36	16:58:50	17:13:29	16:51:41	17:02:57
(End concurrent-flow HOV lane)													
Hyattstown scales	24.70	16:25:43	16:28:49	16:39:17	16:48:14	16:56:44	17:06:20	16:56:32	17:11:10	17:02:36	17:16:27	16:55:07	17:07:01
Md. 109	26.00	16:28:03	16:32:00	16:40:57	16:50:00	16:58:30	17:08:17	16:58:09	17:12:47	17:04:08	17:18:29	16:56:53	17:08:41

Appendix 2-2: Main Lane Volume for Calibration

01	**S2007150053**	**I-270 between MD 121 & MD 109**							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	3709	4135	0	0	0	**3861**
	16:00	0	0	3900	3486	0	0	0	
	17:00	0	0	4084	3754	0	0	0	
	18:00	0	0	3851	3970	0	0	0	
South	6:00	0	0	3915	3984	0	0	0	**4035**
	7:00	0	0	4153	4174	0	0	0	
	8:00	0	0	3935	4050	0	0	0	

02	**B2845**	**I-270-.50 MI N OF MD 121**							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	3965	4170	0	0	0	**3819**
	16:00	0	0	4136	3559	0	0	0	
	17:00	0	0	3737	3684	0	0	0	
	18:00	0	0	3676	3622	0	0	0	
South	6:00	0	0	3957	3863	0	0	0	**3906**
	7:00	0	0	4164	3727	0	0	0	
	8:00	0	0	4129	3594	0	0	0	

03	**B150050**	**I-270-.40 MI S OF MD 121 (ATR0004)**							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	4630	4877	0	0	0	**4433**
	16:00	0	0	4787	4165	0	0	0	
	17:00	0	0	4625	4286	0	0	0	
	18:00	0	0	4086	4004	0	0	0	
South	6:00	0	0	4992	4856	0	0	0	**4610**
	7:00	0	0	4583	4474	0	0	0	
	8:00	0	0	4552	4205	0	0	0	

04	**S1999150048**	**I-270 -.10 MI SOUTH OF STRUC#15040(LITTLE SENECA CREEK)(ATR#04)**							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	0	4895	0	0	0	**4414**
	16:00	0	0	0	4778	0	0	0	
	17:00	0	0	0	4410	0	0	0	
	18:00	0	0	0	3572	0	0	0	
South	6:00	0	0	0	4232	0	0	0	**4104**
	7:00	0	0	0	4124	0	0	0	
	8:00	0	0	0	3955	0	0	0	

05	B150010	I-270-.40 MI N OF MD 118							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	4989	5975	0	0	0	**5236**
	16:00	0	0	5523	5383	0	0	0	
	17:00	0	0	5172	5236	0	0	0	
	18:00	0	0	4578	5029	0	0	0	
South	6:00	0	0	5945	6046	0	0	0	**5305**
	7:00	0	0	5135	5212	0	0	0	
	8:00	0	0	4756	4738	0	0	0	

06	B2968	I-270-.10 MI S OF MD 118							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	0	6631	6493	0	0	**6175**
	16:00	0	0	0	6240	5834	0	0	
	17:00	0	0	0	6318	5506	0	0	
	18:00	0	0	0	6003	6378	0	0	
South	6:00	0	0	0	6302	6642	0	0	**6010**
	7:00	0	0	0	5625	6158	0	0	
	8:00	0	0	0	5470	5865	0	0	

07	B150053	I-270-.50 MI S OF MIDDLEBROOK RD (ATR0060)							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	7779	7658	0	0	0	**7210**
	16:00	0	0	7012	6595	0	0	0	
	17:00	0	0	7564	6539	0	0	0	
	18:00	0	0	7291	7238	0	0	0	
South	6:00	0	0	7900	7771	0	0	0	**6817**
	7:00	0	0	6341	6322	0	0	0	
	8:00	0	0	6460	6108	0	0	0	

08	B2967	I-270-.10 MI S OF MD 124							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	8026	8197	0	0	0	**8049**
	16:00	0	0	8451	7963	0	0	0	
	17:00	0	0	8090	7541	0	0	0	
	18:00	0	0	8053	8068	0	0	0	
South	6:00	0	0	8636	8461	0	0	0	**7903**
	7:00	0	0	8491	8168	0	0	0	
	8:00	0	0	7027	6637	0	0	0	

09	B2966	I-270-.10 MI N OF I-370							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	9516	10264	0	0	0	**9831**
	16:00	0	0	10310	10498	0	0	0	
	17:00	0	0	10214	10429	0	0	0	
	18:00	0	0	8079	9335	0	0	0	
South	6:00	0	0	10107	10204	0	0	0	**9405**
	7:00	0	0	9226	9572	0	0	0	
	8:00	0	0	8175	9147	0	0	0	

10	B2965	I-270-.10 MI N OF SHADY GROVE RD							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	9637	10421	0	0	0	**9756**
	16:00	0	0	9972	10612	0	0	0	
	17:00	0	0	9715	10171	0	0	0	
	18:00	0	0	8272	9249	0	0	0	
South	6:00	0	0	11124	11405	0	0	0	**9844**
	7:00	0	0	9513	9915	0	0	0	
	8:00	0	0	7985	9120	0	0	0	

11	B2847	I-270-.50 MI N OF MD 28							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	0	10872	11163	0	0	**10561**
	16:00	0	0	0	10071	11446	0	0	
	17:00	0	0	0	9793	11099	0	0	
	18:00	0	0	0	9476	10570	0	0	
South	6:00	0	0	0	10682	10792	0	0	**9603**
	7:00	0	0	0	8964	9665	0	0	
	8:00	0	0	0	7659	9857	0	0	

12	B2848	I-270-.10 MI S OF MD 28							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	11212	11452	0	0	0	**11260**
	16:00	0	0	11469	11635	0	0	0	
	17:00	0	0	11490	11348	0	0	0	
	18:00	0	0	10730	10745	0	0	0	
South	6:00	0	0	11473	11627	0	0	0	**10494**
	7:00	0	0	10158	10065	0	0	0	
	8:00	0	0	9600	10042	0	0	0	

13	B2849	I-270-.20 MI N OF MD 927 (MONTROSE RD)							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	11438	11575	0	0	0	**11341**
	16:00	0	0	11047	11592	0	0	0	
	17:00	0	0	11429	11520	0	0	0	
	18:00	0	0	10771	11358	0	0	0	
South	6:00	0	0	11527	11271	0	0	0	**11215**
	7:00	0	0	11291	11284	0	0	0	
	8:00	0	0	10937	10978	0	0	0	
14	**B2850**	**I-270-.10 MI N OF TUCKERMAN LA**							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	11321	11537	0	0	0	**11090**
	16:00	0	0	10654	11239	0	0	0	
	17:00	0	0	11195	11161	0	0	0	
	18:00	0	0	10264	11351	0	0	0	
South	6:00	0	0	11441	11280	0	0	0	**11461**
	7:00	0	0	11518	11552	0	0	0	
	8:00	0	0	11402	11571	0	0	0	
15	**B2851**	**I-270Y-.50 MI N OF DEMOCRACY BLVD**							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	5535	5548	0	0	0	**5499**
	16:00	0	0	5496	5336	0	0	0	
	17:00	0	0	5521	5450	0	0	0	
	18:00	0	0	5545	5560	0	0	0	
South	6:00	0	0	4616	4891	0	0	0	**4836**
	7:00	0	0	4698	4639	0	0	0	
	8:00	0	0	5033	5139	0	0	0	
16	**B2963**	**I-270Y-.10 MI S OF DEMOCRACY BLVD**							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	5103	5294	0	0	0	**4603**
	16:00	0	0	4301	4337	0	0	0	
	17:00	0	0	4067	4386	0	0	0	
	18:00	0	0	4700	4639	0	0	0	
South	6:00	0	0	5293	5296	0	0	0	**5176**
	7:00	0	0	5085	5421	0	0	0	
	8:00	0	0	5074	4885	0	0	0	

17	B150052	I-495-.10 MI E OF STRUC #15105(PERSIMMON TREE RD) (ATR0040)							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	0	8155	8443	0	0	**6649**
	16:00	0	0	0	5536	6522	0	0	
	17:00	0	0	0	5069	6109	0	0	
	18:00	0	0	0	6301	7056	0	0	
South	6:00	0	0	0	7696	7691	0	0	**7800**
	7:00	0	0	0	8021	8688	0	0	
	8:00	0	0	0	7288	8613	0	0	

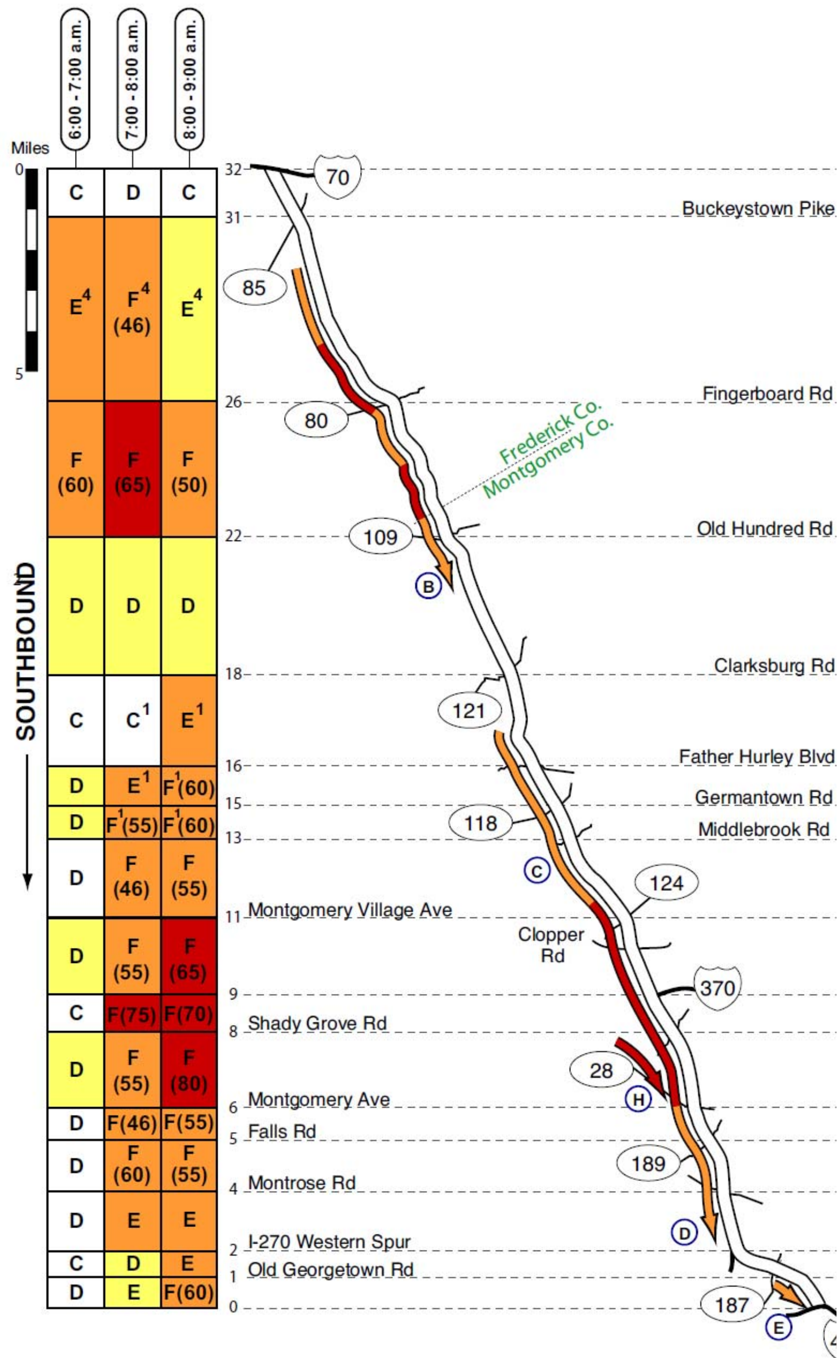
18	B2964	I-270-.30 MI N OF MD 187B							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	5690	5472	0	0	0	**4970**
	16:00	0	0	4812	5403	0	0	0	
	17:00	0	0	3965	5528	0	0	0	
	18:00	0	0	4494	4395	0	0	0	
South	6:00	0	0	5393	5340	0	0	0	**5637**
	7:00	0	0	5536	5330	0	0	0	
	8:00	0	0	6137	6083	0	0	0	

19	B2852	I-270-.10 MI S OF MD 187							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	4917	4922	0	0	0	**4337**
	16:00	0	0	4506	4327	0	0	0	
	17:00	0	0	3462	3862	0	0	0	
	18:00	0	0	4474	4223	0	0	0	
South	6:00	0	0	4875	4758	0	0	0	**4610**
	7:00	0	0	4516	4864	0	0	0	
	8:00	0	0	4394	4252	0	0	0	

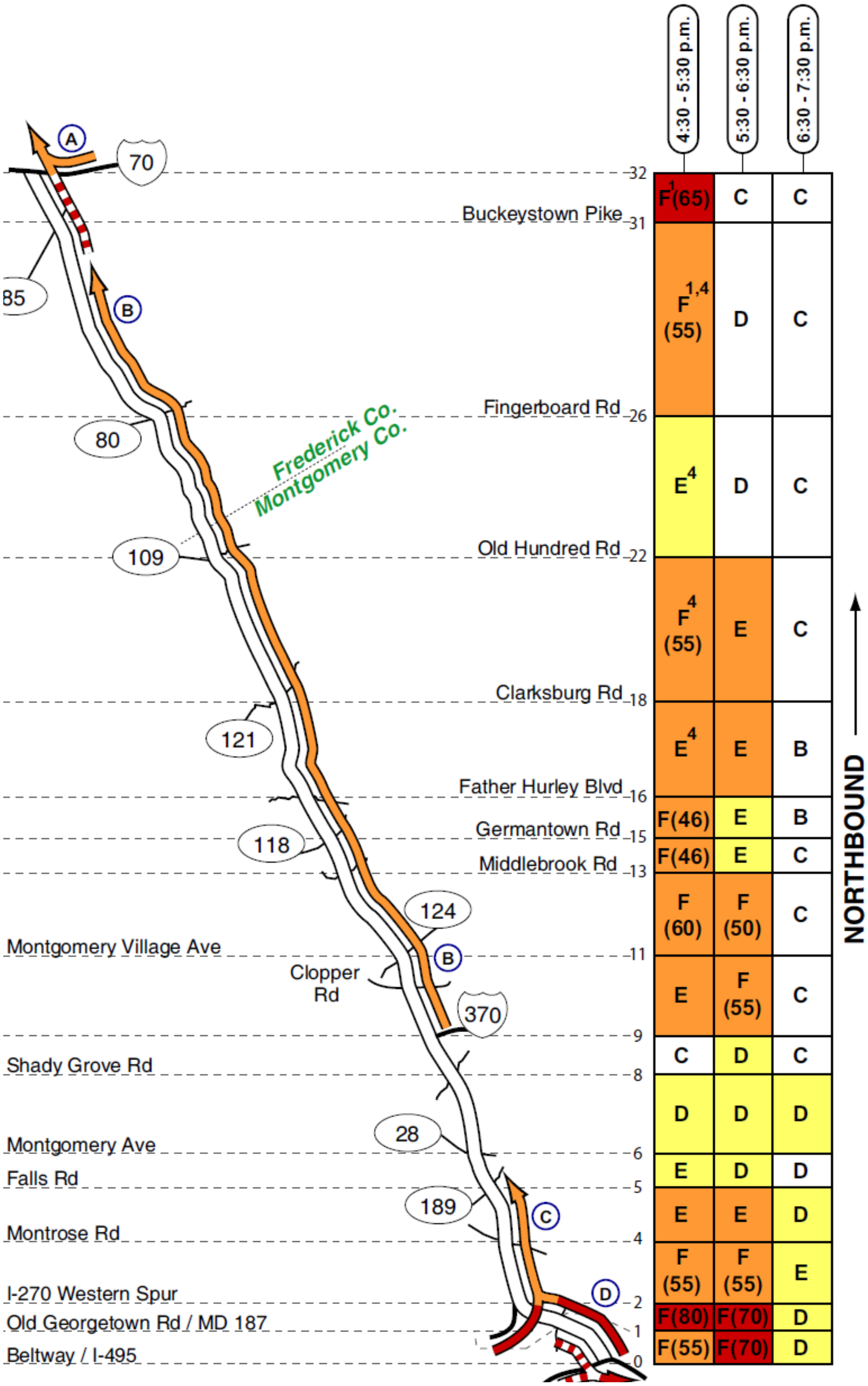
20	B2971	I-495-.20 MI E OF MD 355							
		Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	**Daily Average**
North	15:00	0	0	0	6585	7062	0	0	**6016**
	16:00	0	0	0	5408	5550	0	0	
	17:00	0	0	0	5352	5601	0	0	
	18:00	0	0	0	6276	6292	0	0	
South	6:00	0	0	0	7656	8176	0	0	**8492**
	7:00	0	0	0	8569	8811	0	0	
	8:00	0	0	0	8821	8920	0	0	

Appendix 2-3: Traffic Quality Rating

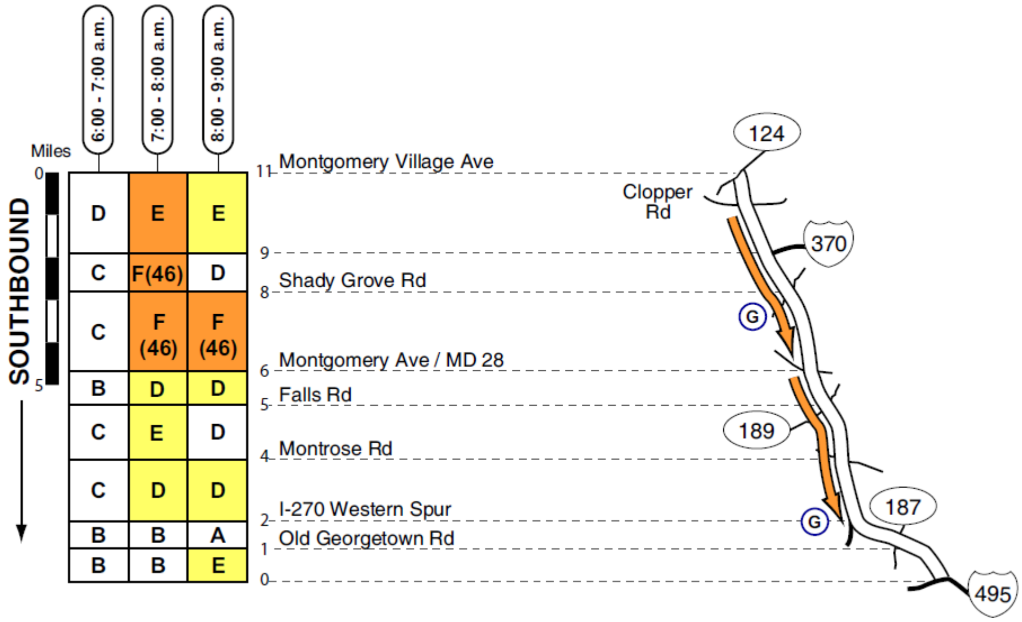
1. I-270 Southbound Morning Peak (6:00A.M.-9:00A.M.)



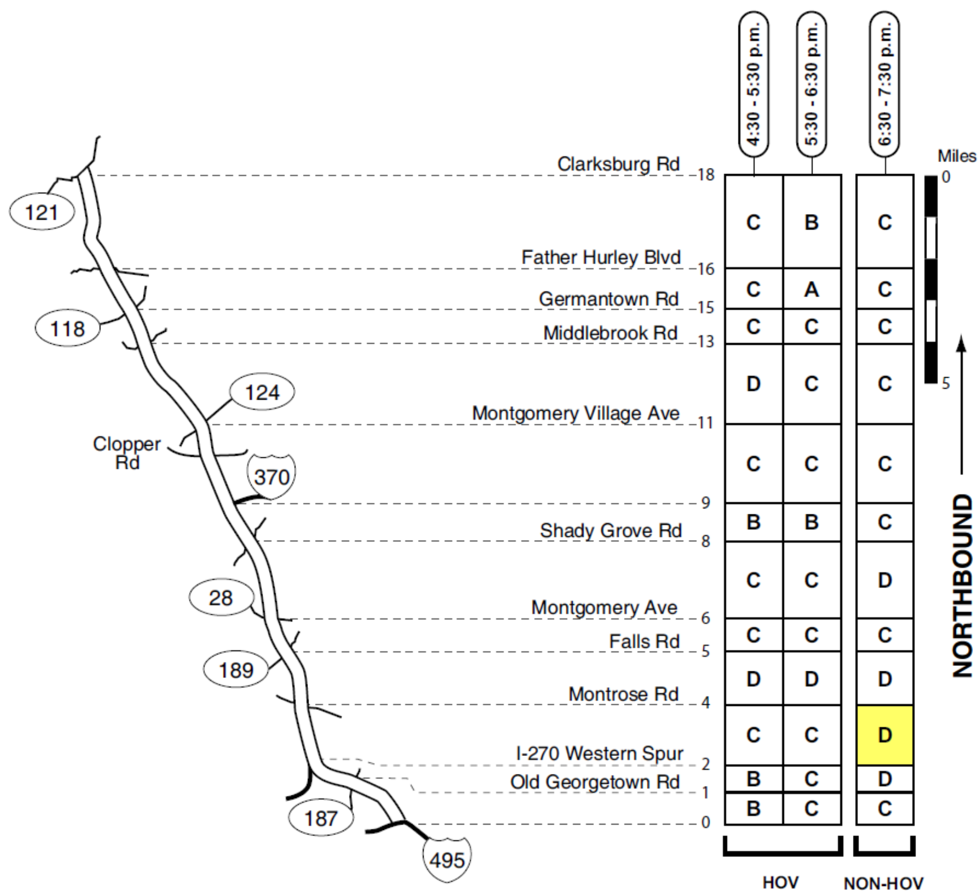
2. I-270 Northbound Evening Peak (4:30P.M.-7:30P.M.)



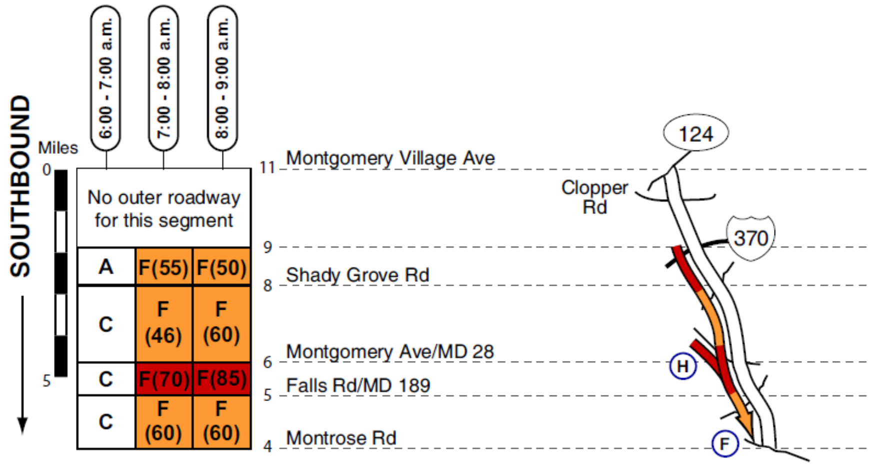
3. HOV Southbound Morning Peak (6:00A.M.-9:00A.M.)



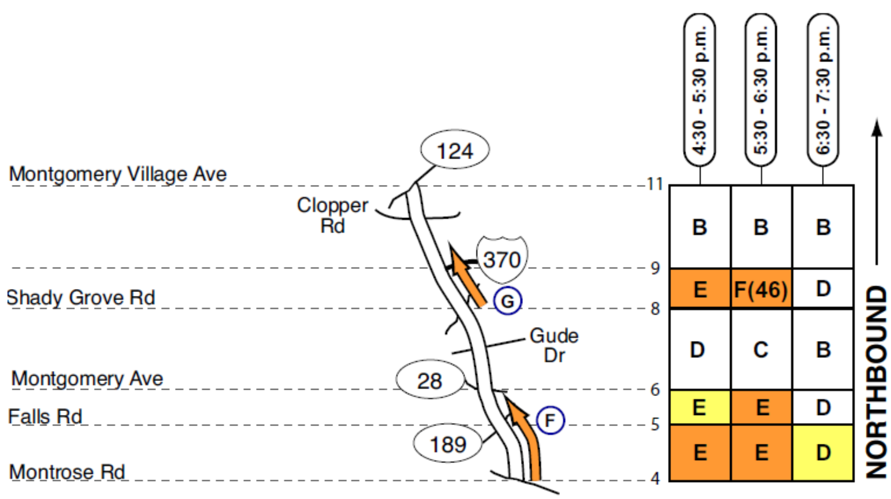
4. HOV Northbound Evening Peak (4:30P.M.-7:30P.M.)



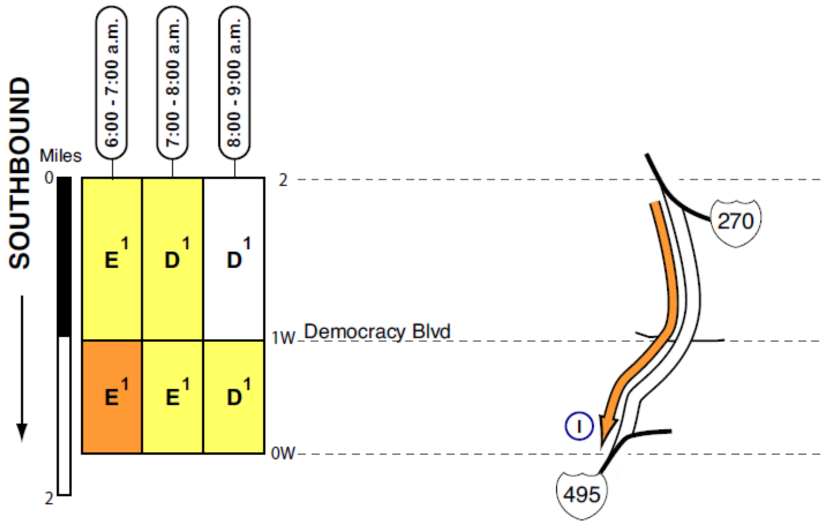
5. CD Lane Southbound Morning Peak (6:00A.M.-9:00A.M.)



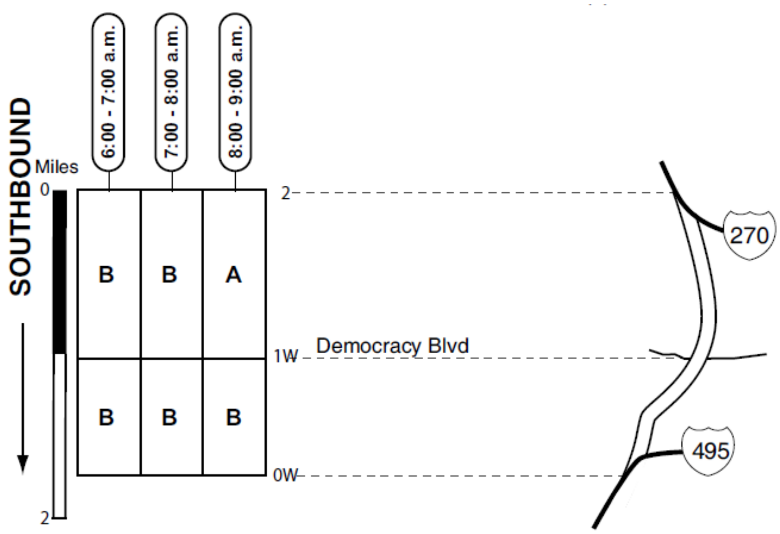
6. CD Lane Northbound Evening Peak (4:30P.M.-7:30P.M.)



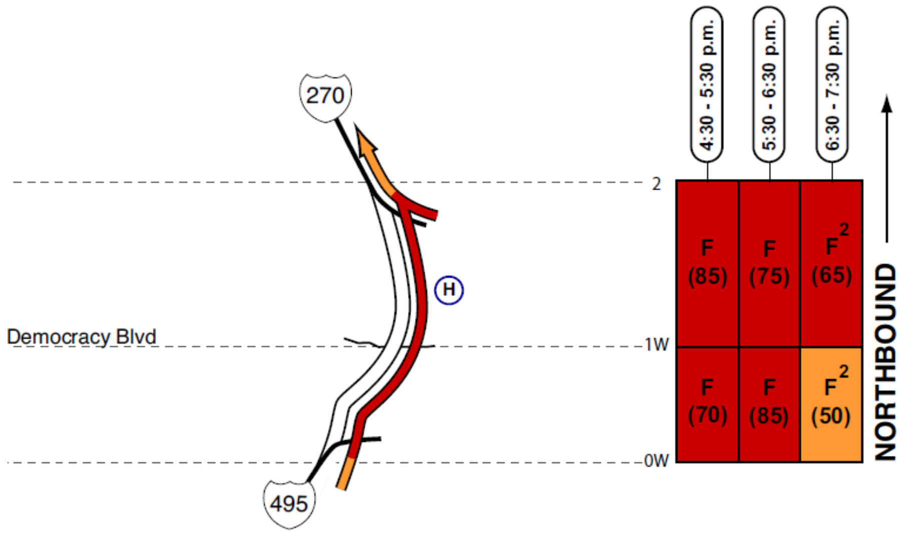
7. **Western Spur GP Southbound Morning Peak (6:00A.M.-9:00A.M.)**



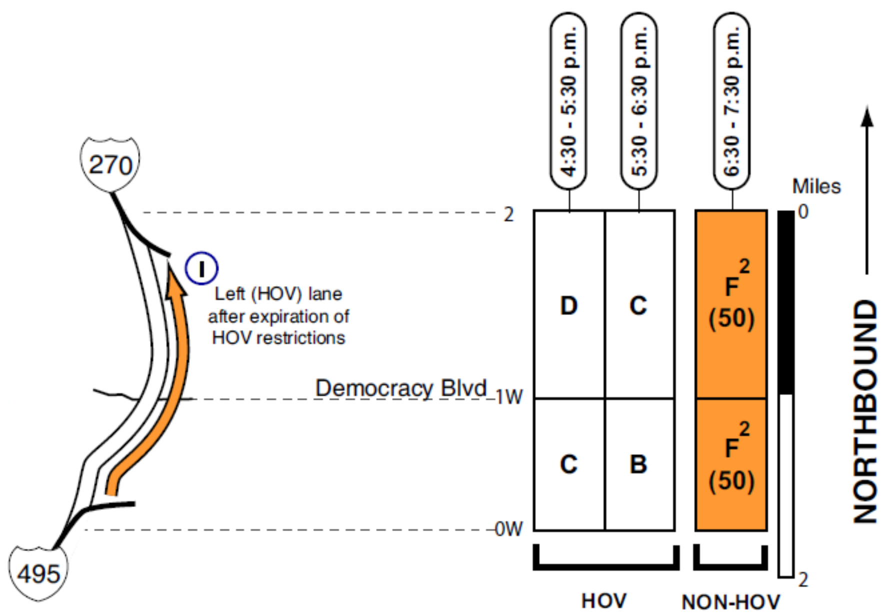
8. **Western Spur HOV Southbound Morning Peak (6:00A.M.-9:00A.M.)**



9. Western Spur GP Northbound Evening Peak (4:30P.M.-7:30P.M.)



10. Western Spur HOV Northbound Evening Peak (4:30P.M.-7:30P.M.)

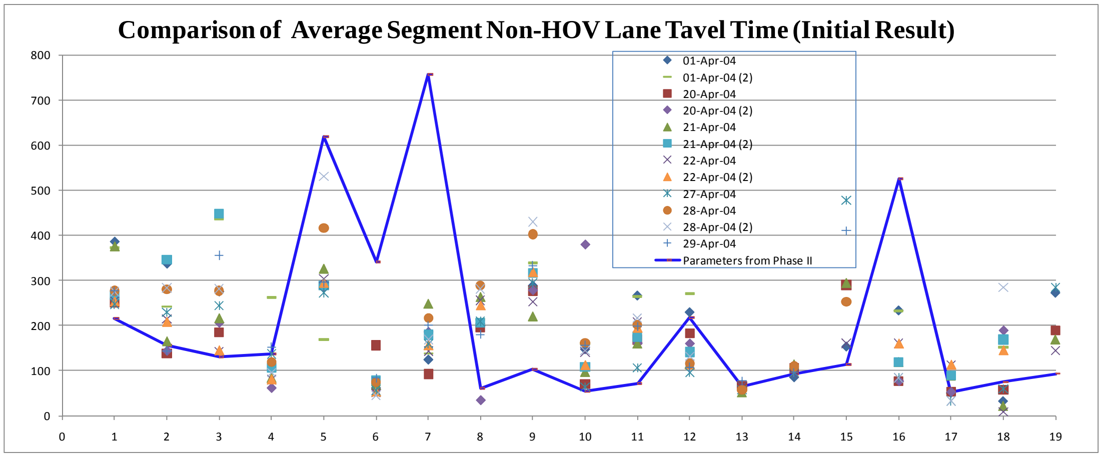


Appendix 3-1: 2k Factorial Design Points

Table3-3. 2^k Factorial Design Points

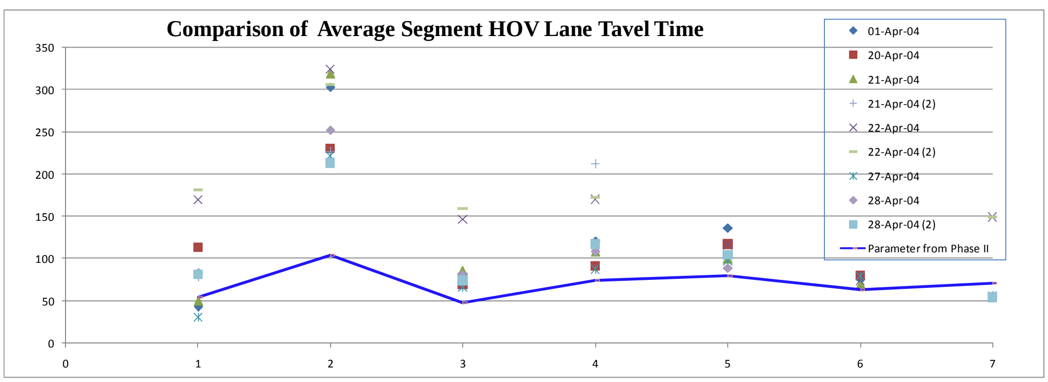
Design Point	CC1	CC2	CC4&5	SDRF	LBD	Design Point	CC1	CC2	CC4&5	SDRF	LBD
1	0.9	13.12	0.1	0.1	328.08	17	0.9	13.12	0.1	0.1	3280.83
2	1.5	13.12	0.1	0.1	328.08	18	1.5	13.12	0.1	0.1	3280.83
3	0.9	65.62	0.1	0.1	328.08	19	0.9	65.62	0.1	0.1	3280.83
4	1.5	65.62	0.1	0.1	328.08	20	1.5	65.62	0.1	0.1	3280.83
5	0.9	13.12	2	0.1	328.08	21	0.9	13.12	2	0.1	3280.83
6	1.5	13.12	2	0.1	328.08	22	1.5	13.12	2	0.1	3280.83
7	0.9	65.62	2	0.1	328.08	23	0.9	65.62	2	0.1	3280.83
8	1.5	65.62	2	0.1	328.08	24	1.5	65.62	2	0.1	3280.83
9	0.9	13.12	0.1	0.9	328.08	25	0.9	13.12	0.1	0.9	3280.83
10	1.5	13.12	0.1	0.9	328.08	26	1.5	13.12	0.1	0.9	3280.83
11	0.9	65.62	0.1	0.9	328.08	27	0.9	65.62	0.1	0.9	3280.83
12	1.5	65.62	0.1	0.9	328.08	28	1.5	65.62	0.1	0.9	3280.83
13	0.9	13.12	2	0.9	328.08	29	0.9	13.12	2	0.9	3280.83
14	1.5	13.12	2	0.9	328.08	30	1.5	13.12	2	0.9	3280.83
15	0.9	65.62	2	0.9	328.08	31	0.9	65.62	2	0.9	3280.83
16	1.5	65.62	2	0.9	328.08	32	1.5	65.62	2	0.9	3280.83

Appendix 3-2: Initial Results Using Phase II Parameter Set with No Additional Tuning



1	MD-109 to MD-121	5	Middlebrook to MD-124	9	ShaddyGrove to MD-28	13	Spur to MD-187	17	Democracy to Begin 495
2	MD-121 to MD-27	6	MD-124 to MD-117	10	MD-28 to MD-189	14	MD-187 to MD-355/I-495 Split	18	Begin I-495 to MD-190
3	MD-27 to MD-118	7	MD-117 to MD-370	11	MD-189 to Montrose Rd	15	355/495 Split to MD-185	19	MD-190 to Clara Barton Pkwy
4	MD-118 to Middlebrook	8	MD-370 to Shaddy Grove	12	Montrose Rd to Spur	16	I-270 Spur to Democracy		

Figure 1: Comparison of Southbound GP Lane Travel Times



1	MD-370 to Shady Grove(HOV)	5	Montrose Rd to Spur (HOV)
2	Shady Grove to MD-28(HOV)	6	Spur to MD-187 (HOV)
3	MD-28 to MD-189 (HOV)	7	I-270 Spur to Democracy(HOV)
4	MD-189 to Montrose Rd (HOV)		

Figure 2: Comparison of Southbound HOV Lane Travel Times

Appendix 3-3: Location Details of On- and Off-ramps in the Existing Network

Collection Points for Southbound Input

Point Code	Link #	Link Name	Point Code	Link #	Link Name
2011	1	N I-70	**2441**	126	on ramp from Montrose E
2021	2	on ramp from I-70	**2471**	131	HOV West Spur
2031	5	on ramp from I-70E	**2481**	136	HOV West Spur con
2051	11	on ramp from MD 85S	**2521**	140	on ramp from DemocracyBlvd
2071	15	on ramp from MD 85N	**2531**	144	S 495 spur west
2091	20	on ramp from MD 80E	**2551**	149	on ramp from MD 190W
2111	26	on ramp from MD 109E	**2581**	155	on ramp from MD 190 E
2131	38	on ramp from MD 121W	**2611**	167	on ramp from Clara
2151	44	on ramp from MD 120W	**2641**	174	on ramp from George Washington MP
2161	47	on ramp from MD 120E	**2671**	180	on ramp from Georgetown
2181	51	on ramp from MD 118S	**2691**	184	on ramp from Rockledge
2191	54	on ramp from MD 118N	**2701**	187	on ramp from Old Georgetown
2201	57	on ramp from Middlebrook	**2721**	191	S 495 spur East
2221	62	on ramp from MD 124S	**2741**	192	S 495 spur East merge
2231	65	on ramp from MD 117 W	**2751**	196	on ramp from 355S
2261	73	on ramp from I-370	**2761**	197	on ramp from 355 N
2291	81	on ramp from Shady Grove S	**2721**	191	S 495 spur East
2301	84	on ramp from Shady GroveN	**2741**	192	S 495 spur East merge
2351	100	on ramp from MD 28 W	**2751**	196	on ramp from 355S
2361	103	on ramp from MD 28 E	**2761**	197	on ramp from 355 N
2391	113	on ramp from MD 189	**2771**	201	S 495 east S10
2421	122	on ramp from Montrose W			

Collection Points for Southbound Output

Point Code	Link #	Link Name	Point Code	Link #	Link Name
2042	9	off ramp to MD 85S	**2412**	120	off ramp to Montrose W
2062	14	off ramp to MD 85N	**2432**	124	off ramp to Montrose E
2082	19	off ramp to MD 80E	**2492**	135	off ramp to Fernwood Rd.
2102	24	off ramp to MD 109 E	**2512**	139	off ramp to DemocracyBlvd
2122	36	off ramp to MD 121W	**2562**	153	off ramp to MD 190
2142	42	off ramp to MD 120W	**2572**	158	S 495 west CD6
2172	49	off ramp to MD 118S	**2602**	165	off ramp to Clara
2212	61	off ramp to MD 124S	**2632**	172	off ramp to George Washington MP
2242	69	off ramp to I-370	**2652**	177	off ramp to Georgetown
2282	80	off ramp to Shady Grove	**2682**	182	off ramp to Rockledge
2342	98	off ramp to MD 28	**2712**	194	off ramp to 355S
2382	111	off ramp to MD 189	**2732**	193	off rampt to 355S

Collection Points for Northbound Input

Point Code	Link #	Link Name	Point Code	Link #	Link Name
4021	424	on ramp from MD 85	**4451**	285	on ramp from Montrosse W
4041	418	on ramp from MD 85 N	**4471**	281	on ramp from Montrose E
4061	406	on rampt from MD 80	**4501**	238	on ramp from Democracy Blvd
4081	400	on ramp from MD 109	**4511**	236	on ramp from Democracy Blvd
4101	388	on ramp from MD 121	**4531**	226	on ramp from River Rd
4121	382	on ramp from MD 120 S	**4541**	224	on ramp from Local
4131	379	on ramp from MD 120 N	**4561**	218	on ramp from Clara Barton Pkwy
4151	375	on ramp from MD 118	**4581**	214	on ramp from George Washington Pkwy
4201	359	on ramp from MD 124 S	**4601**	210	on ramp from Georgetown Pike
4211	356	on ramp from MD 124 N	**4621**	207	N 495 west N1
4261	343	on ramp from I-370 W	**4631**	268	on ramp from Rockledge Dr
4271	340	on ramp from I-370 E	**4661**	259	on ramp from MD 355 S
4301	330	on ramp from Shady Grove S	**4681**	254	on ramp from MD 355 S
4311	325	on ramp from Shady Grove N	**4701**	248	on ramp from MD 185S
4361	312	on ramp from MD 28 W	**4711**	245	on ramp from MD 185 N
4381	308	on ramp from MD 28 E	**4721**	244	N 495 east N24
4421	295	on ramp from MD 189			

Collection Points for Northbound Output

Point Code	Link #	Link Name	Point Code	Link #	Link Name
4012	426	off ramp to I-70	**4372**	310	off ramp to MD 28 W
4032	422	off ramp to MD 85 S	**4392**	306	off ramp to MD 28 E
4052	416	off ramp to MD 85 N	**4432**	293	off ramp to MD 189
4072	404	off ramp to MD 80	**4462**	284	off ramp to Montrose W
4092	398	off ramp to MD 109	**4482**	278	off ramp to Montrose E
4112	386	off ramp to MD 121	**4522**	233	off ramp to Democracy Blvd
4142	377	off ramp to MD 120	**4552**	223	off ramp to River Road
4162	373	off ramp to MD 118 S	**4572**	217	off ramp to Clara Barton Pkwy
4172	371	off ramp to MD 118	**4592**	212	off ramp to George Washington Pkwy
4182	368	off ramp to Middlebrook W	**4612**	208	off ramp to Georgetown Pike
4192	366	off ramp to Middlebrook E	**4642**	266	off ramp to Rockledge Dr
4222	354	off ramp to MD 124 N	**4652**	263	off ramp to MD 187
4232	352	off ramp to MD 117	**4672**	257	N 495 spur West
4282	337	off ramp to I-370	**4692**	252	off ramp to MD 355 S
4322	322	off ramp to Shady Grove			

Appendix 4-1: Volume Inputs and Turning Proportions for the Alternative Network

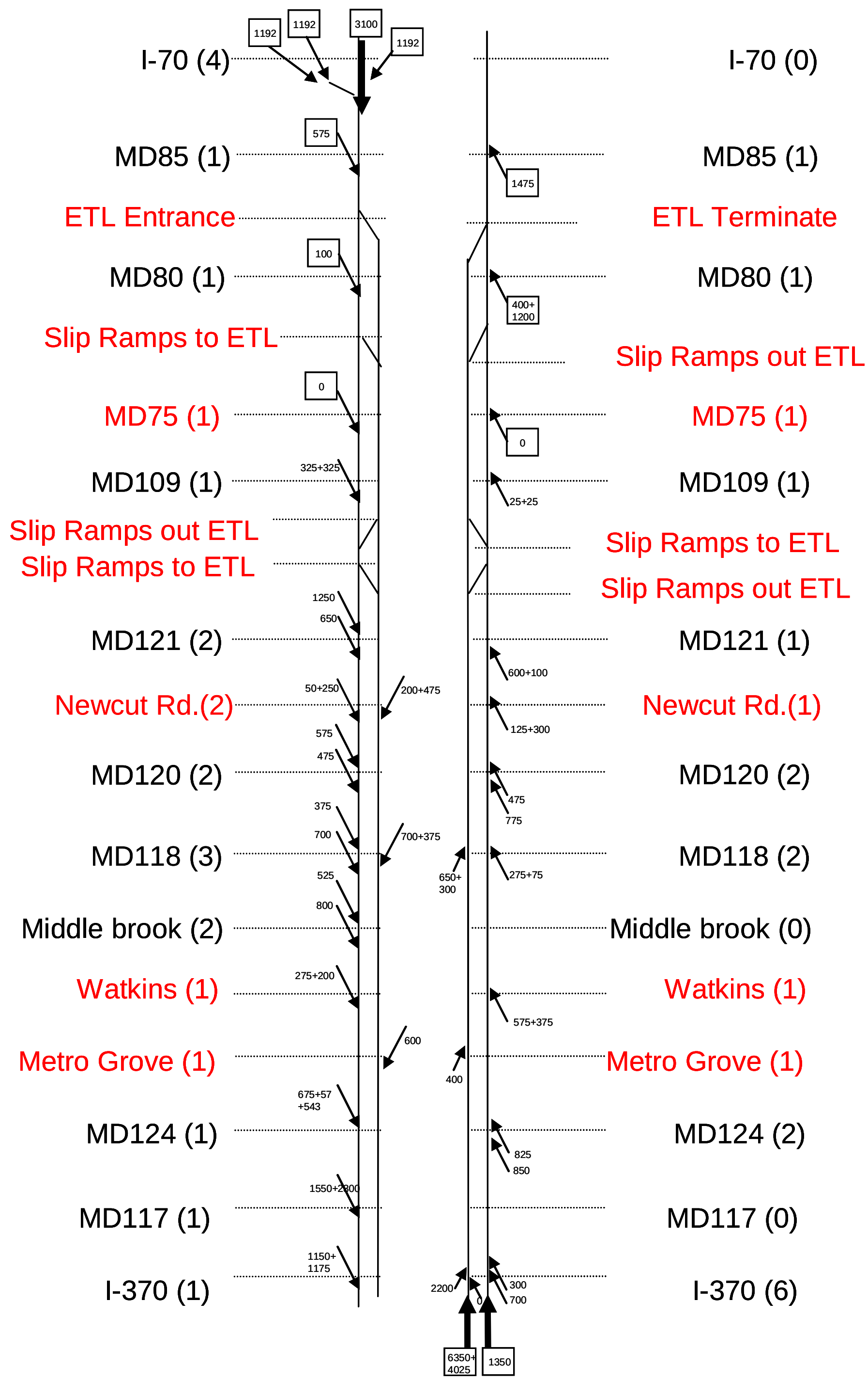


Figure 1: 2030 volume inputs at each ramp of the Alternative Network

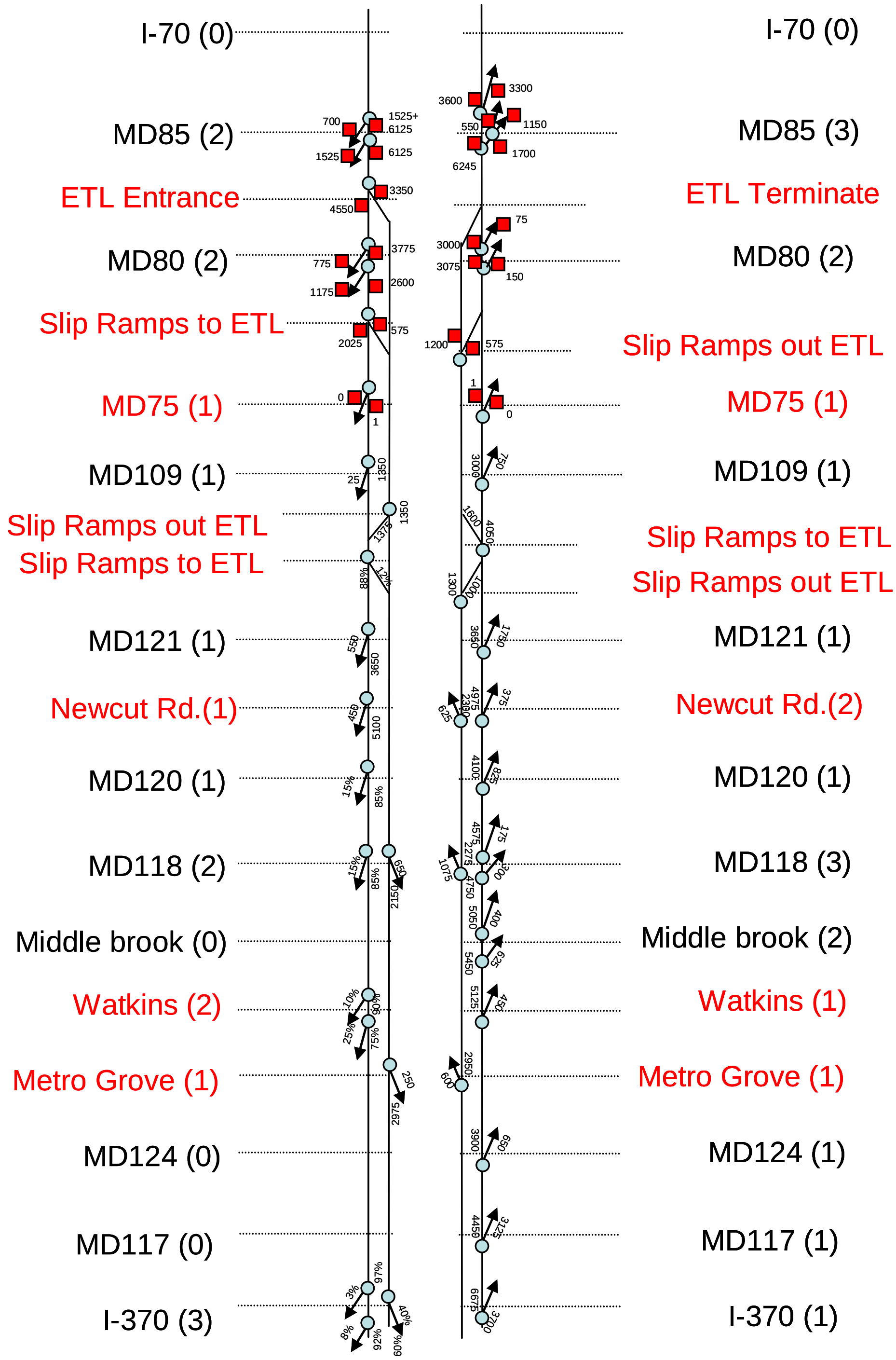
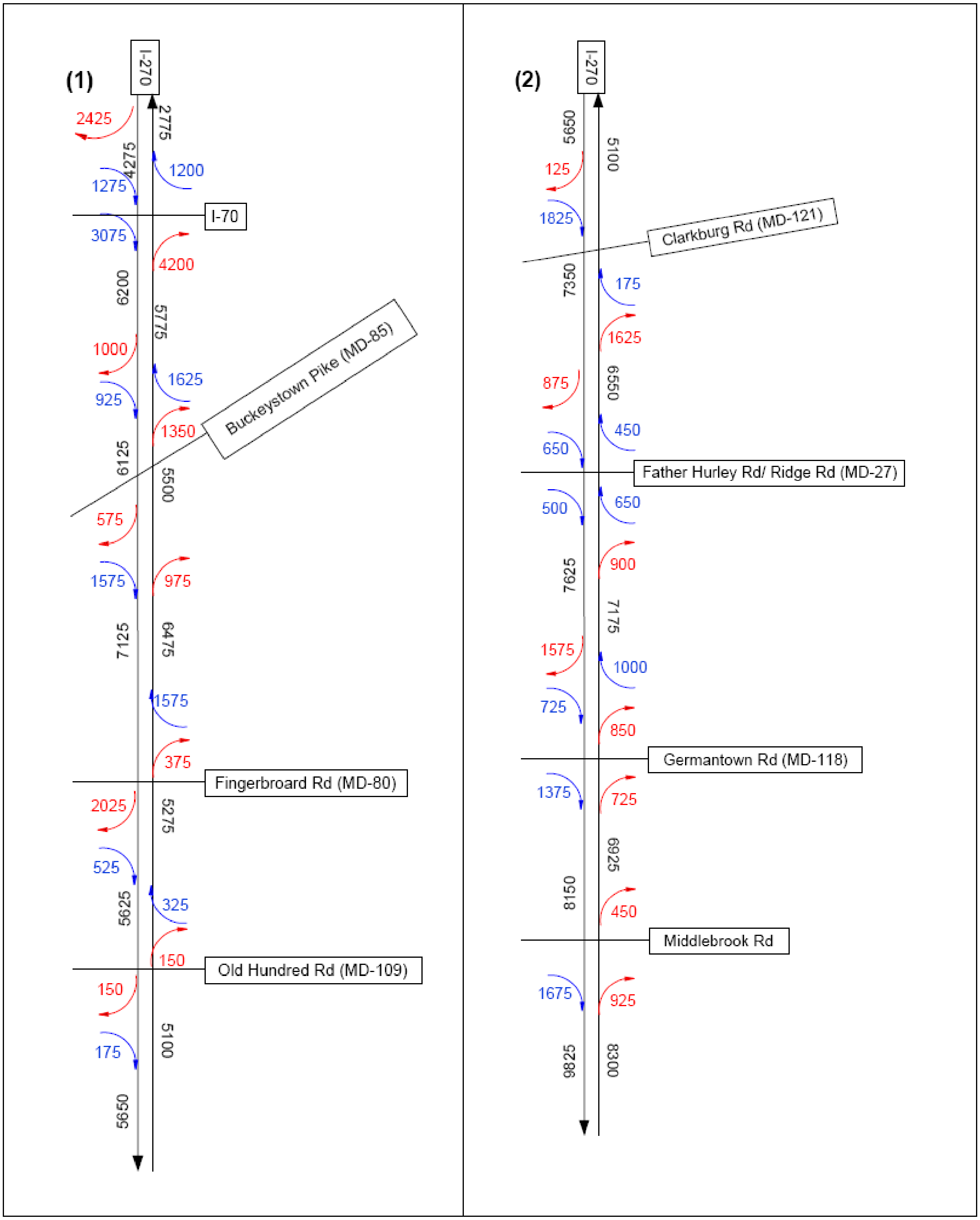
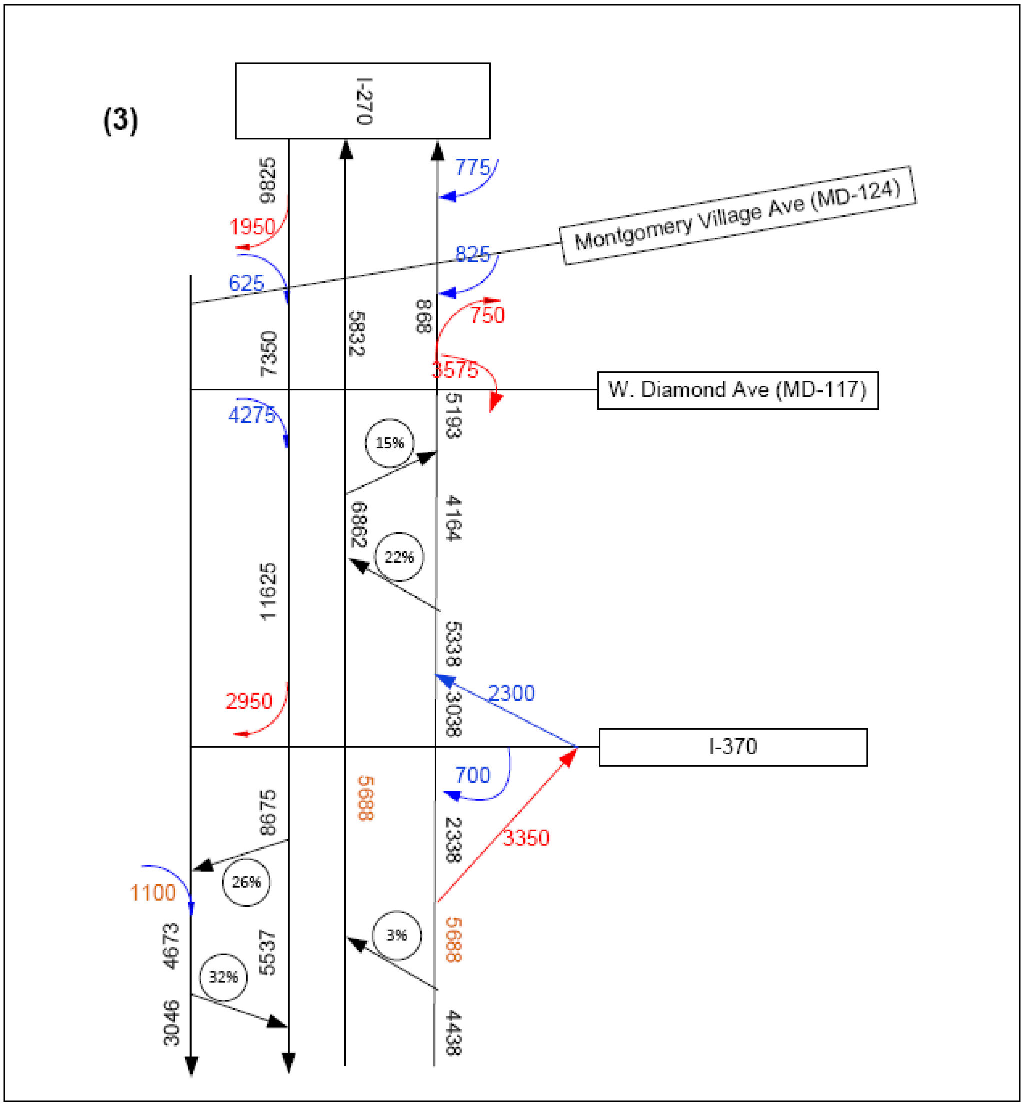


Figure 2: 2030 turning proportions at each ramp of the Alternative Network

Appendix 4-2: Wiring Diagram for No Build 2030 Network




(3)
I-270
Montgomery Village Ave (MD-124)
W. Diamond Ave (MD-117)
I-370
9825
1950
625
775
825
868
750
5832
7350
3575
5193
4275
15%
4164
6862
22%
11625
5338
2300
3038
2950
700
5688
8675
2338
3350
26%
1100
5688
3%
4673
5537
32%
3046
4438