
Appendix E

Data Collection and Modeling

Appendix E – Data Collection and Modeling

■ E.1 Overview of Travel Demand Modeling

Travel demand models are used to project future traffic and are the basis for the determination of the need for new road capacity, transit service changes and changes in land use policies and patterns. Travel demand modeling involves a series of mathematical models that attempt to simulate human behavior while traveling. The models are done in a sequence of steps that answer a series of questions about traveler decisions. Attempts are made to simulate all choices that travelers make in response to a given system of highways, transit and policies. Many assumptions need to be made about how people make decisions, the factors they consider and how they react to a particular transportation alternative.

Travel simulations require that an urban area be represented as a series of small geographic areas called travel analysis zones (TAZs). TAZs are characterized by their population, employment and other factors and are the places where trips begin (trip producers) or end (trip attractors). Trip making is first estimated at the household level and then aggregated to the zone level. Trip making is assumed to begin at the center of activity in a zone (zone centroid). Trips that are very short and that begin and end in a single zone (intrazonal trips) are usually not directly included in the forecasts. This limits the analysis of pedestrian and bicycle trips in the typical travel demand modeling process since they tend to be short trips.

The Twin Cities regional travel demand model was developed by the Metropolitan Council and the Minnesota Department of Transportation. This model, divided up into 1,200 TAZs, was developed in the early 1990s based on Census data, and a Travel Behavior Inventory.

E.1.1 Network Development

The highway system and transit systems are represented as networks for computer analysis. Networks consist of links to represent highway segments or transit lines and nodes to represent intersections and other points on the network. Data for links includes travel times on the link, average speeds, capacity, and direction. Node data includes information about intersections and the location of the node (coordinates).

E.1.1.1 Highway Network

The highway networks for 2000 and 2020 were updated to include major facility changes that have occurred since the model was last updated. This includes improvements to I-394, I-35W (extension of the HOV lanes to 46th Street), and other major roadway capacity changes and connectivity changes that may affect the operation of the HOV lanes.

For this study, capacity and speed adjustments were made to the HOV lane links in the network. In the with HOV scenario, the typical HOV lane capacity was 1,400 vehicles per hour per lane (vphpl) and speeds were approximately the same or five to 10 mph greater than their adjacent general-purpose lanes. For the without HOV scenario, the HOV lane capacities and speeds were made consistent with the general-purpose lanes (capacity of 1,950 vphpl). This resulted in more available capacity for use in the without HOV lane scenario.

For the without HOV scenario, the existing concurrent HOV lane links were removed from the network and a lane was added to the adjacent general-purpose lanes. The barrier-separated section on I-394 was maintained but all modes (SOV and HOV) were permitted to use it in the without HOV scenario.

“Districts” were established for estimating the impacts within the I-394 corridor, I-35W corridor, and in the remainder of the region. These were originally established in IDAS and utilized to disaggregate the model performance estimates.

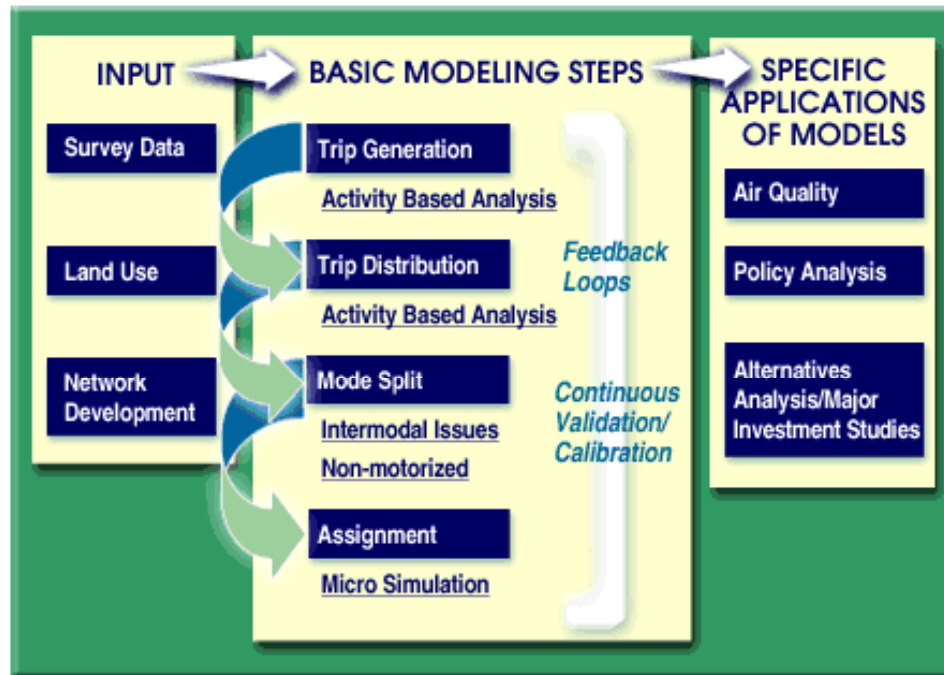
E.1.1.2 Transit Network

The transit network reflects transit facilities currently in operation. Originally, the 2000 transit network was used to forecast the usage of transit. This forecast resulted in approximately 20 percent growth in transit trips in 2020. However, it was later discovered that an updated transit network was available, which doubled the current transit operations. This and the corresponding shifts from mode choice were rerun to compare to the previous analysis. This new analysis resulted in a 50 percent growth in transit trips going to downtown Minneapolis. The changes were compared and deemed by Metro Council to be close enough not to require re-running of 2020 analyses. However, transit person trips for the three bottleneck locations were changed from 20 percent to 50 percent increases in transit trips and vehicles were doubled.

E.1.2 Four-Step Travel Demand Model Process

The travel simulation process follows trips as they begin at a trip generation zone, move through a network of links and nodes and end at a trip-attracting zone. The simulation process is known as the four-step process for the four basic models used. These are trip generation, trip distribution, mode split and traffic assignments. The process used to represent urban areas and the use of model results will also be described. The basic modeling process is illustrated in the diagram below (Figure E.1).

Figure E.1 Basic Travel Demand Forecasting Four-Step Process



Source: U.S. DOT Travel Model Improvement Program.

E.1.2.1 Trip Generation

The first step in travel forecasting is trip generation. In this step, information from land use, population, and economic forecasts are used to estimate how many person trips will be made to and from each zone. This is done separately by trip purpose. Trip purposes that can be used include home-based work trips, home-based shopping trips, home-based other trips, school trips, non-home-based trips, and truck trips. Trip generation uses trip rates that are averages for large segment of the study area. Trip productions are based on household characteristics, such as the number of people in the household and the number of vehicles available. Trip generation is used to calculate person trips. These are later adjusted in the mode split/auto occupancy step to determine vehicle trips.

Total trips generated in the region will not differ due to changes in the transportation system. This is because the amounts of trips are determined primarily by the socioeconomic characteristics of the region, and is independent of the available transportation networks. Therefore, the socioeconomic data were updated in simulated existing conditions and for projecting 2020 transportation alternatives.

E.1.2.2 Trip Distribution

Trip generation finds the number of trips that begin or end at a particular zone. These trip ends are linked together to form an origin-destination pattern of trips through the process of trip distribution. Trip distribution is used to represent the process of destination choice. Trip distribution leads to a large increase in the amount of data, which needs to be dealt

with. Origin-destination tables are very large. For the Twin Cities Model, which consists of 1,200 TAZs, there are 1,440,000 possible trip combinations in its O-D table. Separate tables are also done for each trip purpose.

The Twin Cities Model uses the ‘gravity model’ for trip distribution. The gravity model takes the trips produced at one zone and distributes to other zones based on the size of the other zones (as measured by their trip attractions) and on the basis of the distance to other zones. A zone with a large number of trip attractions will receive a greater number of distributed trips than one with a small number of trip attractions. Distance to possible destinations is the other factor used in the gravity model. The number of trips to a given destination decreases with the distance to the destination (it is inversely proportional). The distance effect is found through a calibration process, which tries to lead to a distribution of trips from the model similar to that found from field data.

‘Distance’ can be measured several ways. The simplest way this is done is to use auto travel times between zones as the measurement of distance. Other ways might be to use a combination of auto travel time and cost as the measurement of distance. Still another way is to use a combination of transit and auto times and costs (composite cost). This method involves multiplying auto travel times and costs by a percentage and transit time/cost another percentage to get a composite time and cost of both modes. Because of calculation procedures, the model must be iterated a number of times in order to balance the trip numbers to match the trip productions and attractions found in trip generation.

E.1.2.3 Mode Choice

Mode choice is one of the most critical parts of the travel demand modeling process. It is the step where trips between a given origin and destination are split into trips using transit, trips by car pool or as automobile passengers and trips by automobile drivers. Calculations are conducted that compare the attractiveness of travel by different modes to determine their relative usage. All proposals to improve public transit or to change the ease of using the automobile are passed through the mode split/auto occupancy process as part of their assessment and evaluation. It is important to understand what factors are used and how the process is conducted in order to plan, design and implement new systems of transportation.

The Twin Cities Model uses the ‘Logit’ model to determine mode split. This involves a comparison of the “disutility” of travel between two points for the different modes that are available. Disutility is a term used to represent a combination of the travel time, cost and convenience of a mode between an origin and a destination. It is found by placing multipliers (weights) on these factors and adding them together. Travel time is divided into two components: 1) in-vehicle time to represent the time when a traveler is actually in a vehicle; and 2) out-of-vehicle time which includes time spent traveling, which occurs outside of the vehicle (time to walk to and from transit stops or parking places, waiting time, transfer time).

Travel cost is multiplied by a factor to represent the value that travelers place on time savings for a particular trip purpose. For transit trips, the cost of the trip is given as the average transit fare and in/out of vehicle time for that trip while for auto trips cost is found by adding the parking cost to the length of the trip as multiplied by a cost per mile.

HOV trip cost is a combination of the two. For instance, many HOVs currently receive reduced parking rates at the Third Avenue Distributor parking garages in Downtown Minneapolis.

Once disutilities are known for the various mode choices between an origin and a destination, the trips are split among various modes based on the relative differences between disutilities. The logit equation is used in this step. A large advantage in disutility will mean a high percentage for that mode. Mode splits are calculated to match splits found from actual traveler data.

Automobile, transit, and HOV trips are converted from person trips to vehicle trips with an auto occupancy model. Mode split and auto occupancy analysis can be two separate steps or can be combined into a single step, depending on how a forecasting process is set up. In the simplest application a highway/transit split is made first which is followed by a split of automobile trips into auto driver and auto passenger trips. The Twin Cities Model divides trips into multiple categories (single occupant auto, two or more person car pool, local bus and express bus, etc.).

E.1.2.3 Time-of-Day Estimation

Time of day models take the estimated daily trips and distribute them across various periods of time to more accurately reflect travel in the peak hours or periods. The time periods used for the HOV study analysis were:

- A.M. peak hour;
- A.M. peak shoulders;
- First P.M. peak hour;
- Second P.M. peak hour; and
- P.M. peak shoulders.

E.1.2.4 Assignment

Upon determining the split of trips into highway and transit modes, the specific path that they use to travel from their origin to their destination is found. These trips are then assigned to that path. Traffic assignment is the most time consuming and data intensive step in the process. The process first involves the calculation of the shortest time path from each origin to all destinations.

Trips for each O-D pair are then assigned to the links in the minimum path and the trips are added up for each link. The assigned trip volume is then compared to the capacity of the link to see if it is congested. If a link is congested the speed on the link needs to be reduced to result in a longer travel time on that link. The whole process undergoes several iterations until there is equilibrium between travel demand and travel supply.

Transit trip assignment is done in a similar way to auto trip assignment, except that transit headways are adjusted rather than travel times.

E.1.3 Model Calibration and Validation

This model was originally calibrated for the Year 1990. Model calibration and validation were updated to the current year for volumes and speeds in a few locations in the study area. The calibration and validation for this study focused on Average Weekday Traffic Volumes (AWDT) and Mn/DOT Quarterly Report data in the study corridors.

■ E.2 ITS Deployment Analysis System (IDAS) Model Parameters

Several of the national default IDAS parameters were adjusted to reflect local conditions in the Twin Cities area and be consistent with the Twin Cities regional travel demand model. The following describes the assumptions and parameters used for the IDAS analysis for estimating the travel time reliability, safety, emissions, and fuel consumption measures.

E.2.1 Import of Travel Demand Model Data

IDAS uses the network and trip table data from the regional travel demand model to establish the database for use in the analysis. The following identifies the network and trip table data obtained from the Twin Cities regional model and imported into IDAS:

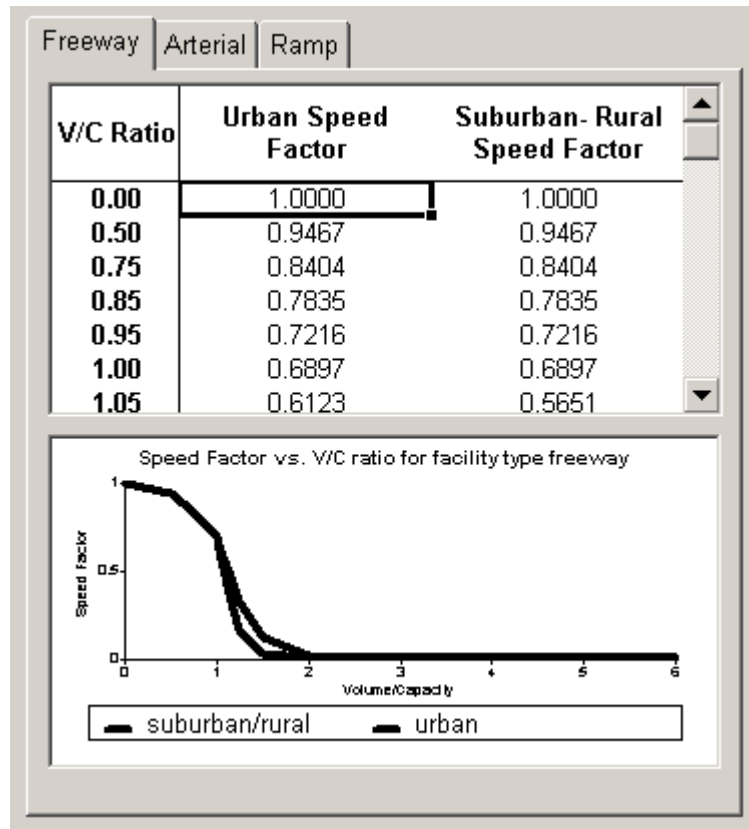
- Node – node number, x coordinate, and y coordinate;
- Link – Anode, Bnode, facility type, area type, number of lanes, capacity, speed, volume, time/speed indicator, and distance; and
- Trip table data – O/D trip matrix, occupancy, trip type (vehicle or person), in-vehicle time, and out-of-vehicle time.

E.2.2 Benefits Assignment Analysis Parameters

The following identifies the parameters adjusted within IDAS to reflect local conditions, including the sources of the information.

Volume delay curves from the Twin Cities regional travel demand model were obtained and entered into IDAS for use in the analysis. Figure E.2 presents a sample view within IDAS of the volume delay curves adjusted for local conditions. The metered freeway curve is reflected under the Urban Speed Factor title and the unmetered freeway values are in the Suburban-Rural Speed Factor. Note that this does not mean that metered freeways are in urban areas or unmetered are in rural. The imported link file was adjusted so that metered freeways would fall into the urban area type and unmetered in suburban-rural so the correct curves would be used in the model assignment.

Figure E.2 Volume Delay Curve for Metered Freeway and Unmetered Freeway



The emission rates used for the analysis were derived from Mobile5A. Figure E.3 presents an example of hydrocarbon emission rates used for 2020 analysis (in grams per VMT).

Figure E.3 Sample HC Emissions Rates for 2020

Hydrocarbon Emissions rates (grams per mile)
Mobile 5a Derived Rates - 2020

Speed	LDGV	LDGT1	LDGT2	LDGT	HdGV	LDDV	LDDT	HDDV	MC	All
38	0.806	0.996	1.165	1.047	1.399	0.303	0.434	1.216	4.707	0.902
39	0.790	0.979	1.145	1.029	1.375	0.296	0.424	1.190	4.688	0.884
40	0.774	0.963	1.125	1.011	1.353	0.290	0.416	1.166	4.671	0.868
41	0.760	0.947	1.106	0.995	1.332	0.285	0.408	1.144	4.656	0.853
42	0.746	0.932	1.088	0.979	1.313	0.280	0.400	1.123	4.643	0.838
43	0.732	0.918	1.071	0.964	1.296	0.275	0.394	1.103	4.631	0.824
44	0.719	0.905	1.055	0.950	1.279	0.270	0.387	1.085	4.621	0.810
45	0.707	0.892	1.039	0.936	1.264	0.266	0.381	1.068	4.612	0.797
46	0.695	0.879	1.024	0.923	1.250	0.262	0.375	1.052	4.605	0.785
47	0.683	0.867	1.010	0.910	1.237	0.258	0.370	1.037	4.598	0.773
48	0.672	0.856	0.996	0.898	1.225	0.255	0.365	1.024	4.593	0.762
49	0.669	0.852	0.992	0.894	1.213	0.252	0.361	1.011	4.593	0.758
50	0.666	0.849	0.988	0.891	1.203	0.249	0.357	1.000	4.593	0.754
51	0.663	0.846	0.984	0.887	1.193	0.246	0.353	0.989	4.593	0.751
52	0.661	0.843	0.981	0.884	1.184	0.244	0.349	0.980	4.593	0.747
53	0.658	0.840	0.978	0.882	1.176	0.242	0.346	0.971	4.593	0.744
54	0.656	0.838	0.975	0.879	1.170	0.240	0.344	0.964	4.593	0.741
55	0.654	0.835	0.972	0.876	1.164	0.238	0.341	0.957	4.593	0.739

Figures E.4 and E.5 identify the fuel rates used for the study. These rates are national default rates included in IDAS. Figure E.4 was used for freeway facilities and rates in Figure E.5 were used for arterial roadways.

Figure E.4 Fuel Consumption Rates for Freeways

Fuel Consumption Rates (Gallons per VMT)
Freeway - National Default Rates

Average Speed (mph)	Auto	Truck Gas	Truck Diesel
0	0.540	0.650	0.450
5	0.185	0.210	0.696
10	0.131	0.144	0.489
15	0.086	0.099	0.297
20	0.061	0.077	0.185
25	0.049	0.074	0.131
30	0.044	0.072	0.110
35	0.045	0.080	0.112
40	0.046	0.088	0.122
45	0.049	0.097	0.136
50	0.052	0.107	0.153
55	0.054	0.118	0.170
60	0.057	0.129	0.187
65	0.061	0.140	0.204
70	0.065	0.151	0.221

Figure E.5 Fuel Consumption Rates for Arterials

Fuel Consumption Rates (Gallons per VMT)
Arterial - National Default Rates

Average Speed (mph)	Auto	Truck Gas	Truck Diesel
5	0.144	0.275	0.383
10	0.091	0.174	0.241
15	0.073	0.140	0.194
20	0.064	0.123	0.171
25	0.059	0.113	0.157
30	0.056	0.106	0.147
35	0.053	0.101	0.140
40	0.051	0.097	0.135

The crash rates in IDAS were adjusted to reflect local conditions since data were available. Typically, the Minnesota State crash rates are lower than the national average. The values shown in Figures E.6 through E.8 are based upon crash data in the *Minnesota Crash Facts 2000* prepared by the Department of Public Safety, Office of Traffic Safety. Crash rates were not available by speed range, so the Minnesota injury and property damage only (PDO) crash rates were adjusted at volume to capacity (v/c) ratios above 0.79 to reflect national increase trends at these v/c ranges.

Figure E.6 Fatality Crash Rates

Fatality Rates (deaths/1,000,000 VMT)
Auto Crashes

V/C Ratio	Freeway	Arterial
0.09	0.0025	0.0092
0.19	0.0025	0.0092
0.29	0.0025	0.0092
0.39	0.0025	0.0092
0.49	0.0025	0.0092
0.59	0.0025	0.0092
0.69	0.0025	0.0092
0.79	0.0025	0.0092
0.89	0.0025	0.0092
0.99	0.0025	0.0092
1.00	0.0025	0.0092

Figure E.7 Injury Crash Rates

Measure/Year	With HOV							Without HOV				
	I-394 Concurrent	I-394 GP	I-35W HOV	I-35W GP	I-394 Barrier	Remainder	Total	I-394 GP	I-35W GP	I-394 Barrier	Remainder	Total
Vehicle Miles of Travel												
2000	20,395	222,769	23,228	132,468	11,030	30,566,107	30,975,997	234,493	177,866	51,398	30,558,571	31,022,327
2020	25,197	252,836	44,453	268,251	16,667	40,789,944	41,397,348	296,243	379,585	60,099	40,646,429	41,382,356
Vehicle Hours of Travel												
2000	355	6,306	375	4,026	197	1,076,448	1,087,707	5,728	4,243	1,211	1,073,792	1,084,974
2020	489	9,986	822	16,453	298	2,460,753	2,488,799	10,037	18,161	1,511	2,454,252	2,483,960

Figure E.8 PDO Crash Rates

Property Damage Only Rates (PDO/1,000,000 VMT)
Auto Crashes

V/C Ratio	Freeway	Arterial
0.09	0.3695	0.7314
0.19	0.3605	0.7314
0.29	0.3605	0.7314
0.39	0.3605	0.7314
0.49	0.3605	0.7314
0.59	0.3605	0.7314
0.69	0.3605	0.7314
0.79	0.411	0.7314
0.89	0.411	0.7314
0.99	0.4887	0.7314
1.00	0.5371	0.7314

Travel time reliability was also estimated using IDAS. As mentioned in the report, travel time reliability is only computed for the freeway facilities within IDAS. Figure E.9 presents the national default rates used to estimate travel time reliability.

Figure E.9 Travel Time Reliability Rates

Travel Time Reliability

Factor to Convert Input Link Capacities to LOS E Equivalent :

Travel Time Reliability Rates (Vehicle-Hours of Incident Delay per Vehicle-Mile)

Number of Lanes	VC Ratio: 0.15	0.3	0.45	0.6	0.75	0.9	1.05	1.2	1.35	1.5
2	3.714E-008	5.66E-007	2.785E-006	8.628E-006	2.074E-005	4.245E-005	7.781E-005	0.0001315	0.00020893	0.00031618
3	1.618E-009	5.213E-008	3.975E-007	1.68E-006	5.138E-006	1.281E-005	2.773E-005	5.413E-005	9.766E-005	0.00016557
4+	5.45E-012	7.222E-010	1.259E-008	9.57E-008	4.615E-007	1.669E-006	4.947E-006	1.268E-005	2.909E-005	6.115E-005

Travel Time Reliability Only Applies to VMT on Freeway Links.

■ E.3 Performance Measure Assumptions and Results

The following describes some of the assumptions used in the analysis and provides more detailed data regarding the findings presented in the body of the final report.

E.3.1 Traffic Flow Impacts

E.3.1.1 Travel Time and Speed

Changes in travel times and speeds were obtained using the Twin Cities regional travel demand model. Average speeds used to compute average travel times through the HOV corridors were obtained from vehicle miles traveled (VMT) and vehicle hours traveled (VHT) estimates for the corridors. The corridors only include the freeway facility itself (the HOV lane and the adjacent general-purpose lanes). These were obtained separately for I-35W and I-394. It does not include parallel facilities. The speeds obtained from the model are identified in Table E.1.

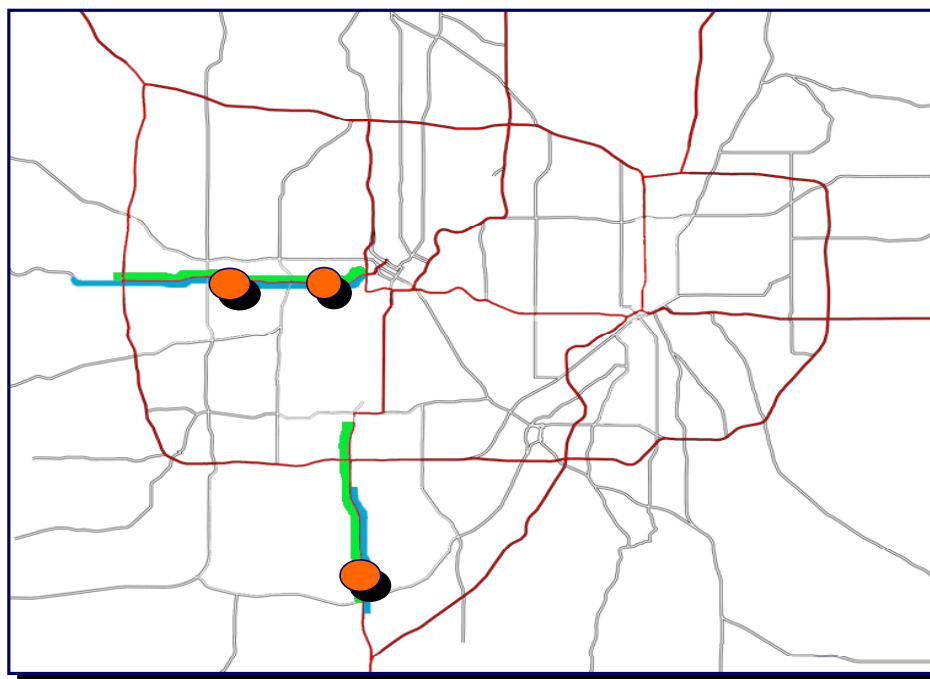
Table E.1 Estimated Travel Speeds for the HOV Corridors from the Model

		2000		2020	
		A.M.	P.M.	A.M.	P.M.
With HOV:	I-394 HOV Concurrent	56.0	58.1	54.5	50.3
	I-394 General-Purpose Lanes	38.2	33.7	26.6	24.6
	I-35W HOV Lanes	62.9	61.4	57.4	52.7
	I-35W General-Purpose Lanes	34.2	32.1	16.1	16.4
	I-394 HOV Barrier	56.4	55.9	56.6	55.7
Without HOV:	I-394 General-Purpose Lanes	43.6	39.5	31.4	28.4
	I-394 Barrier	43.2	42.0	40.6	39.3
	I-35W	42.8	41.3	20.9	20.9
Difference:	I-394 HOV Barrier	-13.3	-13.9	-16.0	-16.5
	I-394 Concurrent	-12.4	-18.6	-23.1	-21.9
	I-394 General-Purpose Lanes	5.4	5.8	4.8	3.9
	I-35W HOV Facility	-20.1	-20.1	-36.5	-31.8
	I-35W General-Purpose	8.6	9.2	4.8	4.5

E.3.1.2 Vehicle and Person Throughput

Vehicle and person throughput were estimated from the model for a few key bottleneck locations (the same locations as in the HOV quarterly reports generated by Mn/DOT Metro Division – Freeway Operations Section). These locations are shown in Figure E.10.

Figure E.10 Bottleneck Locations for Comparing Vehicle and Person Throughput Results



Tables E.2 and E.3 present the estimated vehicle volumes for these three bottleneck locations from the travel demand model.

Table E.2 Estimated Model Vehicle Volumes at Bottleneck Locations (A.M. Peak Period)

		AM Peak Period (6:00 to 8:00 A.M.)			
		2000 Model With HOV	2000 Model Without HOV	2020 Model With HOV	2020 Model Without HOV
EB I-394 at Penn Ave	HOV Lanes	1,289	6,628	1,625	7,712
	General Lanes	11,007	7,366	12,513	10,031
	Total all lanes	12,296	13,994	14,138	17,743
EB I-394 at Louisiana Ave	HOV Lanes	1,038	3,484	1,511	4,618
	General Lanes	7,890	6,968	9,601	9,236
	Total all lanes	8,928	10,452	11,112	13,854
NB I-35W at Minnesota River	HOV Lanes	1,497	4,087	1,988	5,011
	General Lanes	8,822	8,174	10,033	10,023
	Total all lanes	10,319	12,261	12,021	15,034

**Table E.3 Estimated Model Vehicle Volumes at Bottleneck Locations
(P.M. Peak Period)**

		PM Peak Period (3:00 to 6:00 P.M.)			
		2000 Model With HOV	2000 Model Without HOV	2020 Model With HOV	2020 Model Without HOV
WB I-394 at Penn Ave	HOV Lanes	2,620	10,599	3,572	12,421
	General Lanes	16,512	11,893	19,795	16,326
	Total all lanes	19,132	22,492	23,367	28,747
WB I-394 at Winnetka Ave	HOV Lanes	2,420	6,372	3,757	8,244
	General Lanes	14,142	12,743	17,581	16,489
	Total all lanes	16,562	19,115	21,338	24,733
SB I-35W at Minnesota River	HOV Lanes	2,519	5,870	3,573	7,581
	General Lanes	13,289	11,741	15,525	15,161
	Total all lanes	15,808	17,611	19,098	22,742

Using an average vehicle occupancy of one for SOVs and 2.1 for HOVs, consistent with violation rates obtained in the field and used for the HOV Quarterly Reports, person trips were estimated. These are shown in Tables E.4 and E.5. The SOV and HOV values came directly from the vehicle volumes from the travel demand model. Transit trips in the with HOV scenario are from the *Spring 2001 HOV Quarterly Report*. From the travel demand model, total change in transit trips were estimated for each of the peak periods. These changes were applied to the two corridors at I-394/Penn and I-35W/Minnesota River according to the proportion of trips in the with HOV scenario. The change in transit at Louisiana and Winnetka were a proportion of the change at Penn, using the with HOV proportion. The transit trips were applied to the HOV versus general-purpose lanes according to the SOV and HOV proportions in the without HOV scenario. The travel demand model estimated an increase in transit trips over the 2000 with HOV scenario of 50 percent for trips going to downtown Minneapolis. This 50 percent was used to estimate the number of person trips for the 2020 with HOV scenario. The estimated change in transit trips from the 2020 without HOV scenario was applied similarly to the 2000 scenario.

Table E.4 Estimated Person Volumes at Bottleneck Locations for 2000

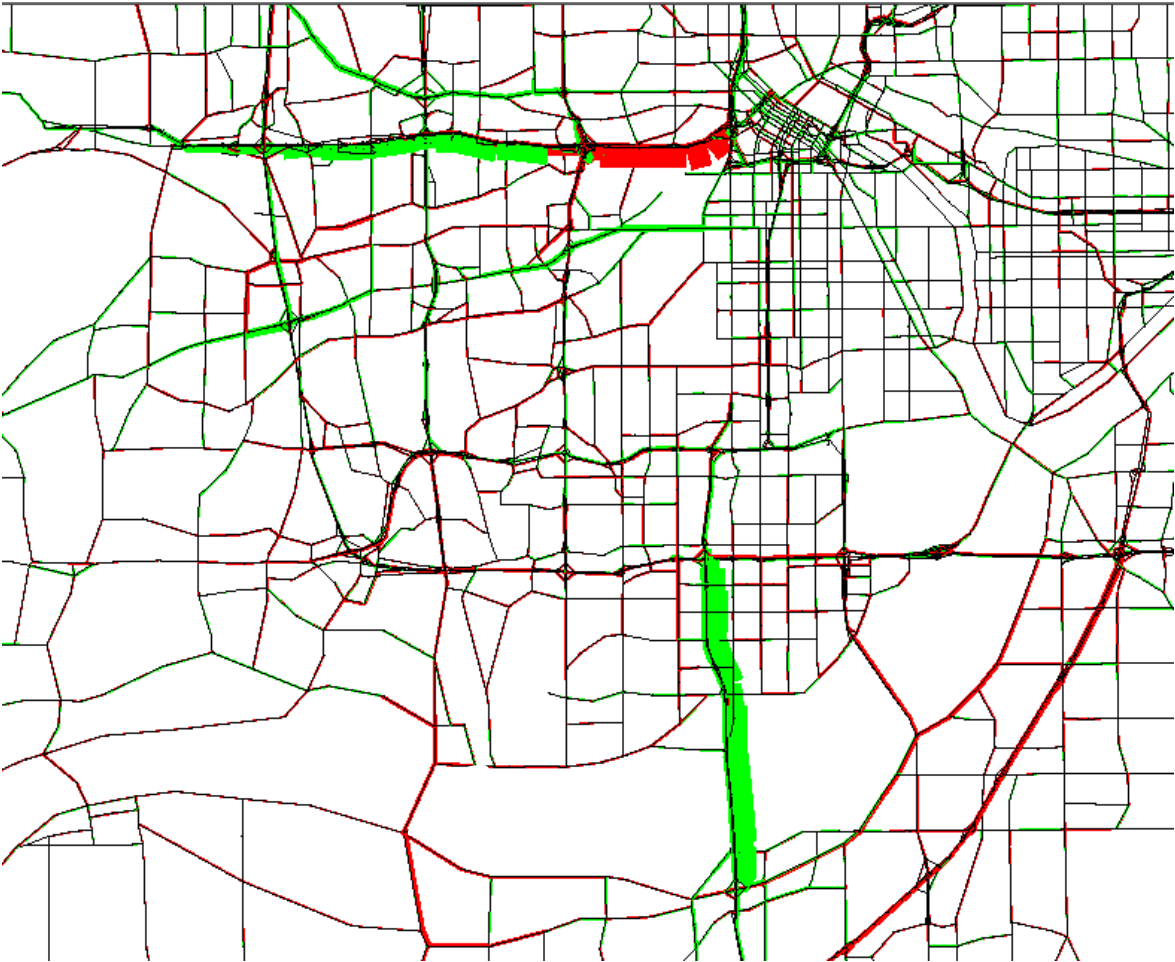
		With			Without			Change	%Change
		SOV & HOV	Transit	Total	SOV & HOV	Transit	Total		
EB I-394 at Penn Ave	HOV	2,707	2,963	5,670	7,032	1,105	8,137	2,467	44%
	General	11,009	0	11,009	7,784	1,223	9,007	-2,002	-18%
	Total	13,716	2,963	16,679	14,816	2,328	17,144	465	3%
EB I-394 at Louisiana Ave	HOV	2,180	1,603	3,783	3,674	420	4,093	311	8%
	General	7,893	0	7,893	7,347	840	8,187	294	4%
	Total	10,073	1,603	11,676	11,021	1,260	12,280	604	5%
NB I-35W at Minnesota River	HOV	3,144	986	4,130	4,258	258	4,516	386	9%
	General	8,822	0	8,822	8,515	517	9,032	210	2%
	Total	11,966	986	12,952	12,773	775	13,547	596	5%
WB I-394 at Penn Ave	HOV	5,502	3,077	8,579	11,412	922	12,334	3,755	44%
	General	16,521	0	16,521	12,752	1,031	13,783	-2,738	-17%
	Total	22,023	3,077	25,100	24,164	1,953	26,117	1,017	4%
WB I-394 at Winnetka Ave	HOV	5,082	1,868	6,950	6,820	395	7,215	266	4%
	General	14,162	0	14,162	13,641	790	14,431	269	2%
	Total	19,244	1,868	21,112	20,461	1,185	21,647	535	3%
SB I-35W at Minnesota River	HOV	5,290	1,031	6,321	6,237	218	6,455	134	2%
	General	13,289	0	13,289	12,473	436	12,909	-380	-3%
	Total	18,579	1,031	19,610	18,710	654	19,364	-246	-1%

Table E.5 Estimated Person Volumes at Bottleneck Locations for 2020

		With			Without			Change	%Change
		SOV & HOV	Transit	Total	SOV & HOV	Transit	Total		
EB I-394 at Penn Ave	HOV	3,413	4,356	7,768	8,275	1,193	9,468	1,700	22%
	General	12,541	0	12,541	10,626	1,532	12,158	-382	-3%
	Total	15,953	4,356	20,309	18,901	2,725	21,626	1,318	6%
EB I-394 at Louisiana Ave	HOV	3,173	2,356	5,530	4,889	491	5,381	-149	-3%
	General	9,601	0	9,601	9,779	983	10,762	1,161	12%
	Total	12,774	2,356	15,131	14,668	1,474	16,142	1,012	7%
NB I-35W at Minnesota River	HOV	4,175	1,449	5,624	5,220	302	5,523	-102	-2%
	General	10,034	0	10,034	10,441	605	11,045	1,011	10%
	Total	14,209	1,449	15,658	15,661	907	16,568	910	6%
WB I-394 at Penn Ave	HOV	7,501	4,523	12,024	13,423	989	14,412	2,387	20%
	General	19,816	0	19,816	17,605	1,297	18,902	-914	-5%
	Total	27,317	4,523	31,840	31,028	2,285	33,313	1,473	5%
WB I-394 at Winnetka Ave	HOV	7,890	2,746	10,636	8,855	462	9,318	-1,318	-12%
	General	17,581	0	17,581	17,710	925	18,635	1,054	6%
	Total	25,471	2,746	28,217	26,566	1,387	27,953	-264	-1%
SB I-35W at Minnesota River	HOV	7,503	1,516	9,019	8,058	255	8,313	-706	-8%
	General	15,589	0	15,589	16,116	510	16,627	1,038	7%
	Total	23,092	1,516	24,608	24,174	766	24,940	332	1%

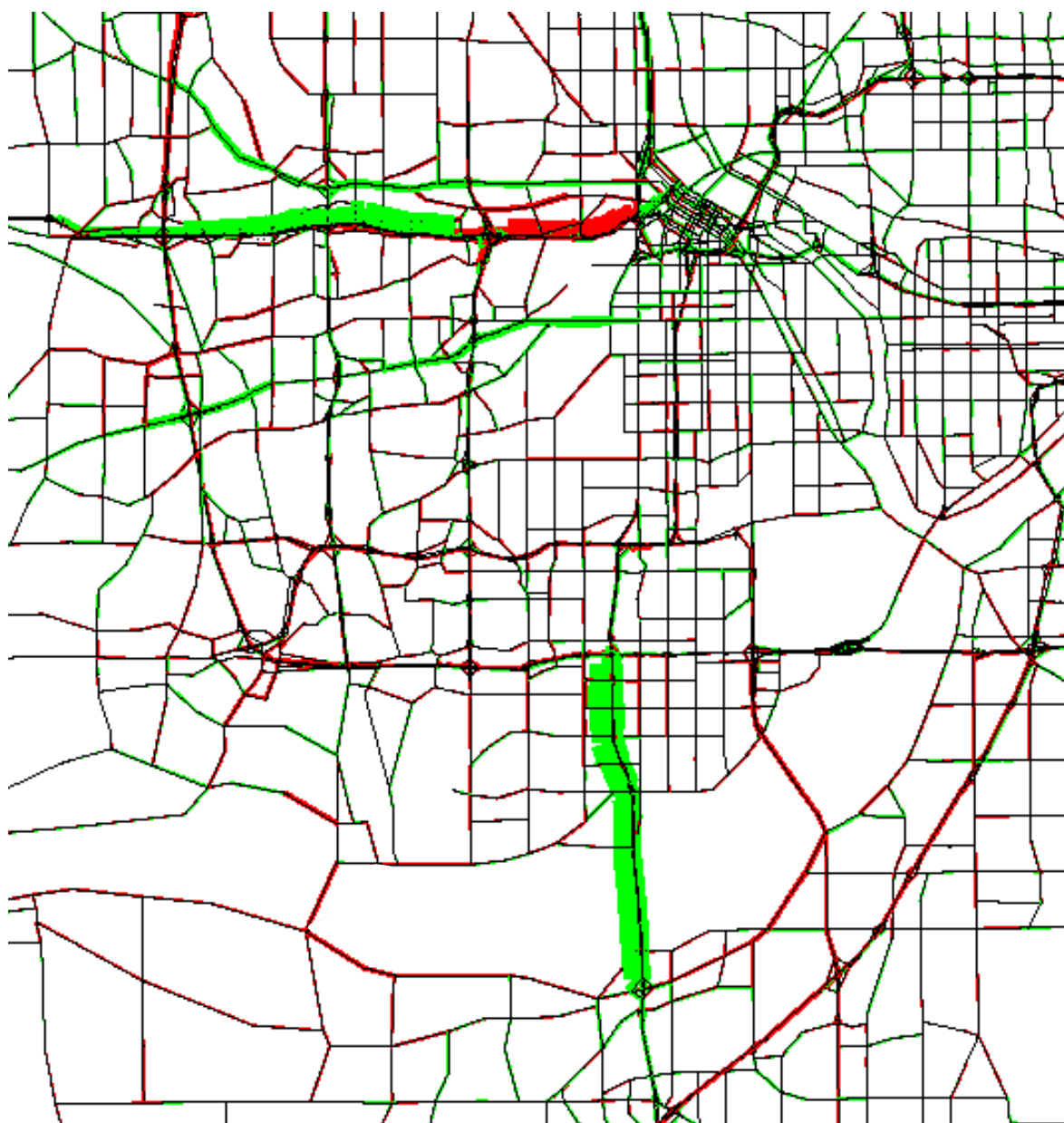
Figures E.11 to E.14 present change in volume plots from the travel demand model. Green represents increases in volumes and red shown decreases in volumes. Note that these only represent the general-purpose lanes in the case of I-394. The increase in volume in the barrier-separated lanes is not represented in these figures.

Figure E.11 Estimated Model Volume Changes When HOV Lanes Opened to All Traffic - 2000 A.M. Peak Hour (6:30 A.M. to 7:30 A.M.)



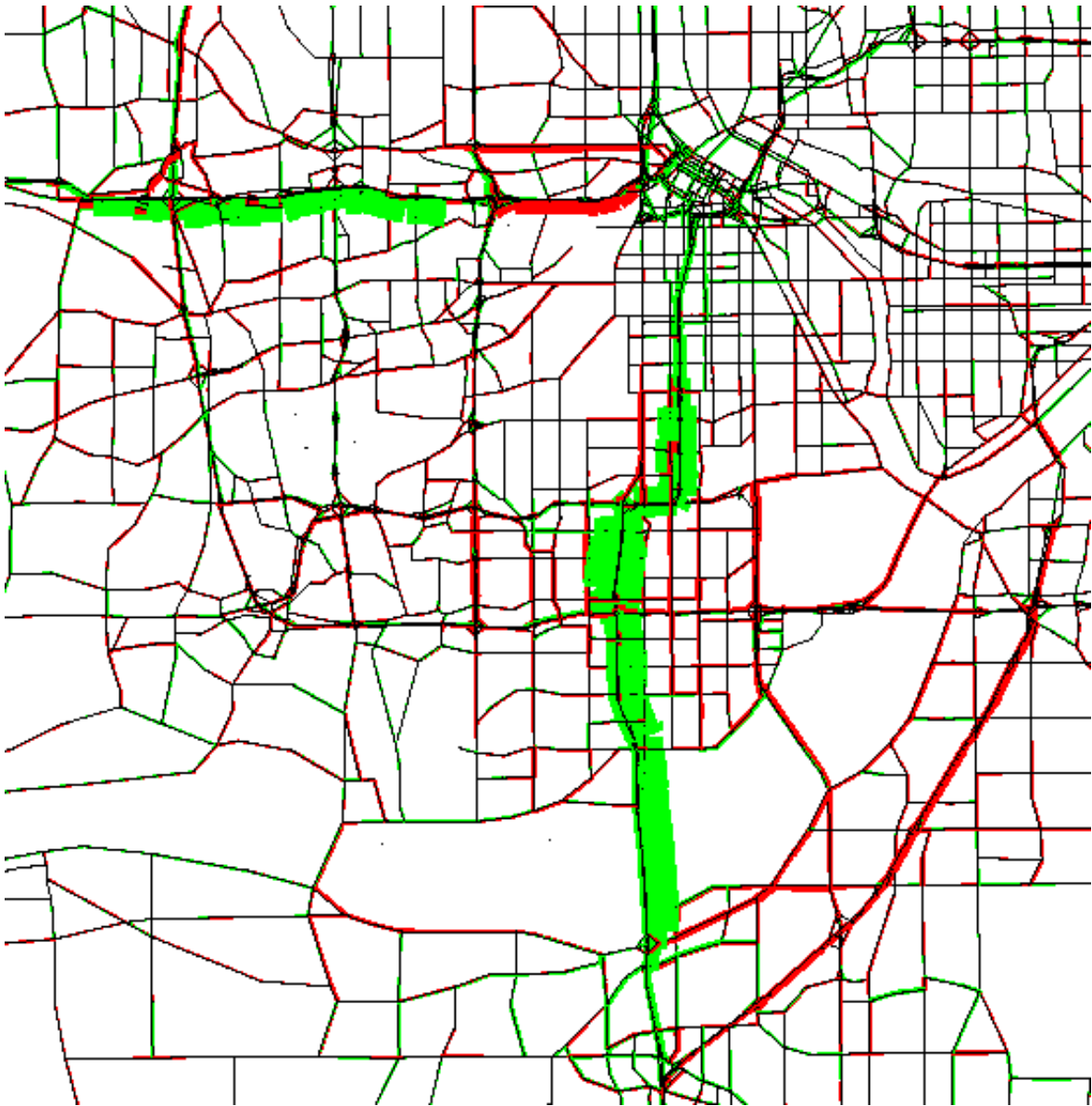
Red (dark shading) - decreases, green (light shading) - increases.

Figure E.12 Estimated Model Volume Changes When HOV Lanes Opened to All Traffic – 2000 P.M. Peak Hour (4:40 P.M. to 5:40 P.M.)



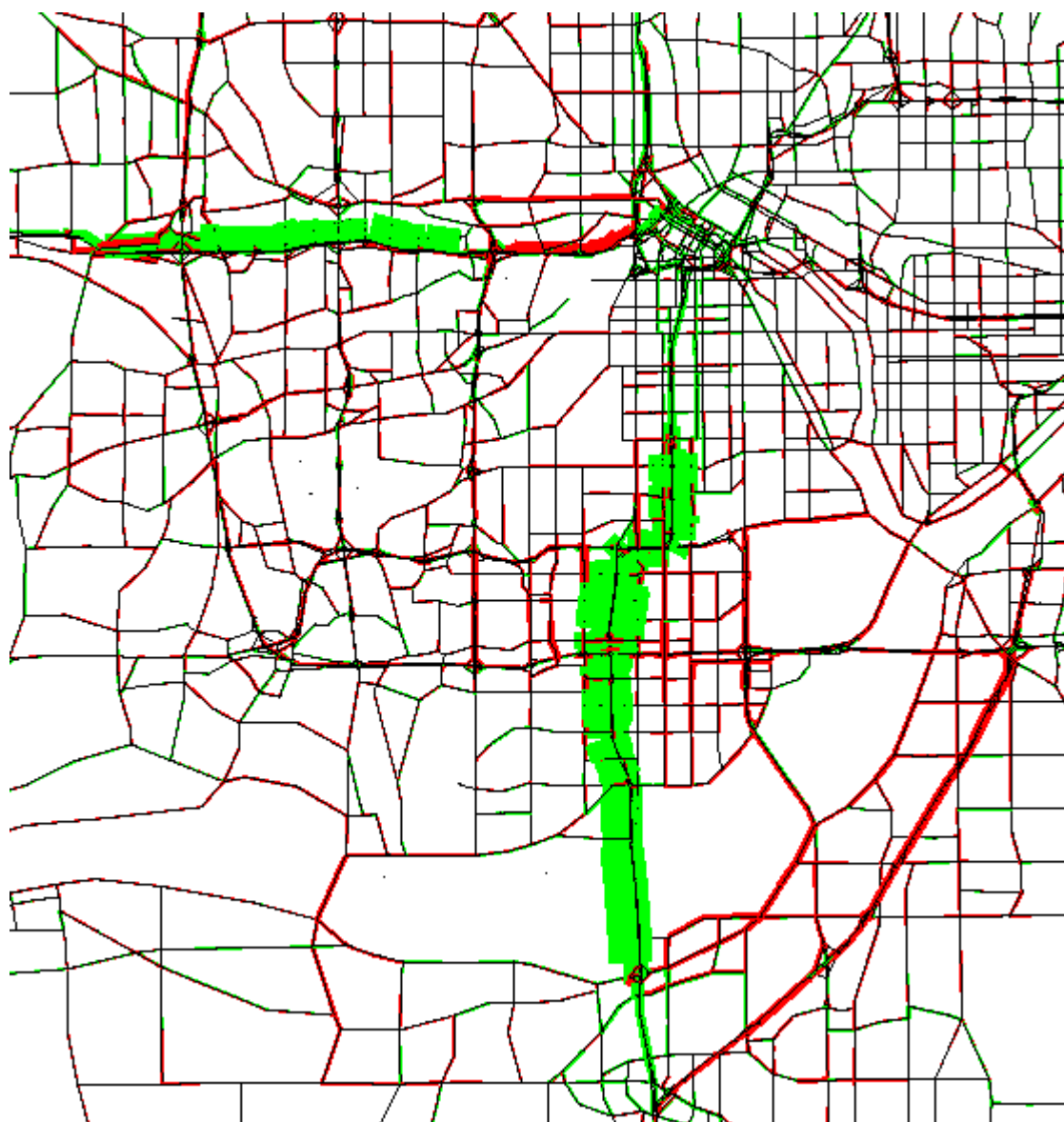
Red (dark shading) – decreases, green (light shading) – increases.

Figure E.13 Estimated Model Volume Changes When HOV Lanes Opened to All Traffic - 2020 A.M. Peak Hour (6:30 A.M. to 7:30 A.M.)



Red (dark shading) - decreases, green (light shading) - increases.

Figure E.14 Estimated Model Volume Changes When HOV Lanes Opened to All Traffic – 2020 P.M. Peak Hour (4:40 P.M. to 5:40 P.M.)



Red (dark shading) – decreases, green (light shading) – increases.

Volume to capacity (v/c) values were also computed for the three bottleneck locations. These are shown in Table E.6. Figures E.15 to E.24 show v/c ratios in 2000 in the HOV corridors and a parallel roadway (TH 77) both with HOV and without HOV.

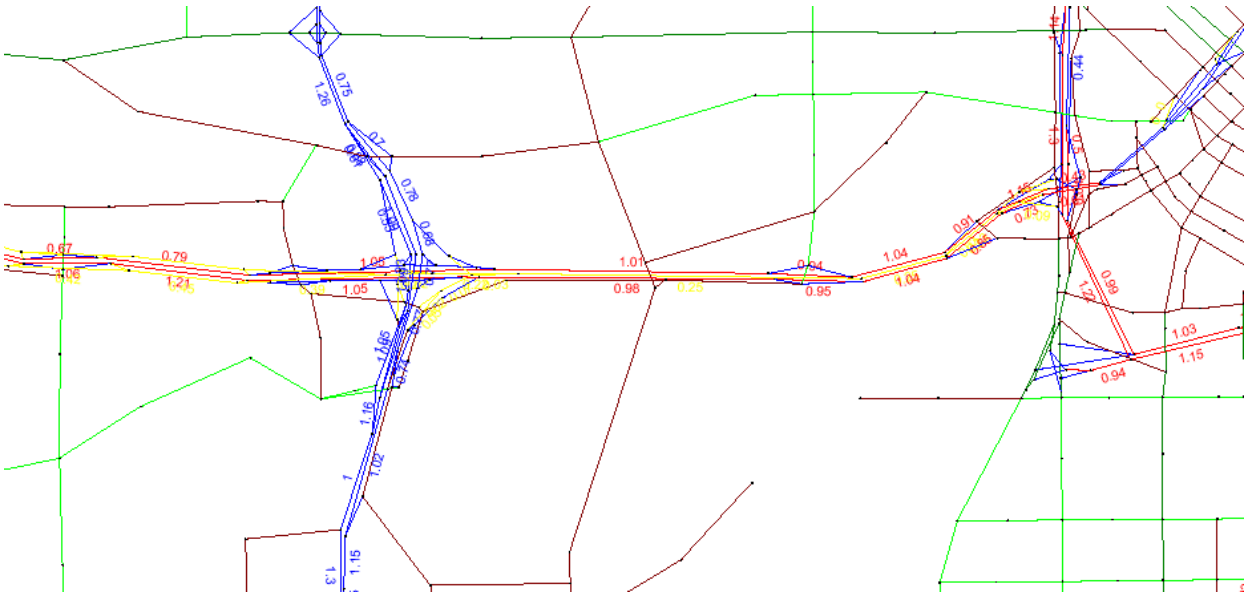
Table E.6 Volume to Capacity Ratios for Bottleneck Locations from Model

AM		2000		2020	
Location		With HOV	Without HOV	With HOV	Without HOV
EB I-394 at Penn Ave	HOV Lanes	0.23	0.83	0.29	0.96
	General Lanes	0.94	0.63	1.07	0.86
	Total all lanes	0.71	0.71	0.82	0.90
EB I-394 at Louisiana Ave	HOV Lanes	0.37	0.89	0.54	1.18
	General Lanes	1.01	0.89	1.23	1.18
	Total all lanes	0.84	0.89	1.05	1.18
NB I-35W at Minnesota River	HOV Lanes	0.53	1.05	0.71	1.28
	General Lanes	1.13	1.05	1.29	1.28
	Total all lanes	0.97	1.05	1.13	1.28

PM		2000		2020	
Location		With HOV	Without HOV	With HOV	Without HOV
WB I-394 at Penn Ave	HOV Lanes	0.31	0.88	0.43	1.04
	General Lanes	0.94	0.68	1.13	0.93
	Total all lanes	0.74	0.76	0.90	0.97
WB I-394 at Winnetka Ave	HOV Lanes	0.58	1.09	0.89	1.41
	General Lanes	1.21	1.09	1.50	1.41
	Total all lanes	1.04	1.09	1.34	1.41
SB I-35W at Minnesota River	HOV Lanes	0.60	1.00	0.85	1.30
	General Lanes	1.14	1.00	1.33	1.30
	Total all lanes	0.99	1.00	1.20	1.30

Figure E.16 Model Estimated V/C on I-394 from Hwy 100 to Downtown - 2000 A.M. Peak Hour (6:30 A.M. to 7:30 A.M.)

With HOV



Without HOV

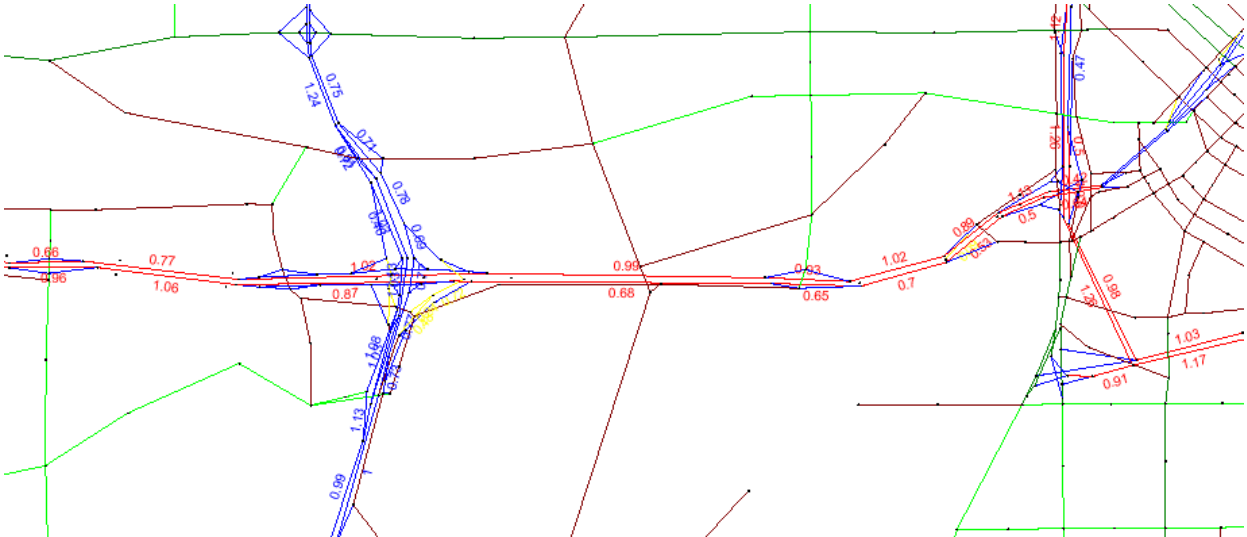
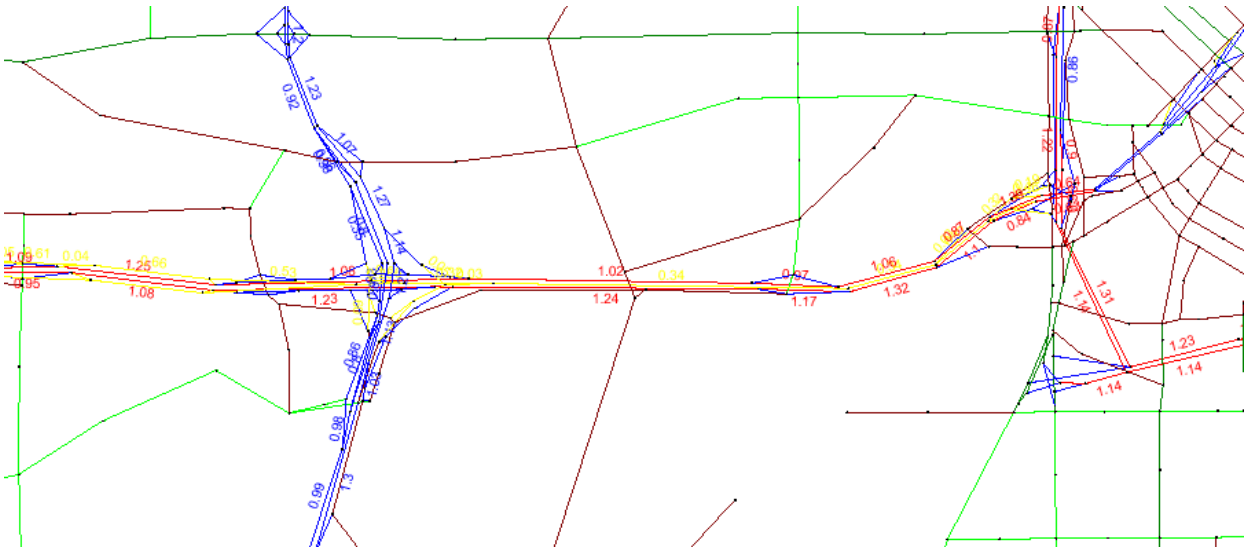
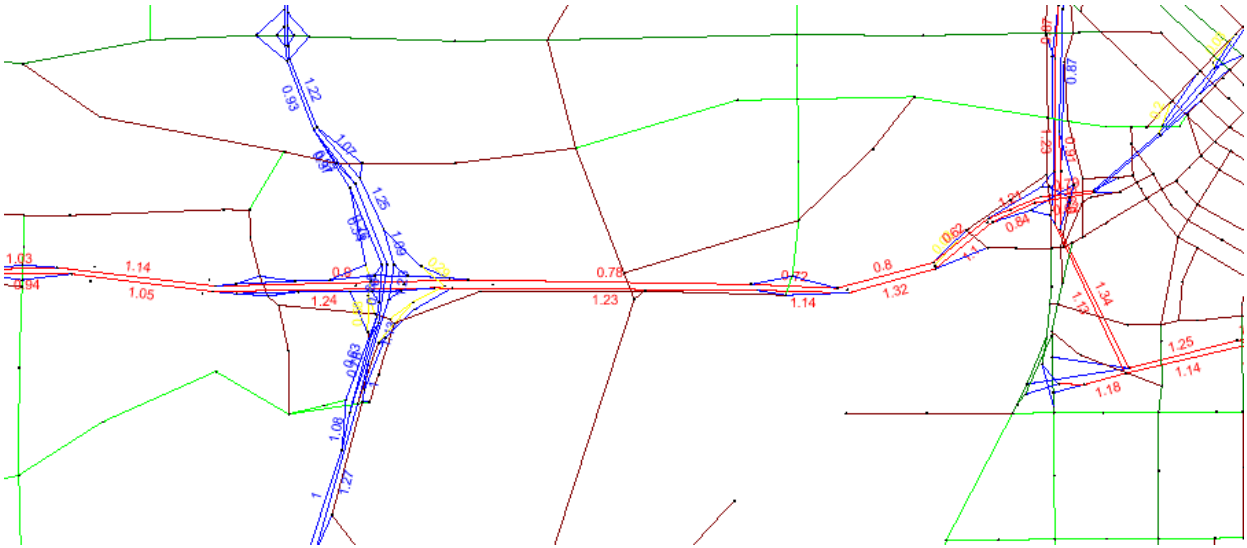


Figure E.20 Model Estimated V/C on I-394 from Hwy 100 to Downtown - 2000 P.M. Peak Hour (4:40 P.M. to 5:40 P.M.)

With HOV

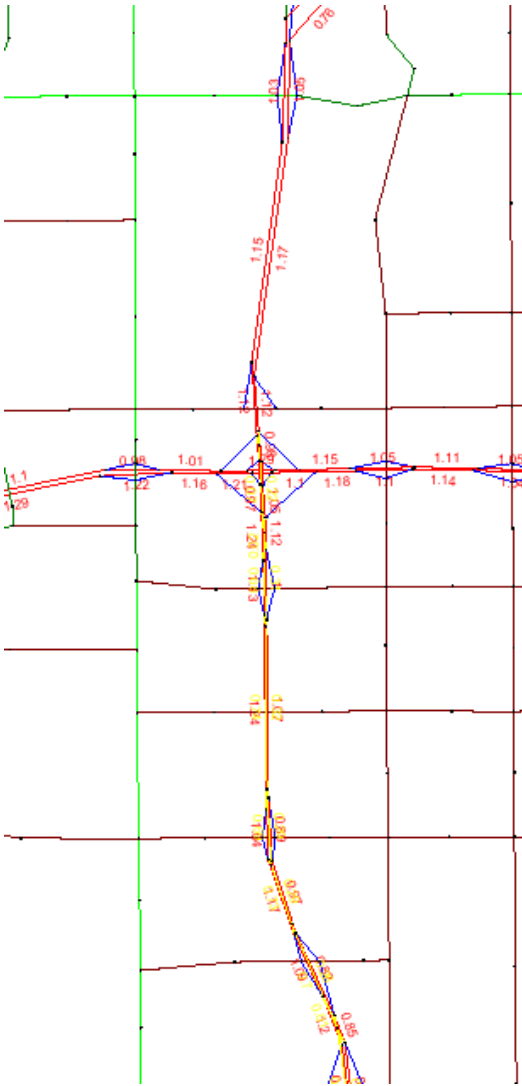


Without HOV



**Figure E.22 Model Estimated V/C on I-35W near I-494 - 2000 P.M.
Peak Hour (4:40 P.M. to 5:40 P.M.)**

With HOV



Without HOV

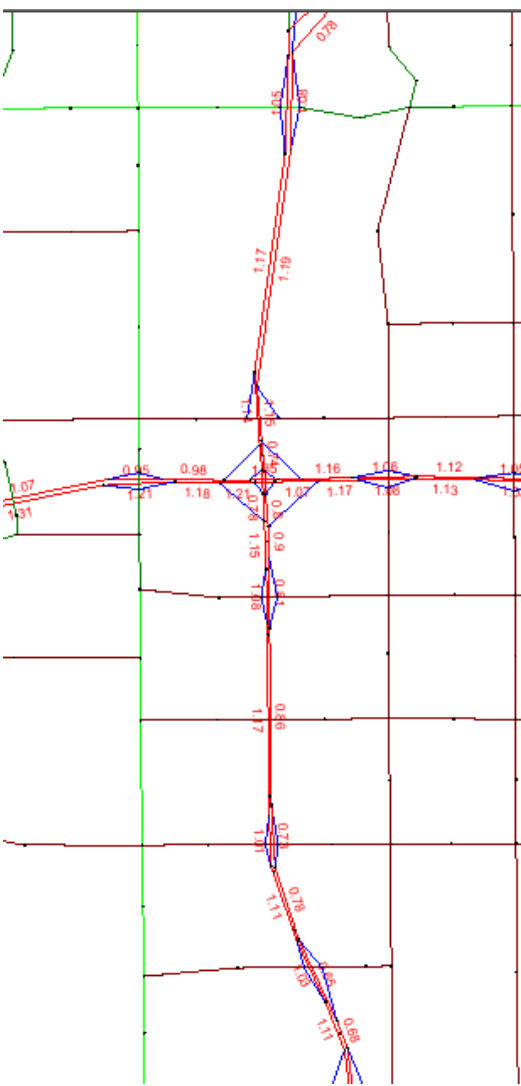
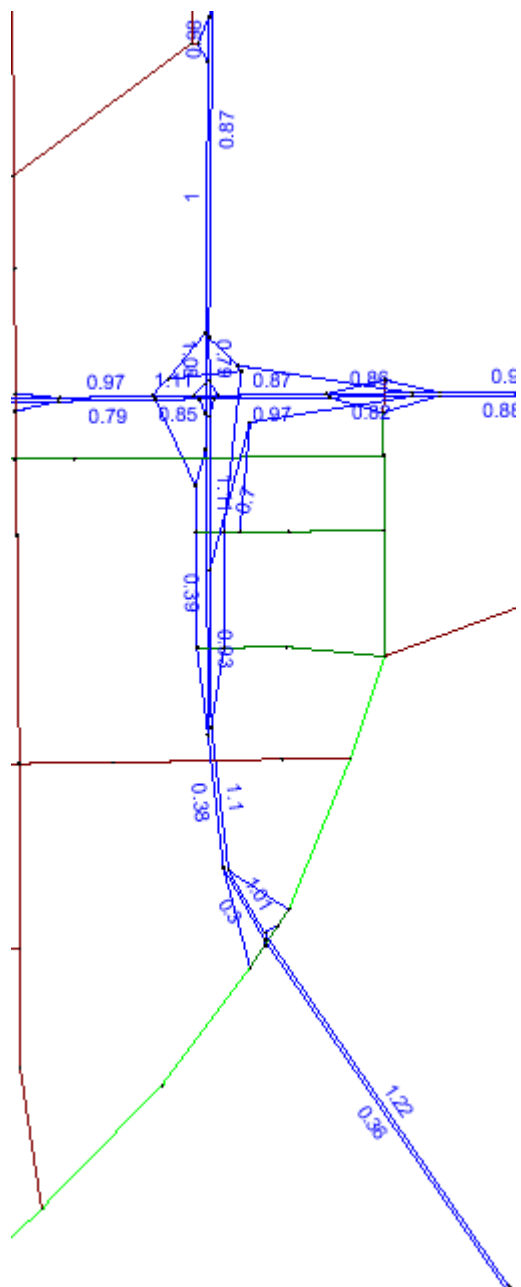


Figure E.23 Model Estimated V/C on Parallel Facility TH 77 – 2000 A.M. Peak Hour (6:30 A.M. to 7:30 A.M.)

With HOV



Without HOV

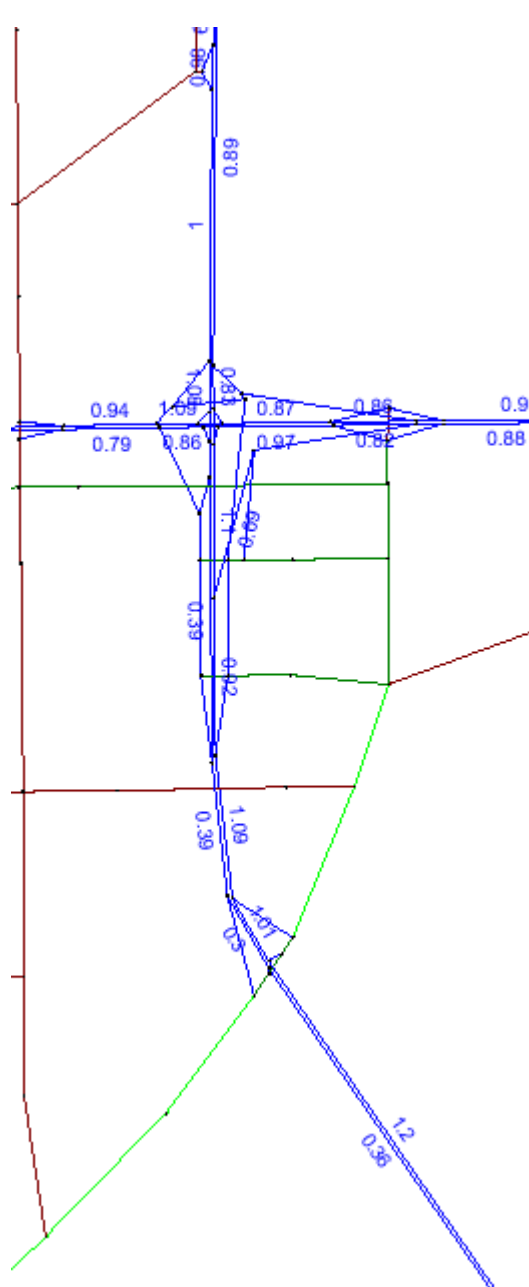


Table E.7 presents the VMT and VHT estimates from the travel demand model for auto trips by corridor.

Table E.7 Vehicle Miles Traveled and Vehicle Hours Traveled for Autos from the Travel Demand Model by Corridor

Measure/Year	With HOV							Without HOV				
	I-394		I-35W		I-394			I-394				
	Concurrent	I-394 GP	HOV	I-35W GP	Barrier	Remainder	Total	I-394 GP	I-35W GP	Barrier	Remainder	Total
Vehicle Miles of Travel												
2000	20,395	222,769	23,228	132,468	11,030	30,566,107	30,975,997	234,493	177,866	51,398	30,558,571	31,022,327
2020	25,197	252,836	44,453	268,251	16,667	40,789,944	41,397,348	296,243	379,585	60,099	40,646,429	41,382,356
Vehicle Hours of Travel												
2000	355	6,306	375	4,026	197	1,076,448	1,087,707	5,728	4,243	1,211	1,073,792	1,084,974
2020	489	9,986	822	16,453	298	2,460,753	2,488,799	10,037	18,161	1,511	2,454,252	2,483,960

E.3.1.3 Travel Time Reliability

Table E.8 presents the travel time reliability estimates from IDAS. These values are for freeways only and do not include arterials or reliability for transit in the bus-only shoulders.

Table E.8 Travel Time Reliability from IDAS (for Freeways Only)

Year	With HOV			Without HOV			Change	
	SOV	HOV	Total	SOV	HOV	Total	Value	Percent
2000	783	36	819	739	36	775	44	5%
2020	2323	100	2423	2097	105	2202	221	9%

E.3.2 HOV and Transit Use Impacts

E.3.2.1 Mode Shift

Table E.9 presents the estimated shift in total trips when the HOV lanes are opened to all traffic using the model. The increase in HOV trips in 2020 is likely a result of transit trips shifting to auto and realizing a parking advantage and/or being constrained by income level. These shifts represent a small portion of the overall carpool and transit trips in the region. For transit, this is approximately three percent (both 2000 and 2020) and for carpool it is about one percent in 2000 and 0.1 percent in 2020.

Table E.9 Shift in Total Trips

Year	SOV	HOV	Transit
2000			
A.M. Peak Period	2807	-934	-846
P.M. Peak Period	3620	-1009	-1501
Total	6427	-1943	-2347
2020			
A.M. Peak Period	2036	65	-2173
P.M. Peak Period	2639	166	-2988
Total	4675	231	-5160

E.3.2.2 Change in Transit Vehicles to Maintain Headways

An approach for determining the additional number of buses/operators that may result if the HOV lanes were open to all traffic was developed with assistance from the transit representatives on the TWG. This study assumed that current headways would need to be maintained, regardless of any ridership increases or decreases. This approach is outlined below. There were cases where this approach did not apply (e.g., where service is demand-based, not run on headways). To address this, the approach was applied to all of the routes affected, and then the results were discussed with each of the transit representatives and the values were adjusted to reflect these discussions.

Approach

According to typical transit planning methods, the number of buses required to maintain a specific headway is:

$$\text{Number of buses} = \frac{\text{cycle time}}{\text{headway}}$$

The cycle time, if the lanes were opened to all traffic, became the existing cycle time, plus the change in travel time on the roadway segments that are being opened to all traffic. This assumed that travel times on the other portions of the bus routes remained the same. The increase in travel time on the roadway segments opened to all traffic was estimated using speeds generated from the travel demand model and an estimate of speed for bus-only shoulder operations.

The assumptions included:

- Buses would use bus-only shoulder facilities where feasible, and the general lanes with all traffic where bus-only shoulders are not feasible;
- The maximum speed for bus-only shoulders is 35 mph;

- The estimated average speed for the bus-only shoulder is 25 mph (from Metro Transit);
- Speed for the mixed-flow traffic, once the lanes are open to all traffic, will be estimated using the travel demand model;
- The same level of service (headway) will be maintained;
- Annual operating cost changes will include additional drivers and vehicle operations (fuel) and maintenance; and
- The estimate of capital cost changes will include additional vehicles.

The equation then became:

$$\text{Adjusted cycle time} = \text{Current cycle time} + \text{Change in Travel Time on Opened HOV Segment}$$

The data obtained from each of the transit operators consisted of the following:

- Bus routes using the I-394 or I-35W HOV facilities;
- Average headway for each route;
- Cycle time for each route;
- Peak direction ridership and bus capacity;
- Average annual operating cost (driver and vehicle operation and maintenance);
- Average annual capital cost per vehicle.

Tables E.10 and E.11 present the bus routes using the HOV facilities during the a.m. and p.m. peak periods. As shown, approximately 31 bus routes provide 120 transit trips on I-394 eastbound in the morning peak hours of 6:00 to 8:00 a.m. Six routes on I-35W serve 48 bus trips in the morning peak northbound. In the afternoon, there are eight bus routes on I-35W with 50 trips. Westbound I-394 during the afternoon peak period has 128 bus trips.

The analysis and further discussions with the transit representatives resulted in 15 additional buses being needed to maintain current headway levels. There are also additional operations and maintenance costs associated with the increase in trip time and drivers needed for these new buses.

**Table E.10 Morning Peak Period Transit Routes Using HOV Lanes
(6:00 am to 8:00 am)**

Agency	Bus Route	From	To	Trips	Avg. Headway (min)	Cycle (min)	
I-35W Northbound							
MVTA	431	Hwy 13	82nd	3	31	60	
	460	Hwy 13	Downtown	26	5	72	
	464	Hwy 13	Downtown	3	30	105	
	490	Hwy 13	Downtown	2	30	120	
Metro	47	98th	Downtown	10	12	110	
	44C	98th	Downtown	4	25	60	
Total Trips				48			
I-35W Southbound							
MVTA	460	Entire	entire	2	30	72	
Southwest Metro	681	Downtown	Hwy 62	3	42	90	
Metro	47	Downtown	98th	4	19	–	
	551	Downtown	98th	2	88	–	
Total Trips				11			
I-394 Eastbound							
Plymouth	776	Entire	Entire	4	30	100	
	772	Co Rd 73	Downtown	5	23	90	
	790	Hwy 169	Downtown	7	18	90	
Southwest Metro	683	Hwy 169	Downtown	1	–	130	
	680	Hwy 169	Downtown	2	39	130	
	682	Hwy 169	Downtown	1	30	100	
	684	Hwy 169	Downtown	3	18	130	
	685	Hwy 169	Downtown	4	25	100	
	688	Hwy 169	Downtown	1	–	130	
	690	Hwy 169	Downtown	6	14	90	
	691	Hwy 169	Downtown	1	–	130	
	692	Hwy 169	Downtown	4	27	130	
	Metro	52M	Plymouth	Downtown	2	15	84
588		Hwy 100	Downtown	4	33	63	
587		Hwy 100	Downtown	3	27	91	
663		Louisiana	Downtown	6	18	63	
667		Hwy 169	Downtown	10	16	60	
668		Hwy 169	Downtown	3	30	–	
671		Plymouth	Downtown	4	28	72	
672		Entire	Entire	4	28	120	
674		Entire	Entire	3	40	–	
673		Co Rd 73	Downtown	10	14	45	
675		Start to Plymouth	General Mills to downtown	6	18	180	
676		Entire	entire	2	92	150	
677		Entire	Entire	3	33	–	
764		Hwy 100	Downtown	4	20	–	
765		Hwy 100	Downtown	4	20	–	
Laidlaw		58	Hwy 100	Downtown	3	30	60
		664	Hwy 100	Downtown	4	30	52
	665	Hwy 169	Downtown	3	30	52	
	670	Hwy 169	Downtown	3	30	69	
Total Trips				120			

**Table E.11 Afternoon Peak Period Transit Routes Using HOV Lanes
(3:00 A.M. TO 6:00 P.M.)**

Agency	Bus Route	From	To	Trips	Avg. Headway (min)	Cycle (min)
I-35W Southbound						
MVTA	431	82 nd	Hwy 13	3	30	60
	460	Entire	Entire	27	6	80
	464	Entire	Entire	3	30	120
	490	Entire	Entire	2	30	120
Southwest Metro	681	Downtown	Hwy 62	1	-	90
	696	Downtown	Hwy 62	1	-	90
Metro	47	Downtown	98 th	10	13	-
	44C	Downtown	98 th	3	31	80
Total Trips				50		
I-35W Northbound						
MVTA	460	Entire	Entire	2	30	80
Southwest Metro	681	Hwy 62	Downtown	5	37	90
Metro	47	98 th	Downtown	4	44	-
	551	98 th	Downtown	2	120	-
Total Trips				13		
I-394 Westbound						
Plymouth	776	Entire	Entire	5	31	100
	772	Downtown	Co Rd 73	5	33	90
	790	Downtown	Hwy 169	8	18	90
Southwest Metro	680	Downtown	Hwy 169	2	29	130
	682	Downtown	Hwy 169	2	27	100
	684	Downtown	Hwy 169	3	33	130
	685	Downtown	Hwy 169	4	30	100
	689	Downtown	Hwy 169	2	113	100
	690	Downtown	Hwy 169	5	20	90
	692	Downtown	Hwy 169	4	33	130
	675	Downtown to General Mills	Plymouth to end	7	31	180
Metro	52M	Downtown	Plymouth	3	34	-
	587	Downtown	Hwy 100	5	27	60
	588	Downtown	Hwy 100	3	52	-
	663	Downtown	Louisiana	9	14	60
	667	Downtown	Hwy 169	8	22	80
	668	Downtown	Hwy 169	3	30	-
	671	Downtown	Plymouth	3	29	-
	672	Entire	Entire	4	39	120
	674	Entire	Entire	4	27	-
	673	Downtown	Co Rd 73	10	18	45

**Table E.11 Afternoon Peak Period Transit Routes Using HOV Lanes
(3:00 A.M. to 6:00 P.M.) (continued)**

Agency	Bus Route	From	To	Trips	Avg. Headway (min)	Cycle (min)
	676	Entire	Entire	4	50	160
	677	Entire	Entire	3	30	-
	764	Downtown	Hwy 100	3	31	-
	765	Downtown	Hwy 100	5	26	-
	58	Downtown	Hwy 100	3	31	60
Laidlaw	664	Downtown	Hwy 100	5	30	52
	665	Downtown	Hwy 169	3	30	52
	670	Downtown	Hwy 169	3	30	69
Total Trips				128		

Table E.12 Additional Buses and O&M Costs to Maintain Headways

Transit Provider	Additional Buses	Capital Cost	Annual Operations and Maintenance Costs
Plymouth Metro Link	3	\$825,000	\$264,400
Metro Transit	5	\$1,350,000	\$710,700
Southwest Metro	4	\$1,740,000	\$510,000
MVTA	3	\$652,500	\$436,300
Laidlaw	0	\$-	\$24,800
Total	15	\$4,567,500	\$1,946,200