Appendix A

Dates and Locations of License Plate Number Data Collection

Appendix A
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Table A.1 Dates and Locations of License Plate Number Data Collection

Location	Date and Time	Highway or Ramp	Collection Point	Direction
Corridor 494	Tuesday 9/12 a.m.	R	Rockford Road	S
		H	494 north of Carlson Parkway	S
	Tuesday 9/12 p.m.	R	55	N
		H	494 north of Carlson Parkway	N
	Wednesday 9/13 a.m.	R	Bass Lake Road	S
		H	494 north of Carlson Parkway	S
	Wednesday 9/13 p.m.	R	55	N
		H	494 north of Carlson Parkway	N
	Thursday 9/14 a.m.	R	55	S
		H	494 north of Carlson Parkway	S
	Thursday 9/14 p.m.	R	55	N
		H	494 north of Carlson Parkway	N
	Friday 9/15 a.m.	R	Rockford Road	S
		H	494 north of Carlson Parkway	S
	Friday 9/15 p.m.	R	55	N
		H	494 north of Carlson Parkway	N
	Monday 9/18 a.m.	R	Rockford Road	S
		H	494 north of Carlson Parkway	S
	Monday 9/18 p.m.	R	Rockford Road	N
		H	494 north of Carlson Parkway	N
Corridor 35W	Tuesday 9/12 a.m.	R	106th Street	N
		H	35W South of Burnsville Parkway	N
	Tuesday 9/12 p.m.	R	106th Street	S
		H	35W South of Burnsville Parkway	S
	Wednesday 9/13 a.m.	R	106th Street	N
		H	35W South of Burnsville Parkway	N
	Wednesday 9/13 p.m.	R	106th Street	S

Table A.1 Dates and Locations of License Plate Number Data Collection (continued)

Location	Date and Time	Highway or Ramp	Collection Point	Direction
Corridor 35W (continued)		H	35W South of Burnsville Parkway	S
	Thursday 9/14 a.m.	H	35W South of Burnsville Parkway	N
	Thursday 9/14 p.m.	H	35W South of Burnsville Parkway	S
	Friday 9/15 a.m.	R	HW 13	N
	Friday 9/15 p.m.	R	35W to 13	W
	Monday 9/18 a.m.	R	HW 13	N
	Monday 9/18 p.m.	R	35W to 13	W
	Tuesday 9/19 a.m.	R	HW 13	N
		R	35W to 106st Street	E
		R	42	N
	Tuesday 9/19 p.m.	R	35W to 13	W
		R	106th Street	S
		R	35W to 42	W
	Wednesday 9/20 a.m.	R	Cliff Raod	N
		R	106th Street	N
		R	42	N
	Wednesday 9/20 p.m.	R	35W toCliff Raod	E
		R	106th Street	S
		R	35W to 42	W
Corridor 94	Tuesday 9/12 a.m.	H	94 East of Snelling	E
	Tuesday 9/12 p.m.	H	94 East of Snelling	E
		R	94 West to Huron	N
	Wednesday 9/13 a.m.	H	94 East of Snelling	E
		R	Lexington	W
	Wednesday 9/13 p.m.	H	94 East of Snelling	E
		R	Lexington	W
		R	Huron	W
	Thursday 9/14 p.m.	R	280	W ½ Shift
			94 East to 280	N ½ Shift
	Friday 9/15 a.m.	R	Snelling	W
	Friday 9/15 p.m.	R	Snelling	W
		R	Snelling	E
		R	Cretin	E ½ Shift
			Cretin	W ½ Shift

Table A.1 Dates and Locations of License Plate Number Data Collection (continued)

Location	Date and Time	Highway or Ramp	Collection Point	Direction
Corridor 94 (continued)	Monday 9/18 a.m.	R	Snelling	W
		R	Snelling	E
	Monday 9/18 p.m.	R	Snelling	W
	Tuesday 9/19 a.m.	R	Lexington	W
	Tuesday 9/19 p.m.	R	Lexington	E
	Wednesday 9/20 a.m.	R	Lexington	E
	Thursday 9/21 a.m.	R	Snelling	E
		R	Lexington	E
	Thursday 9/21 p.m.	R	Snelling	W
		R	Lexington	W
Corridor 35E	Tuesday 9/12 a.m.	H	35E North of Maryland	S
		R	Little Canada Road	S
	Tuesday 9/12 p.m.	R	Larpenteur	N
		R	Little Canada Road	N
	Wednesday 9/13 a.m.	R	Maryland	S
		R	County Road E	S
	Wednesday 9/13 p.m.	R	Roselawn	N
		R	County Road E	N ½ shift
			35E to County Road E	E ½ shift
	Thursday 9/14 a.m.	R	Roselawn	S
		R	Highway 96	S
	Thursday 9/14 p.m.	R	Maryland	N
		R	35E to 96	E
	Friday 9/15 a.m.	R	Larpenteur	S
	Friday 9/15 p.m.	R	Maryland	N
		R	35E to CRJ	E
	Monday 9/18 a.m.	R	Little Canada Road	S
	Monday 9/18 p.m.	R	Little Canada Road	N
		R	Maryland	N
	Tuesday 9/19 a.m.	R	County Road E	S
Corridor 35E (continued)	Tuesday 9/19 p.m.	R	35E to County Road J	E
		R	Roselawn	N
	Wednesday 9/20 a.m.	R	County Road J	S
	Wednesday 9/20 p.m.	R	Pennsylvania	N

Appendix B

Summary of Field Data: Freeway and Arterial Speeds

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Summary of Field Data: Freeway and Arterial Speeds

This appendix presents a summary of findings from the travel time and speed surveys conducted on freeway and arterial segments as part of the evaluation of the ramp metering system in the Twin Cities region.

In the figures, the arterial routes are identified as follows:

- CR-61 = County Route 61;
- Vick = Vicksburg Avenue;
- TH-77 = TH-77;
- Univ = University Avenue;
- Marsh = Marshall Avenue;
- Rice = Rice Avenue; and
- Edge = Edgerton Avenue.

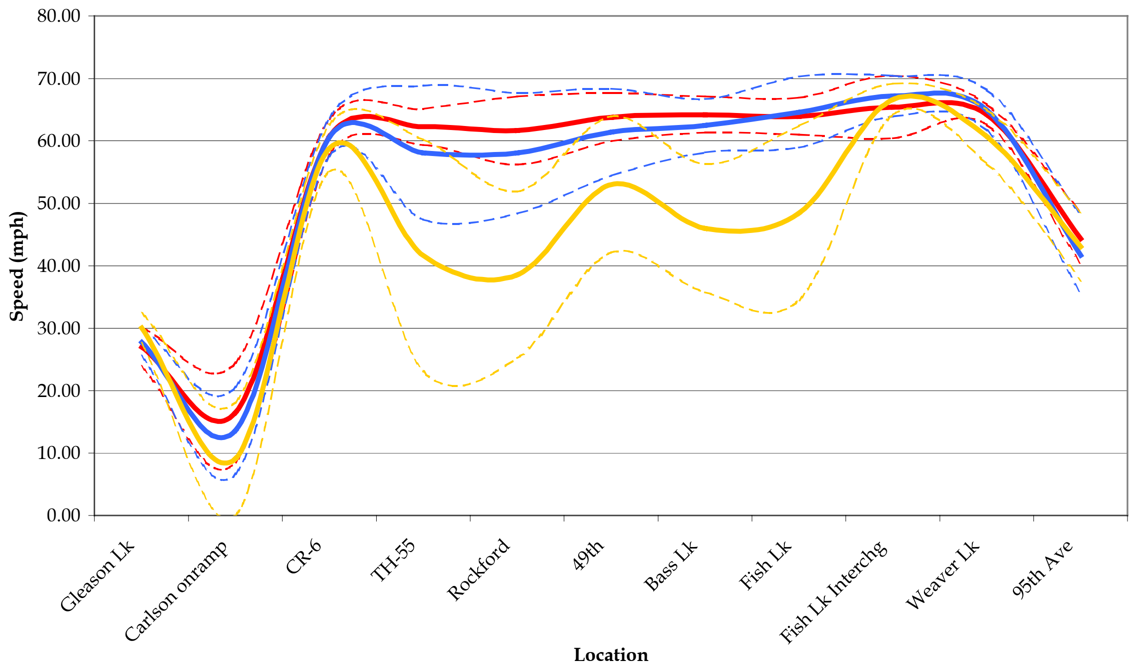
The colors in the graphics indicate the day of the week in which the travel time surveys were performed, as follows:

- Red = Travel time surveys performed on a Monday;
- Blue = Travel time surveys performed on Tuesday through Thursday; and
- Yellow = Travel time surveys performed on a Friday.

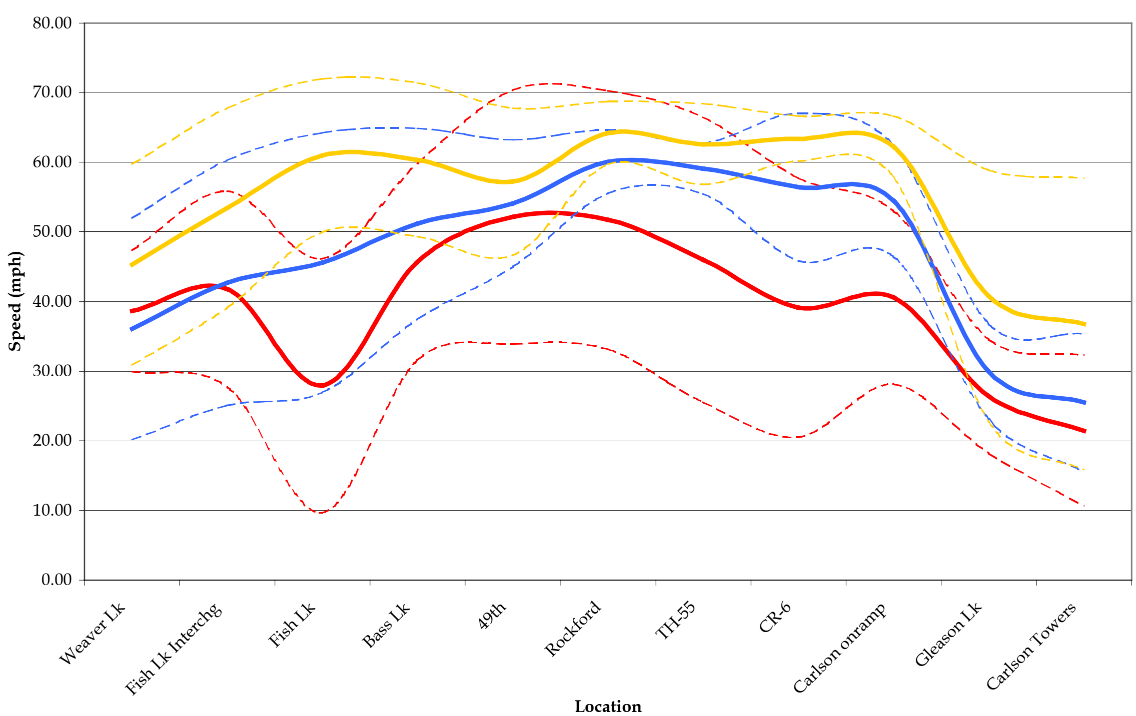
The two evaluation study periods are represented as follows:

- "With" = With ramp metering; and
- "Without" = Without ramp metering.

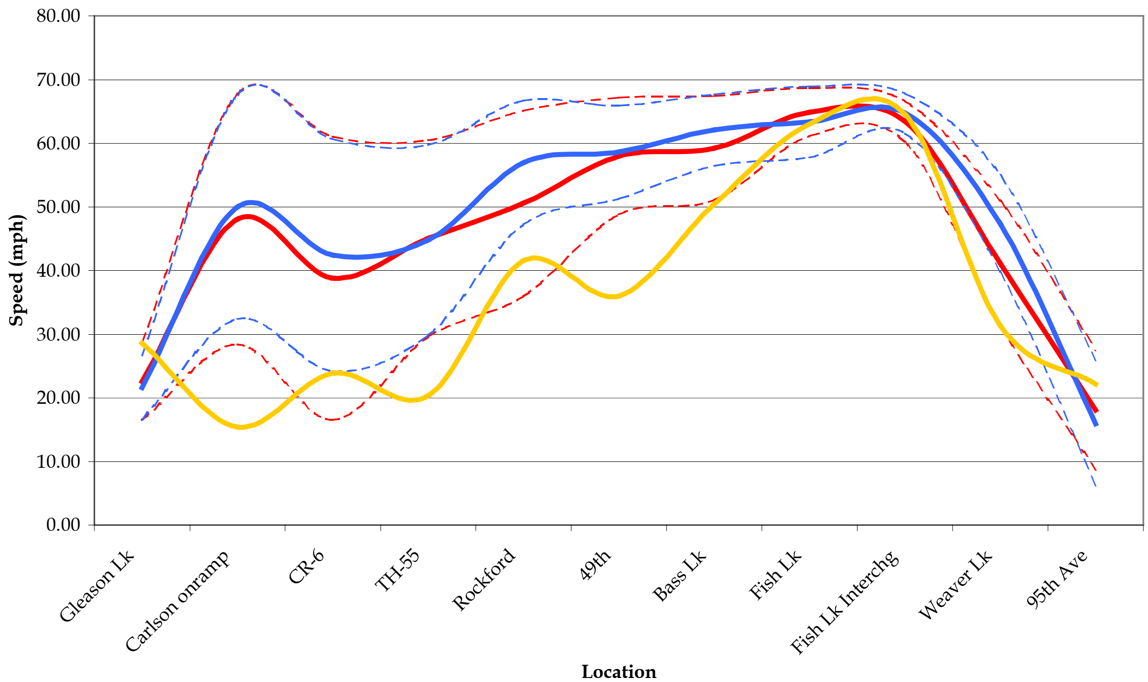
I-494 NB P.M. Peak (With)



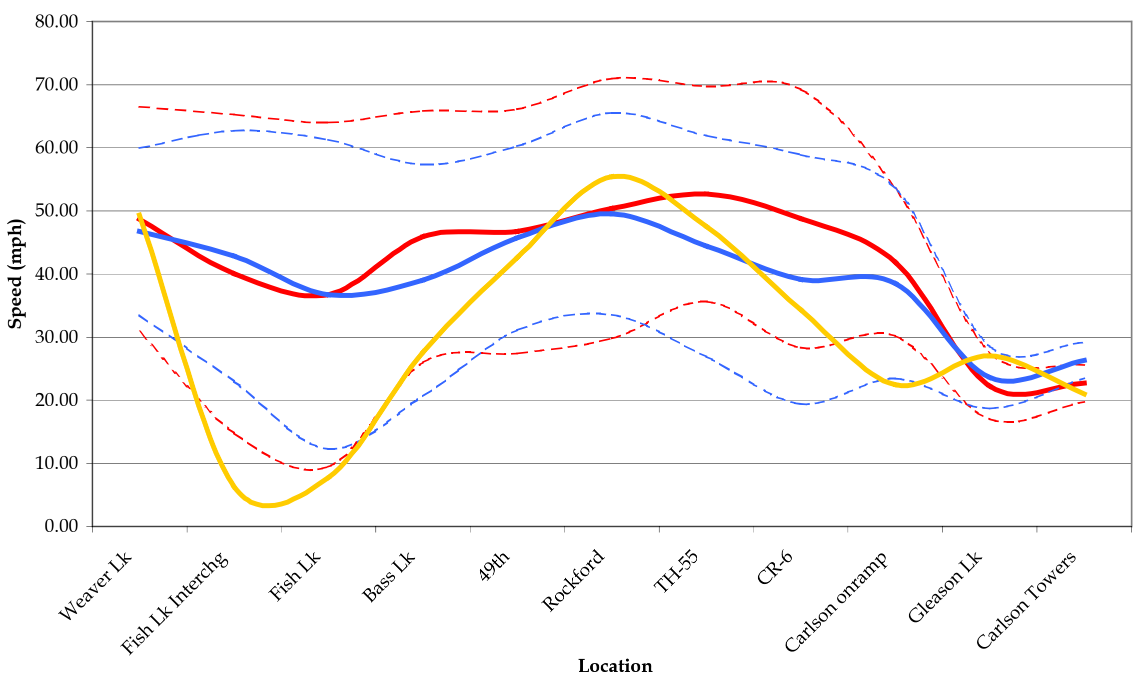
I-494 SB A.M. Peak (With)



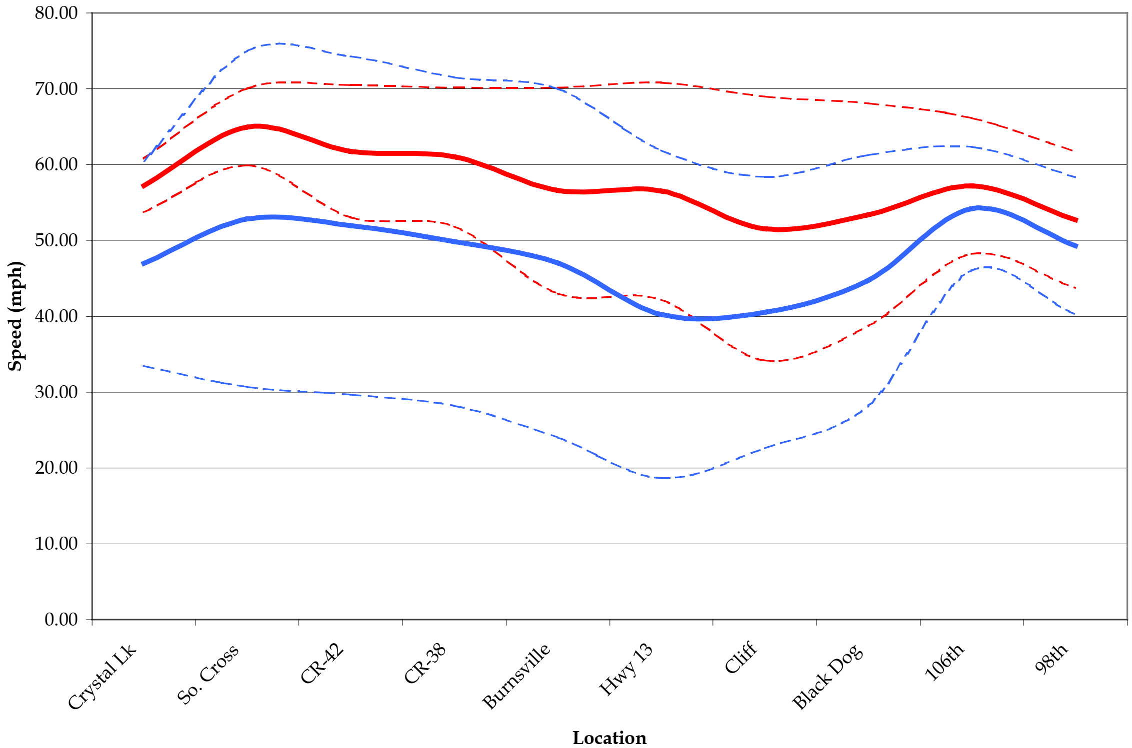
I-494 NB P.M. Peak (Without)



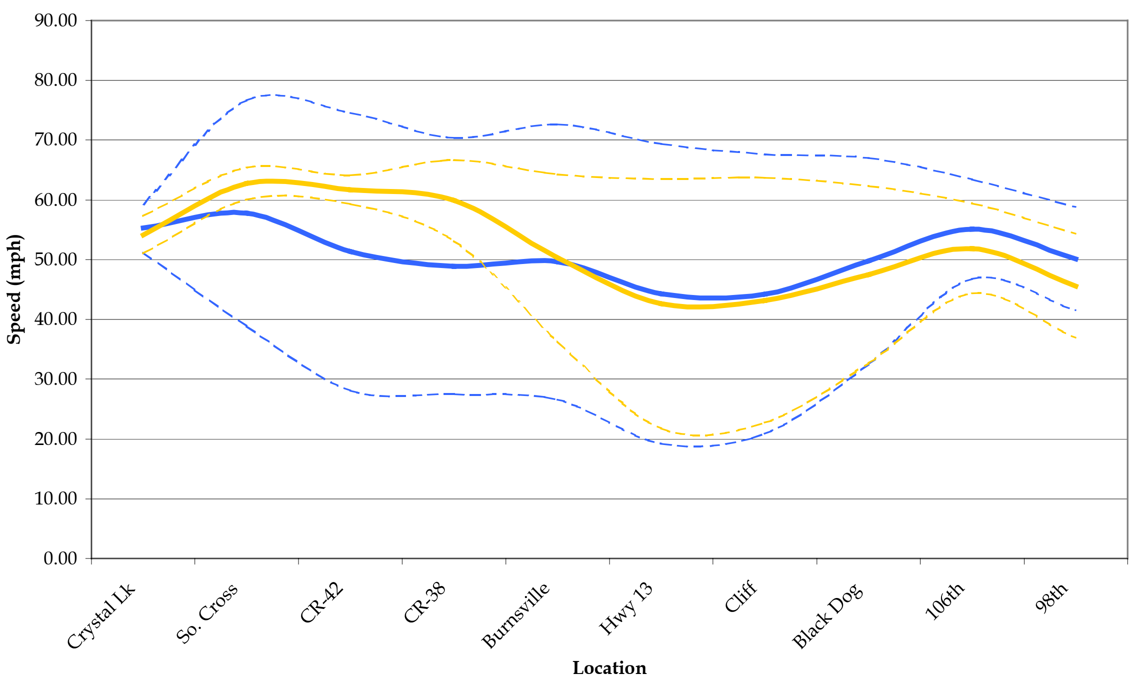
I-494 SB A.M. Peak (Without)



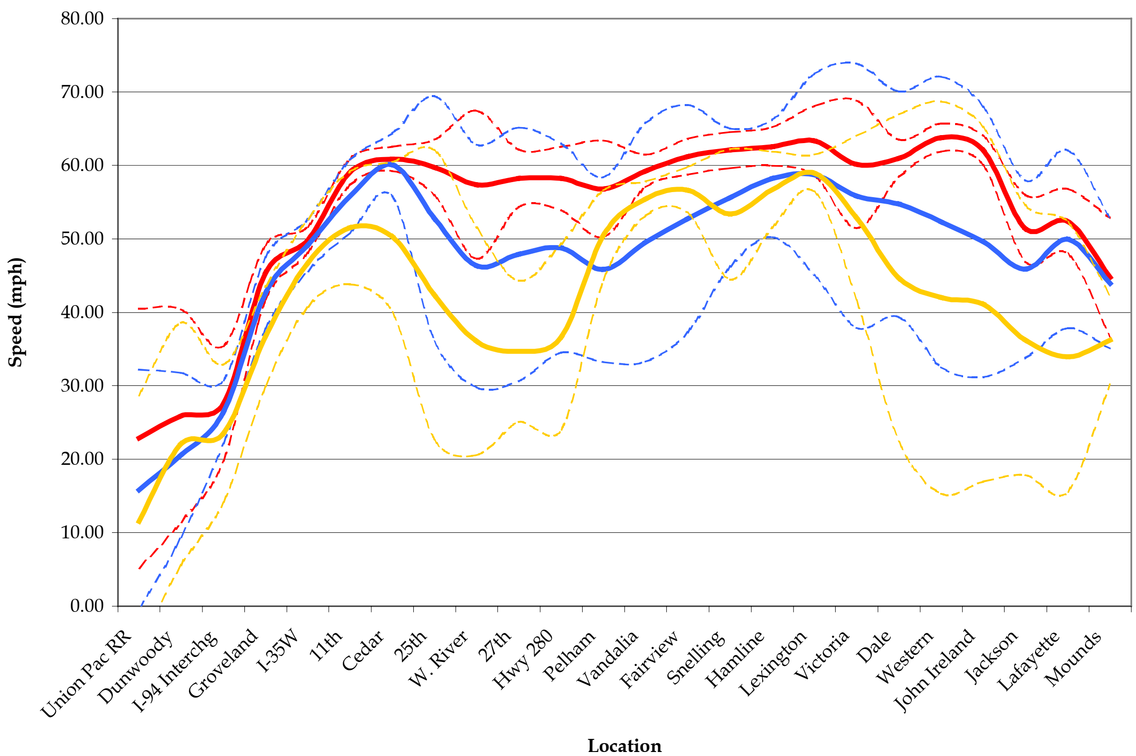
I-35W NB A.M. Peak (With)



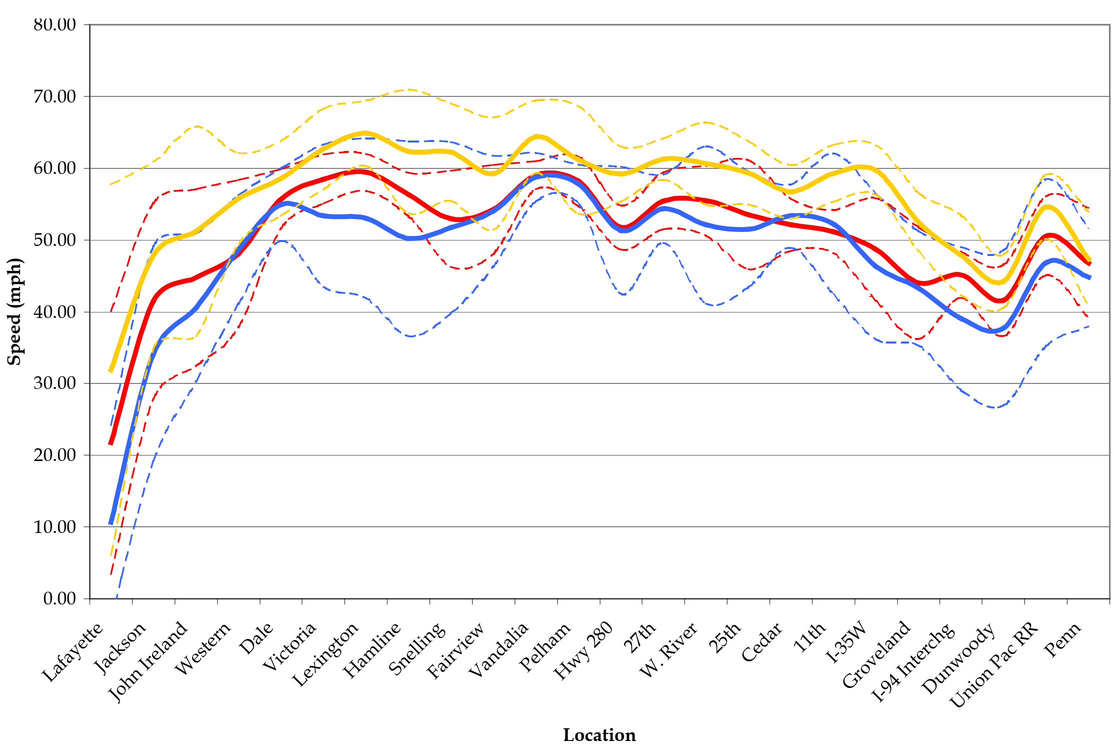
I-35W NB A.M. Peak (Without)



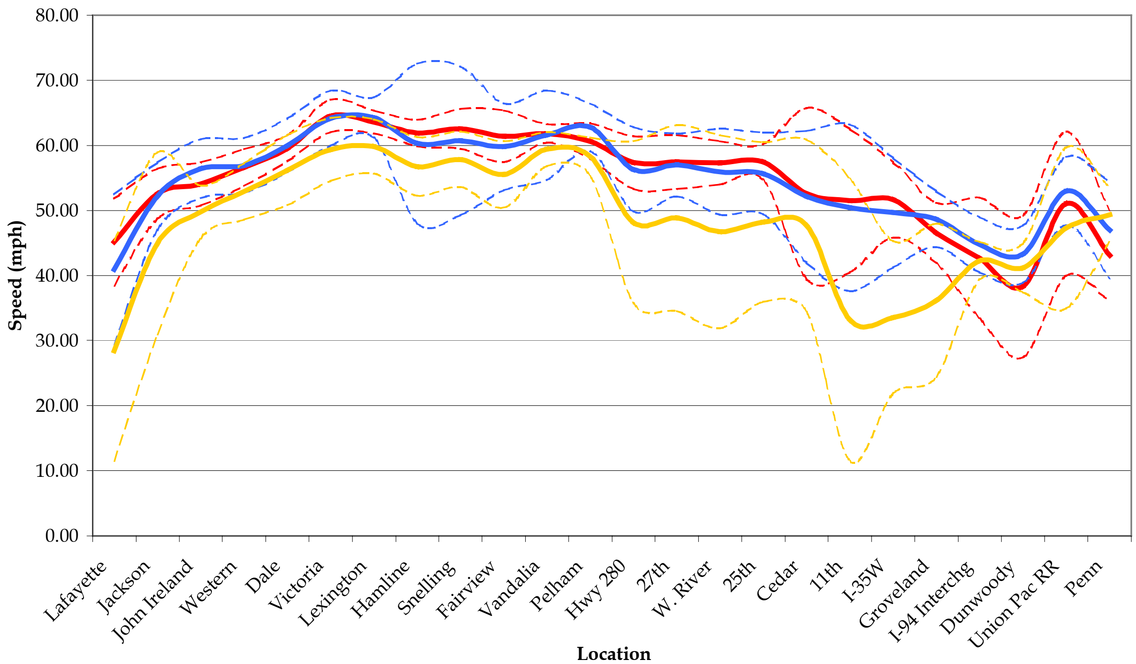
I-94 EB P.M. Peak (With)



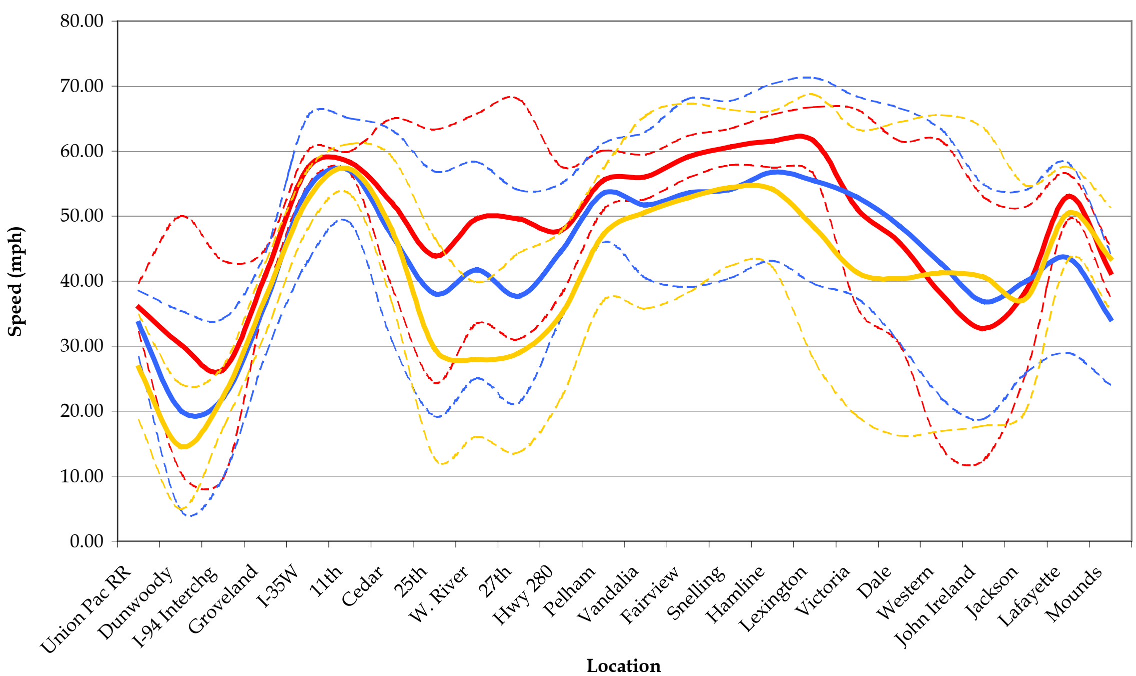
I-94 WB A.M. Peak (With)



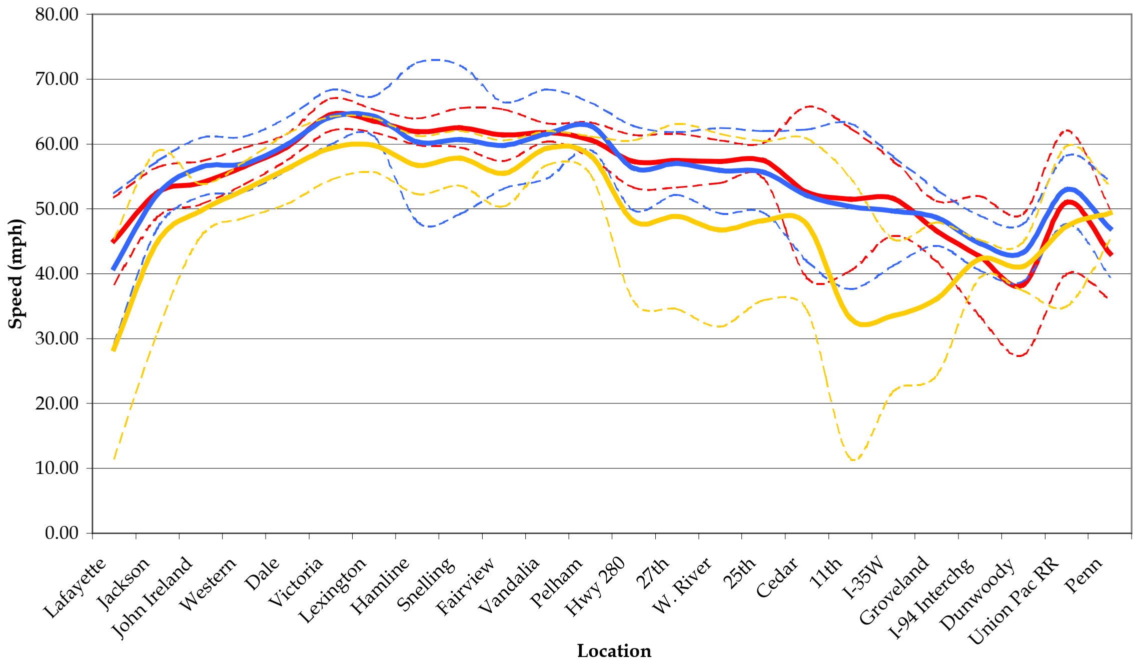
I-94 WB P.M. Peak (With)



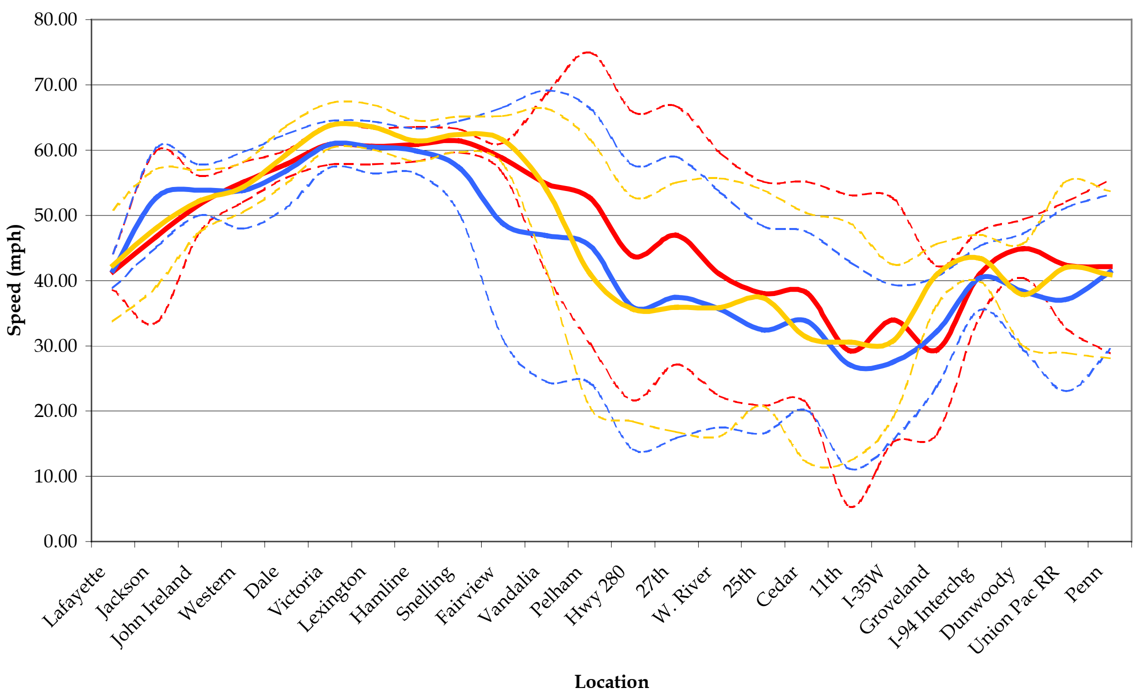
I-94 EB P.M. Peak (Without)



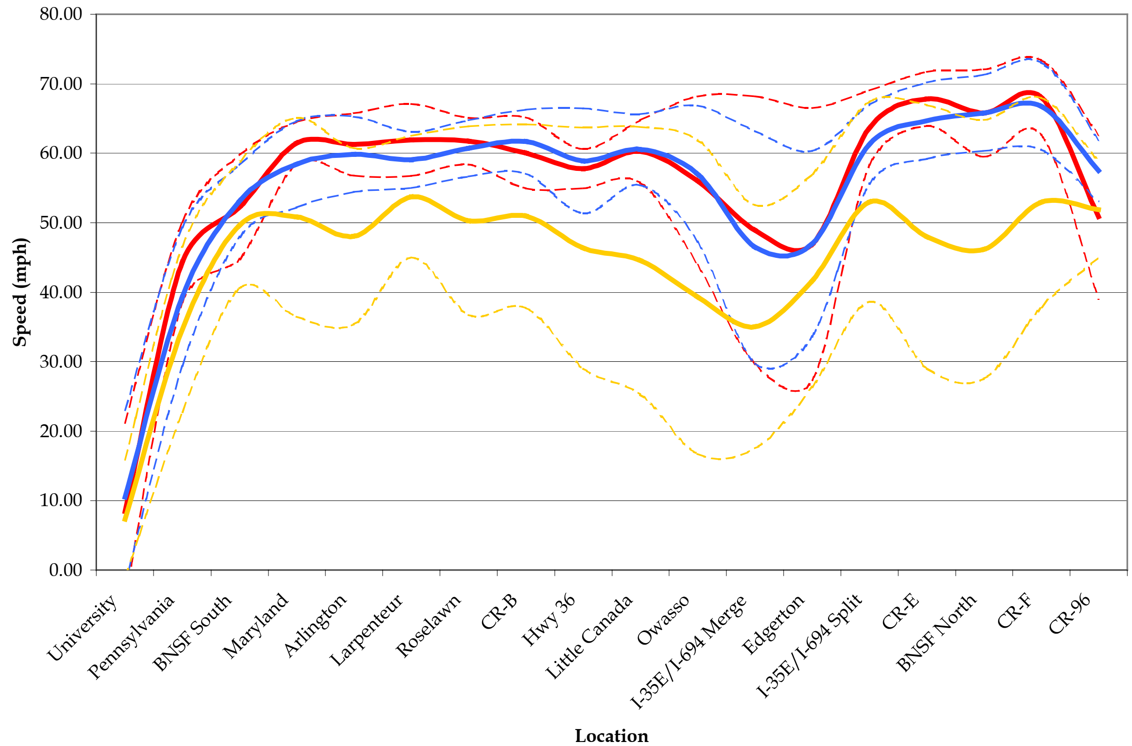
I-94 WB A.M. Peak (Without)



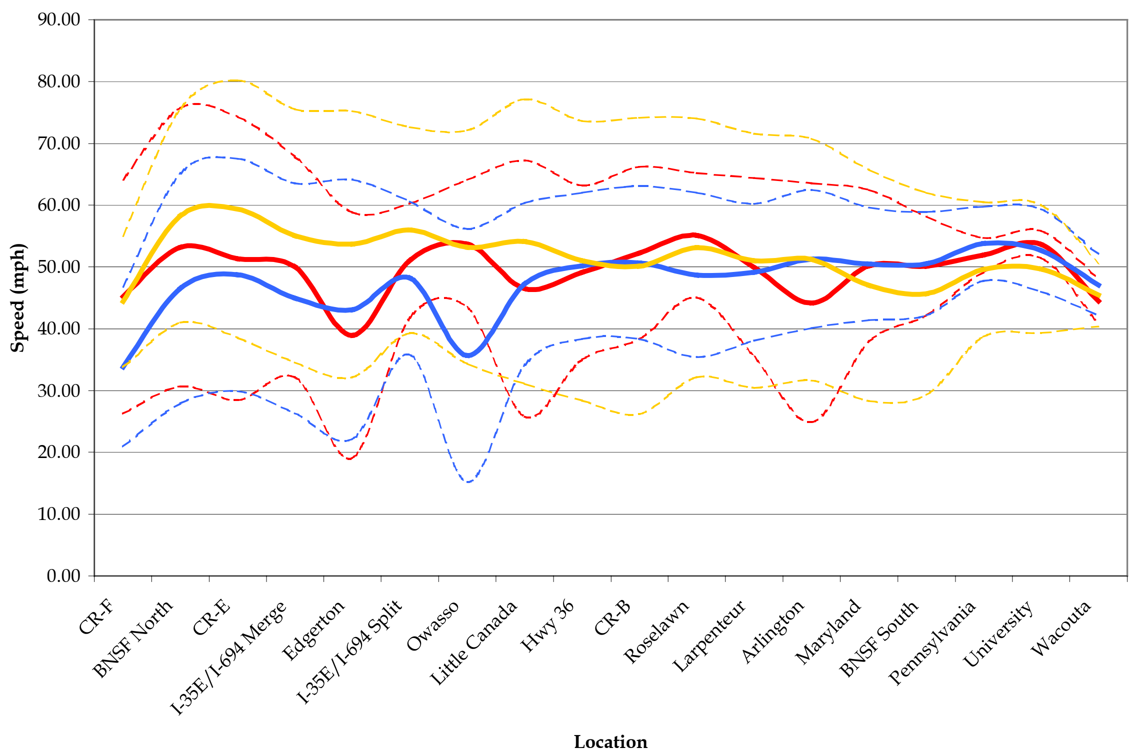
I-94 WB P.M. Peak (Without)



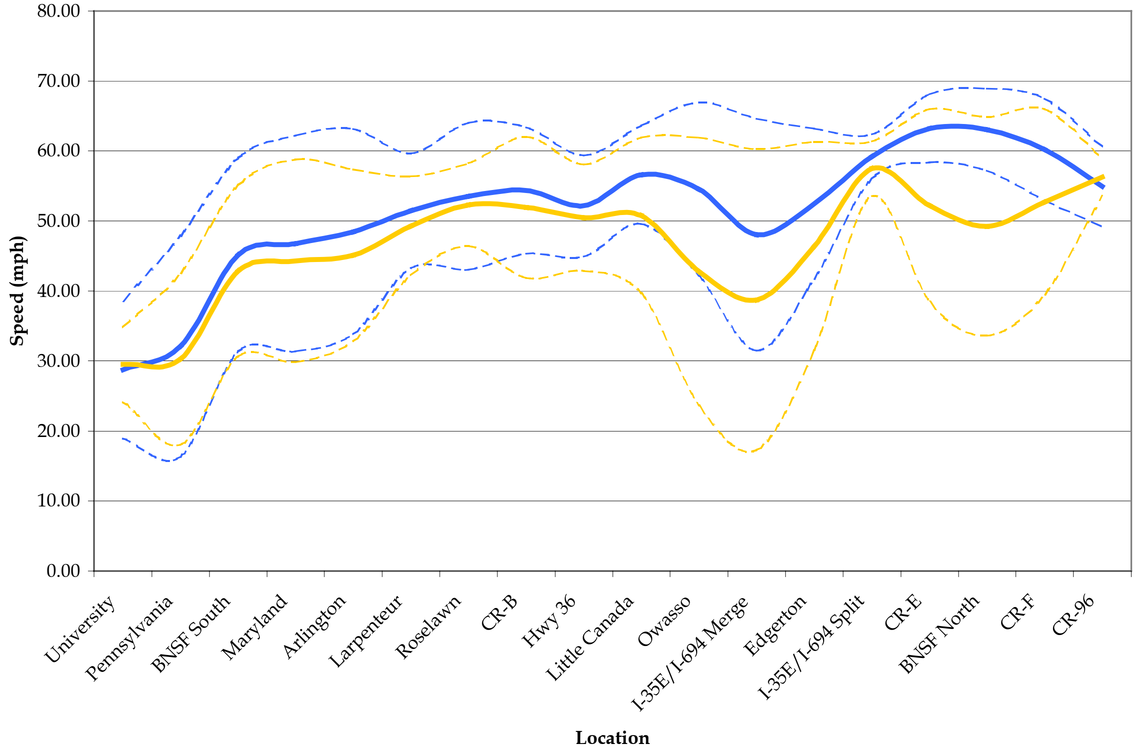
I-35E NB P.M. Peak (With)



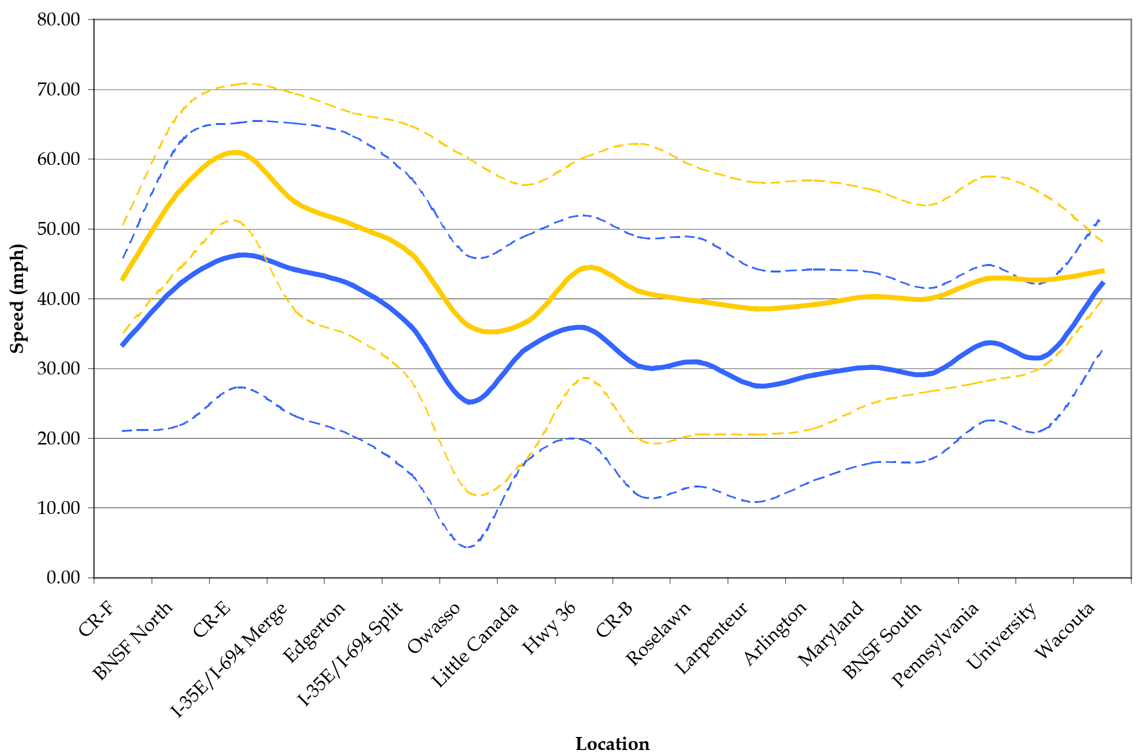
I-35E SB A.M. Peak (With)



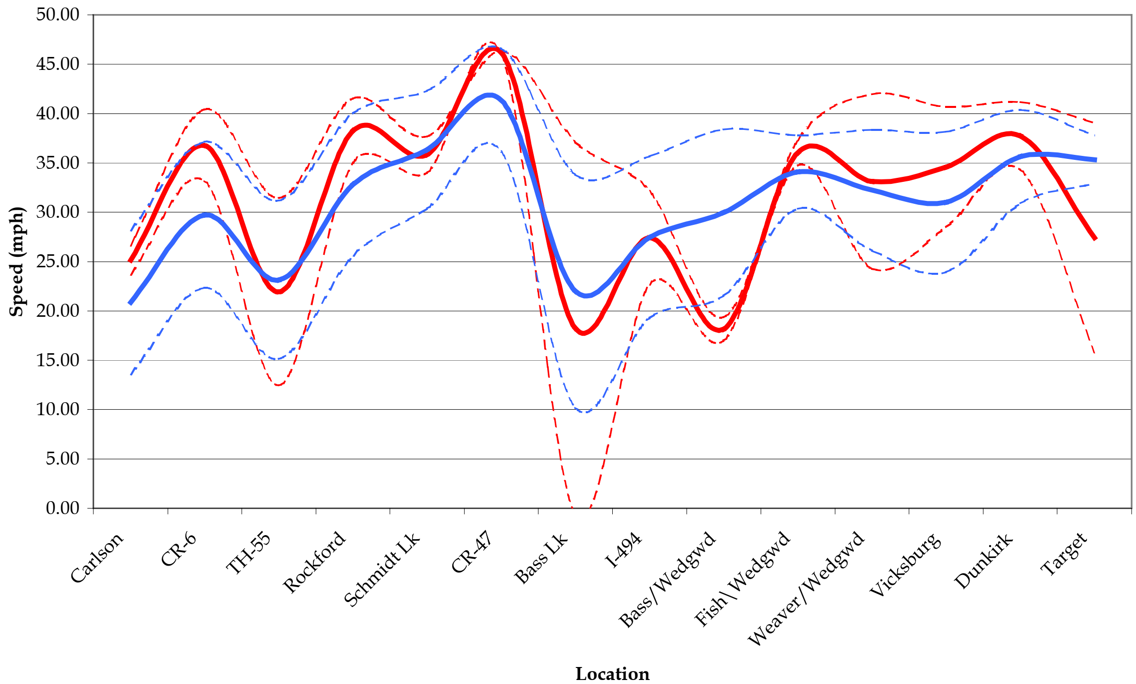
I-35E NB P.M. Peak (Without)



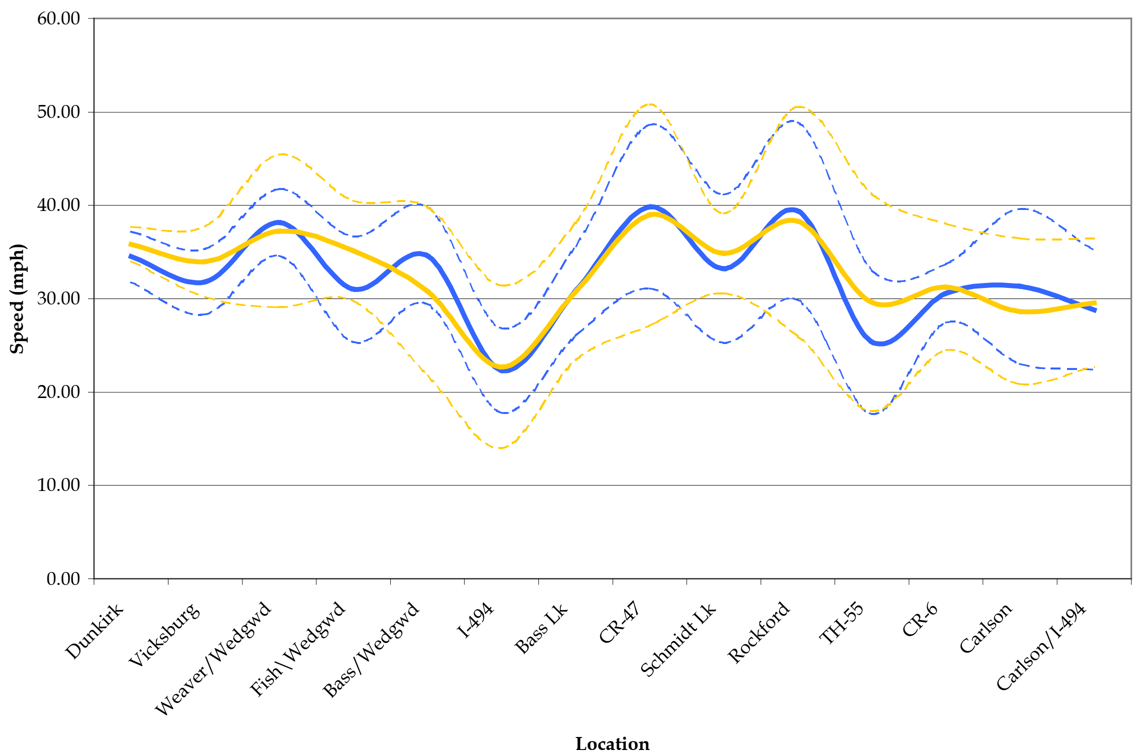
I-35E SB A.M. Peak (Without)



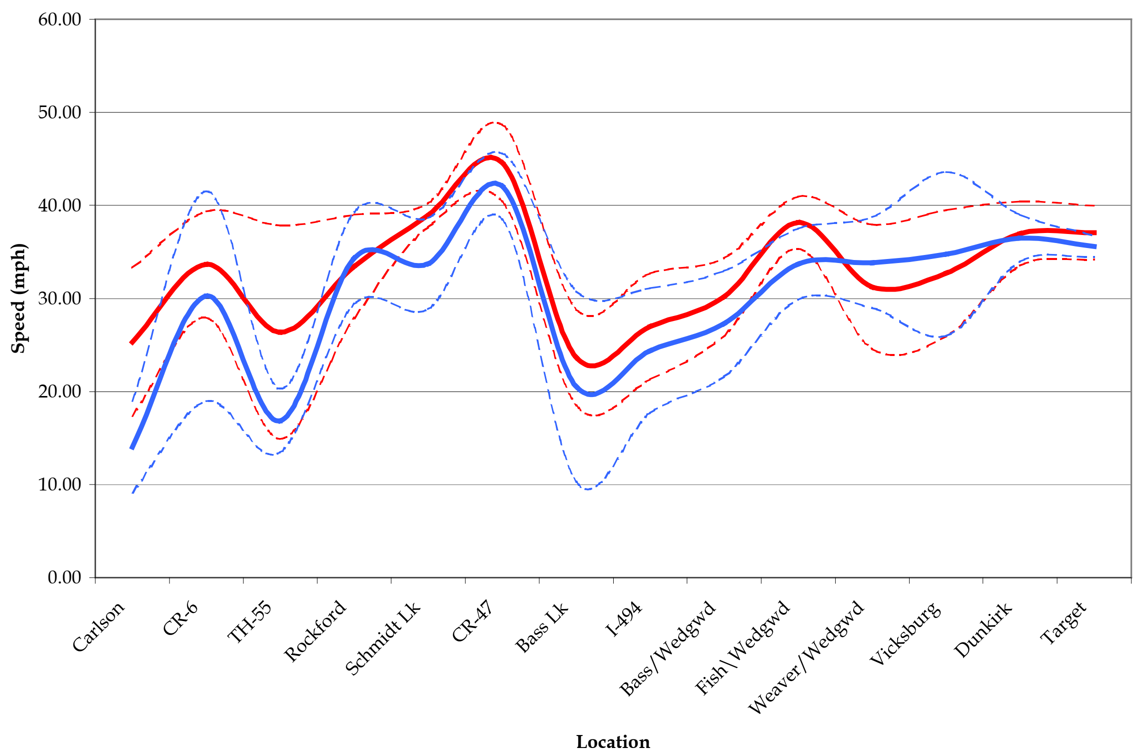
I-494 CR-61 NB P.M. Peak (With)



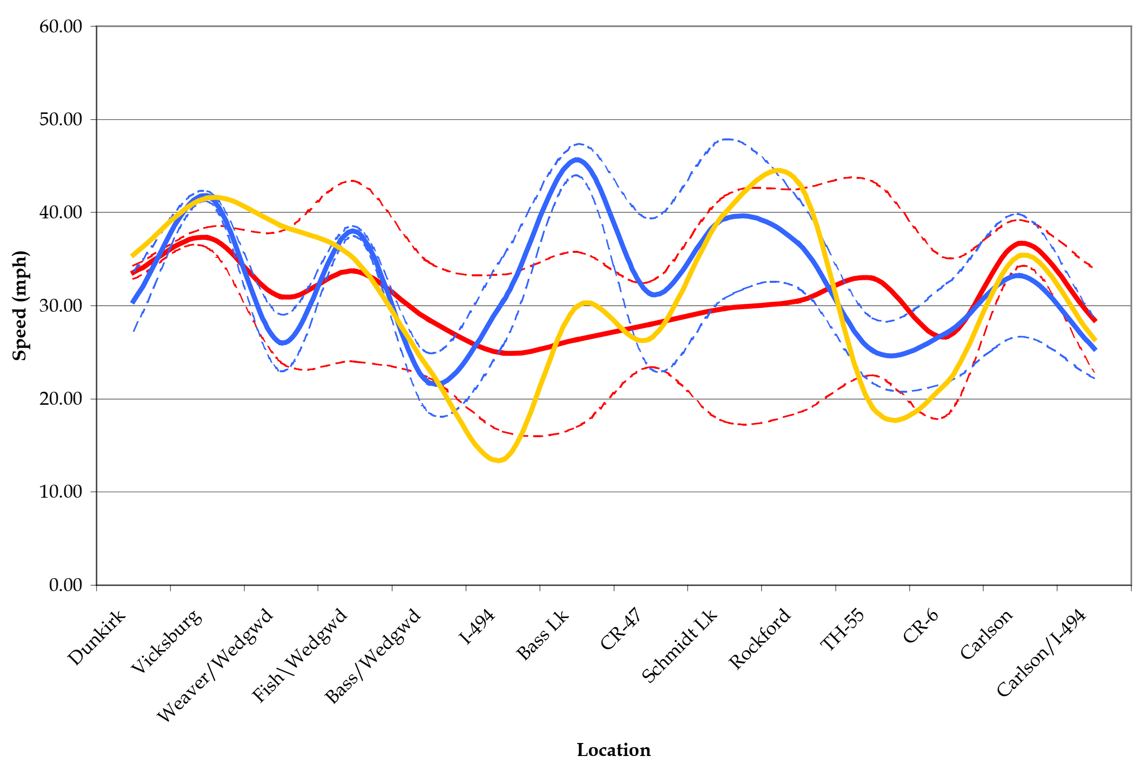
I-494 CR-61 SB A.M. Peak (With)



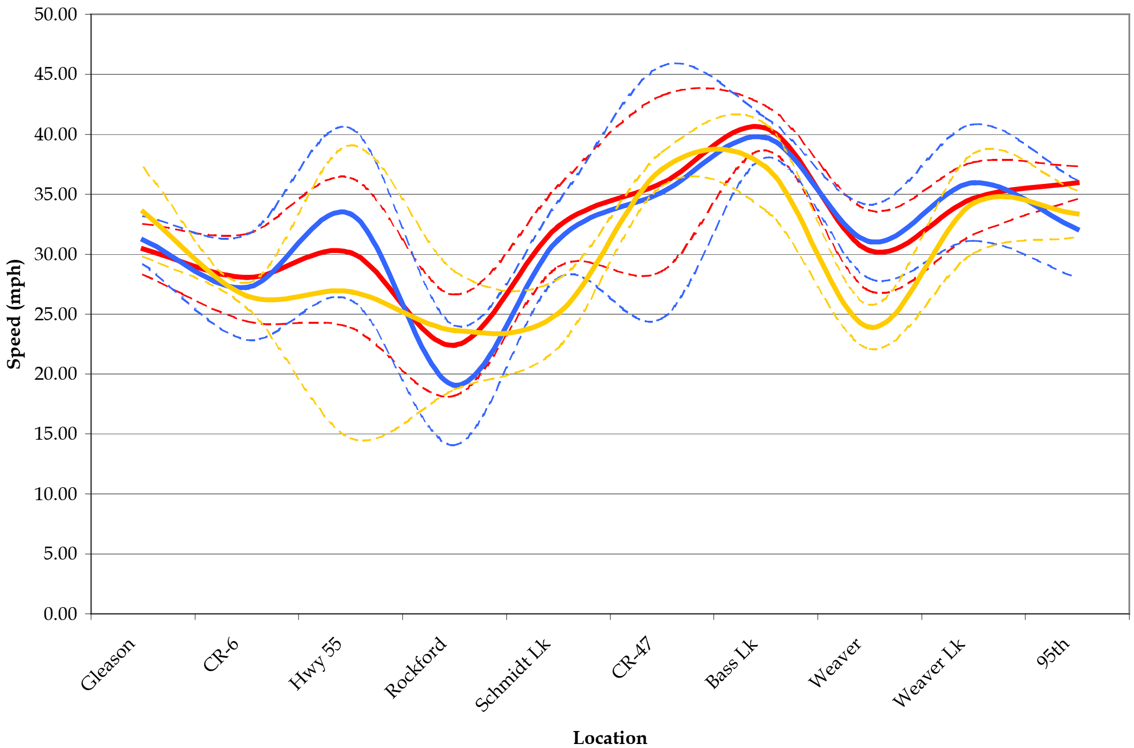
I-494 CR-61 NB P.M. Peak (Without)



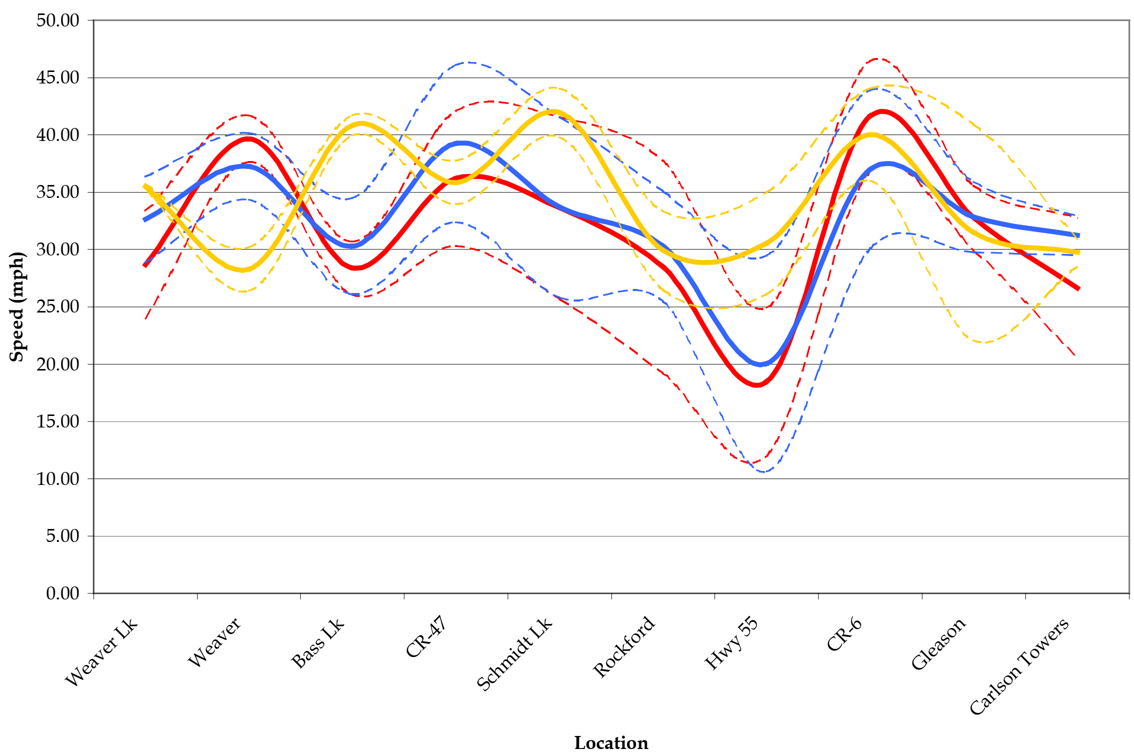
I-494 CR-61 SB A.M. Peak (Without)



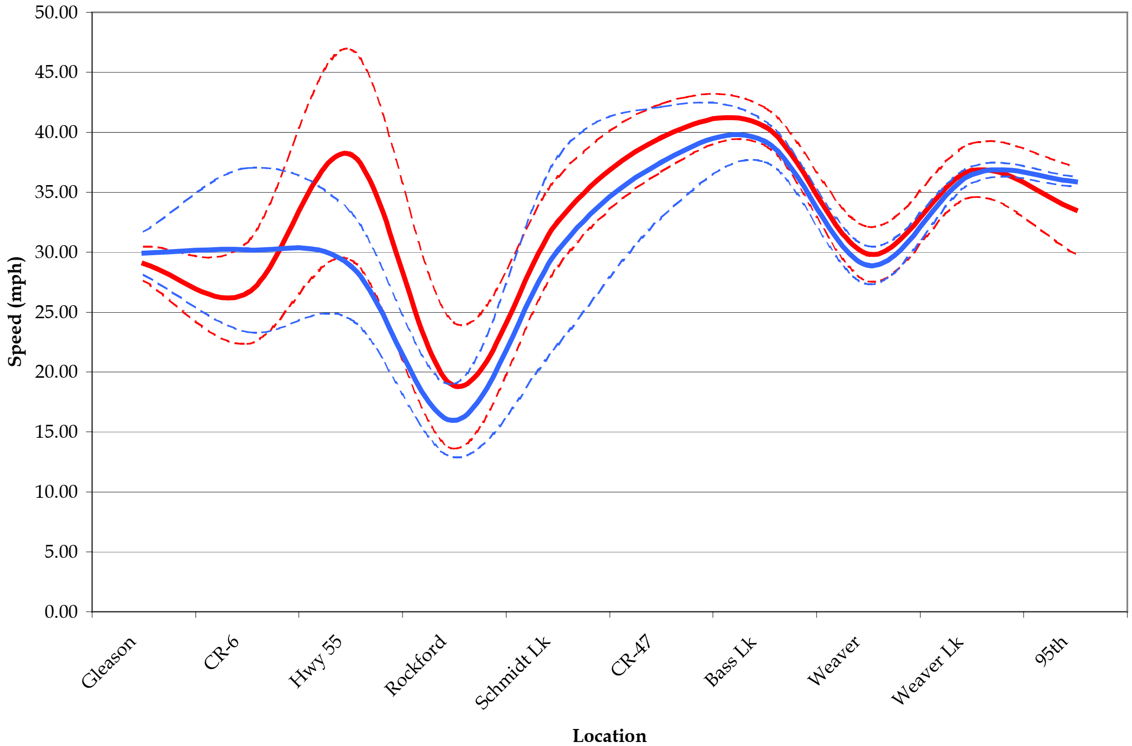
I-494 Vick NB P.M. Peak (With)



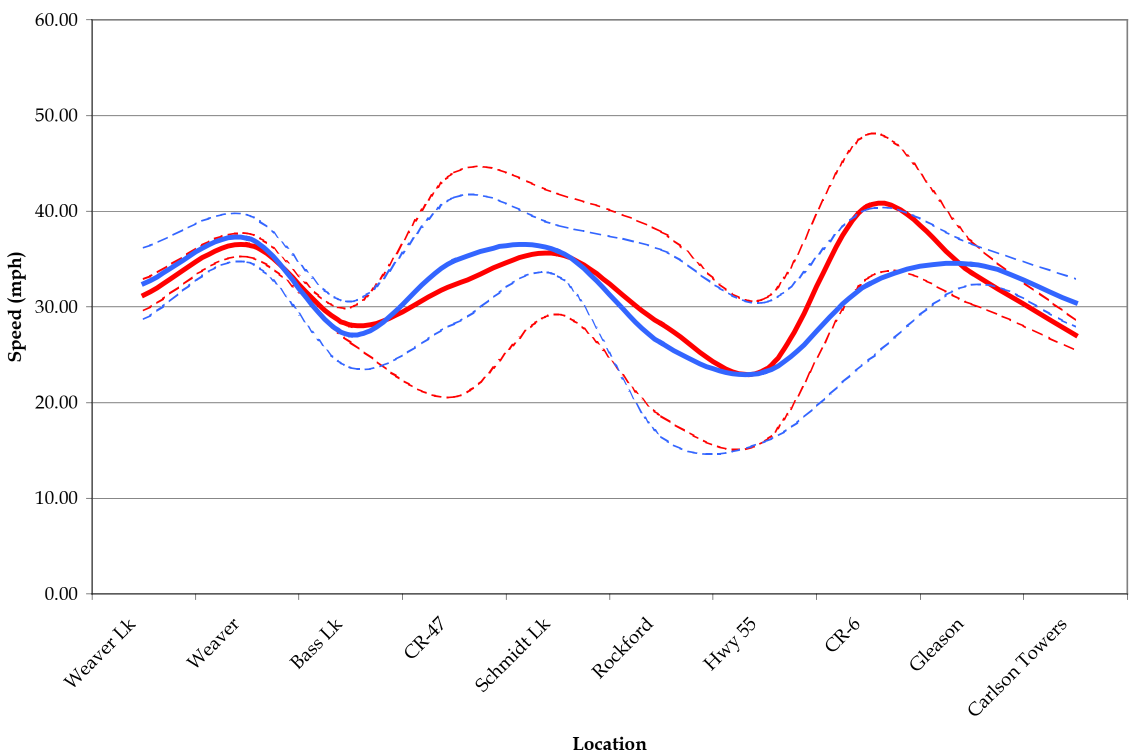
I-494 Vick SB A.M. Peak (With)



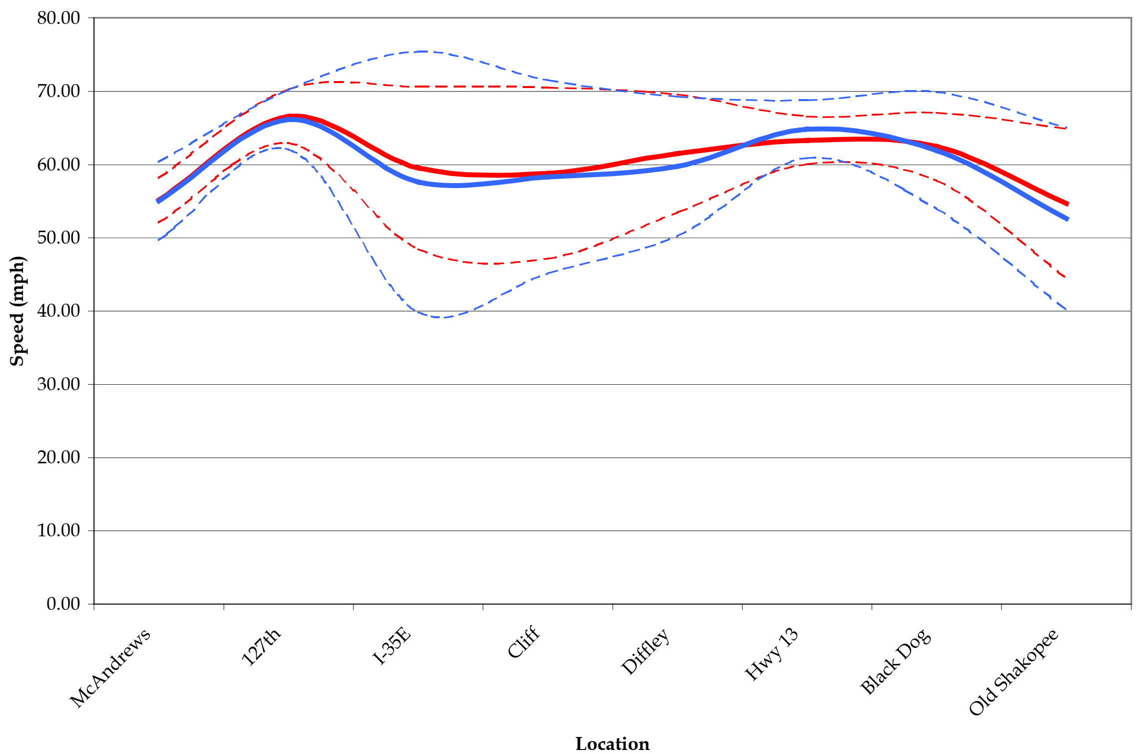
I-494 Vick NB P.M. Peak (Without)



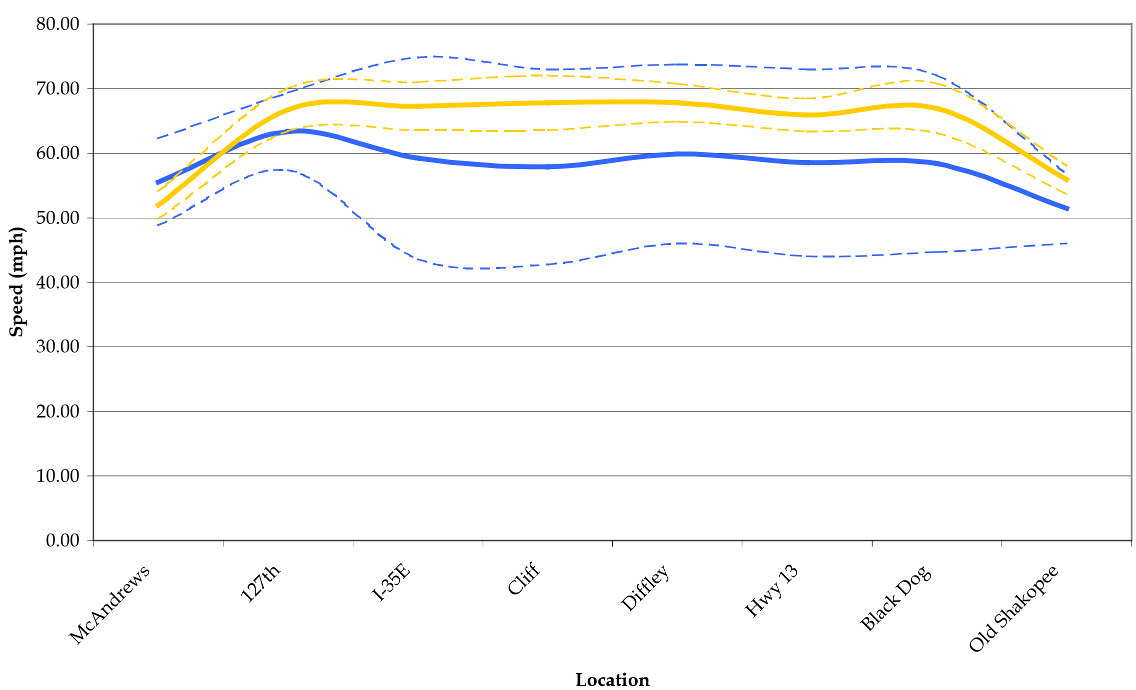
I-494 Vick SB A.M. Peak (Without)



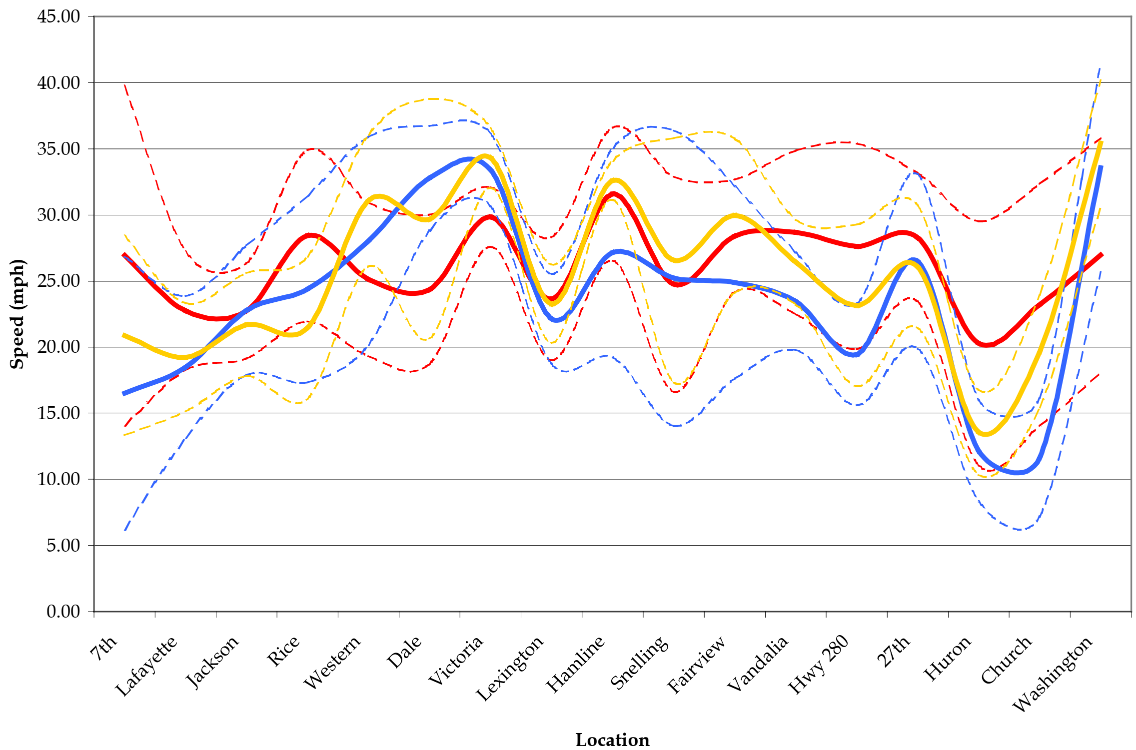
I-35W TH-77 NB A.M. Peak (With)



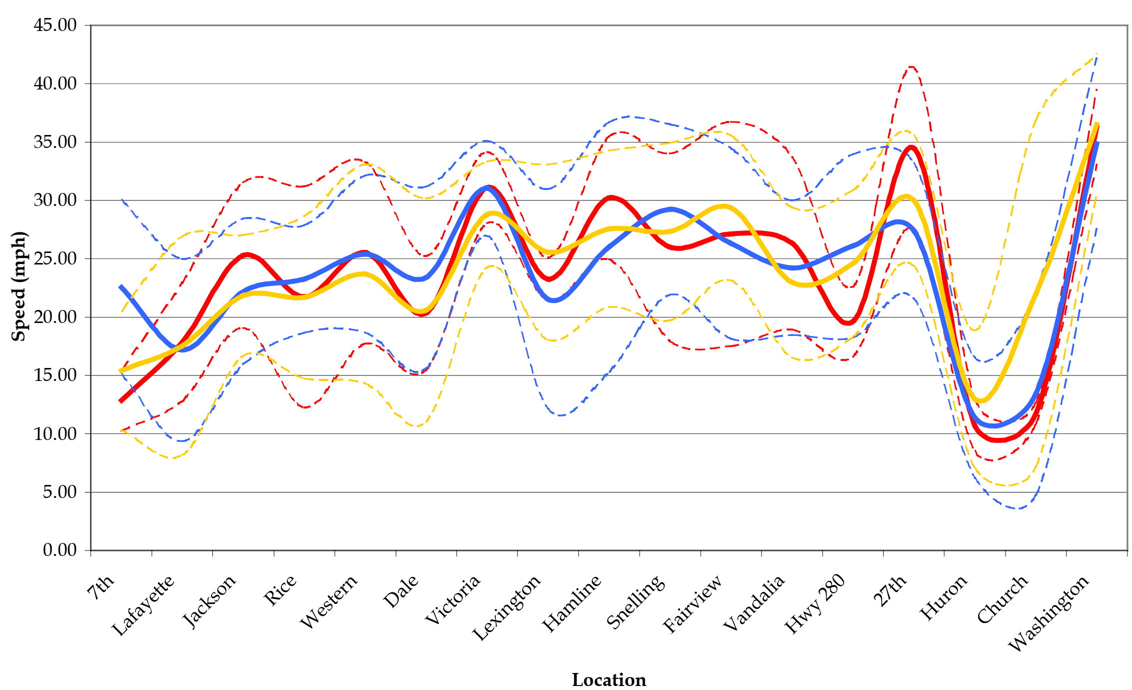
I-35W TH-77 NB A.M. Peak (Without)



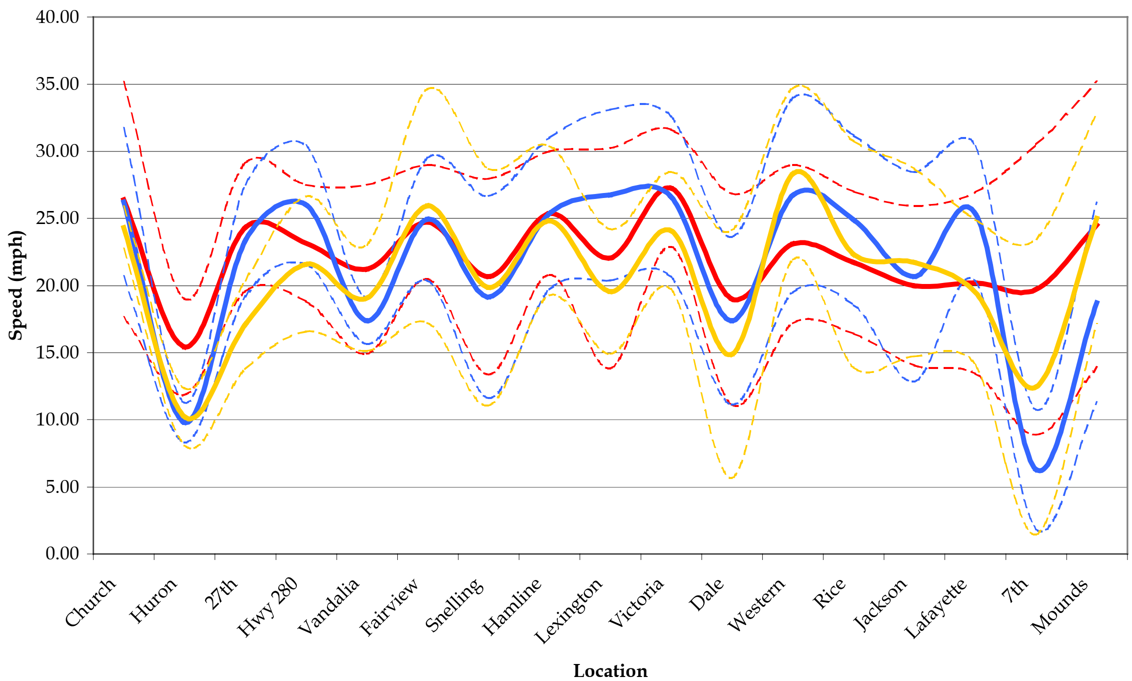
I-94 Univ WB A.M. Peak (With)



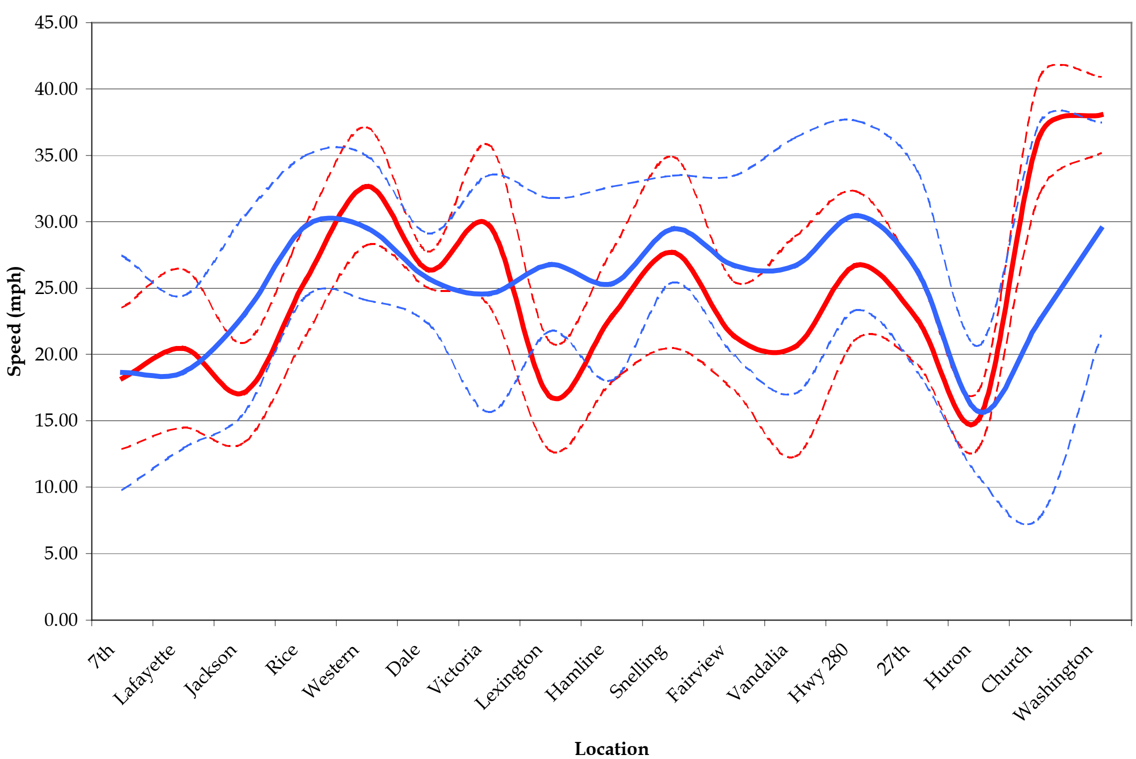
I-94 Univ WB P.M. Peak (With)



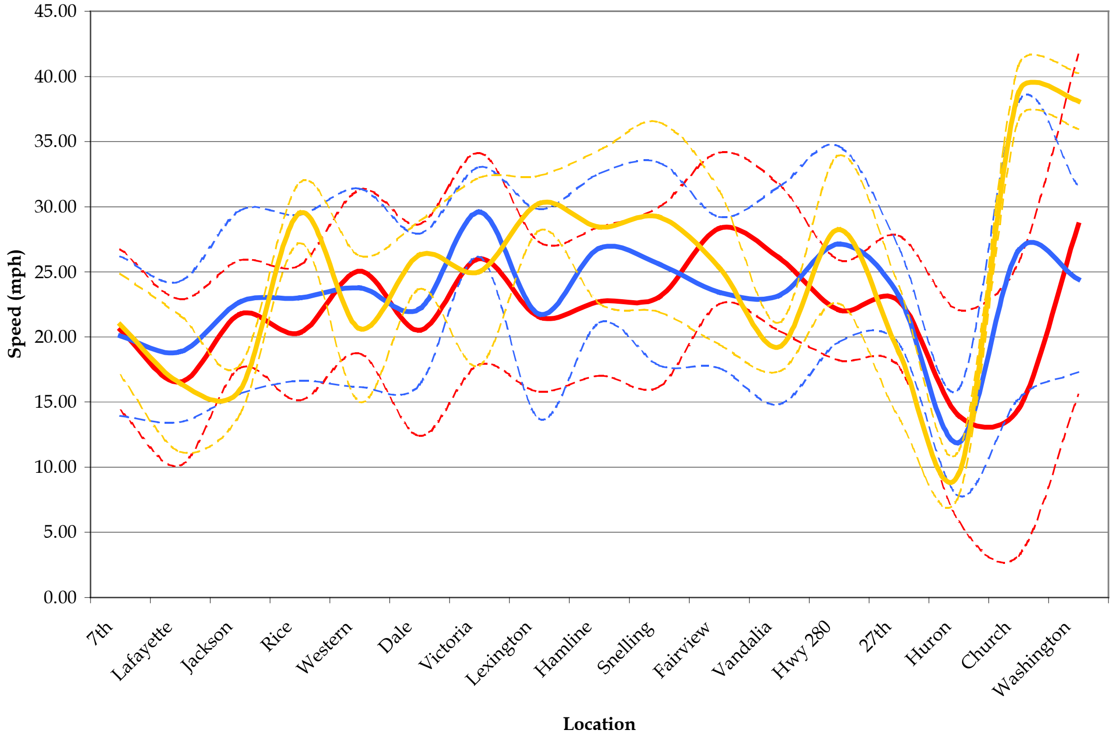
I-94 Univ EB P.M. Peak (Without)



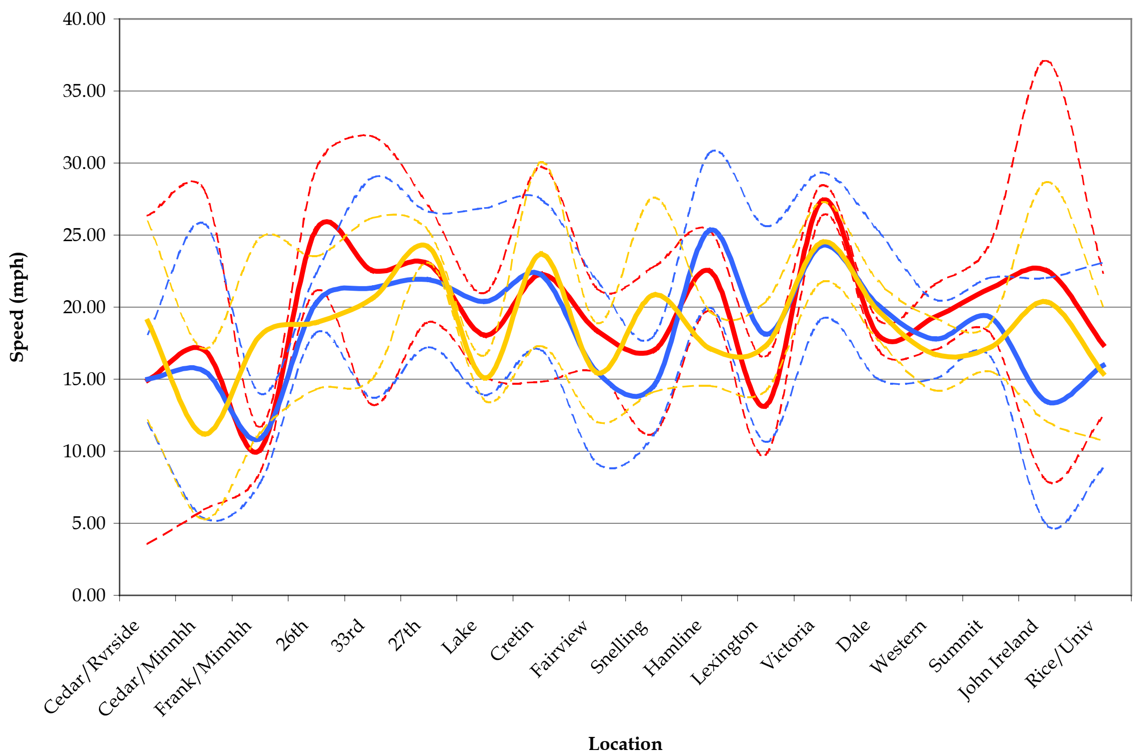
I-94 Univ WB A.M. Peak (Without)



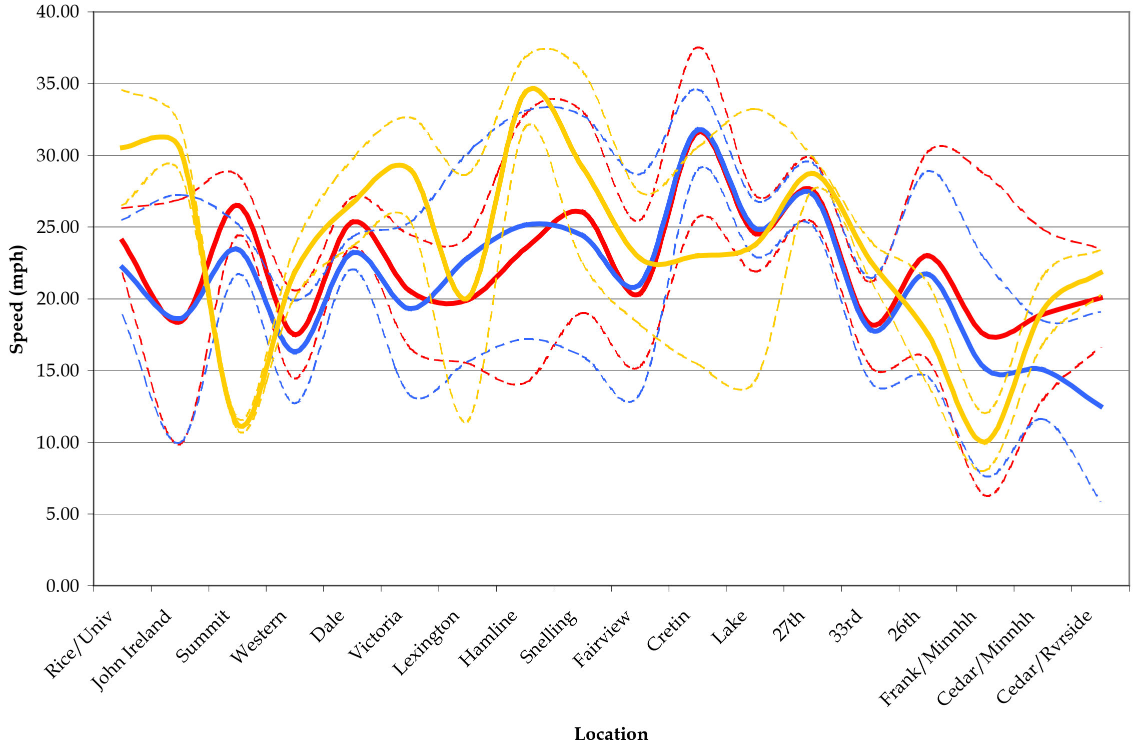
I-94 Univ WB P.M. Peak (Without)



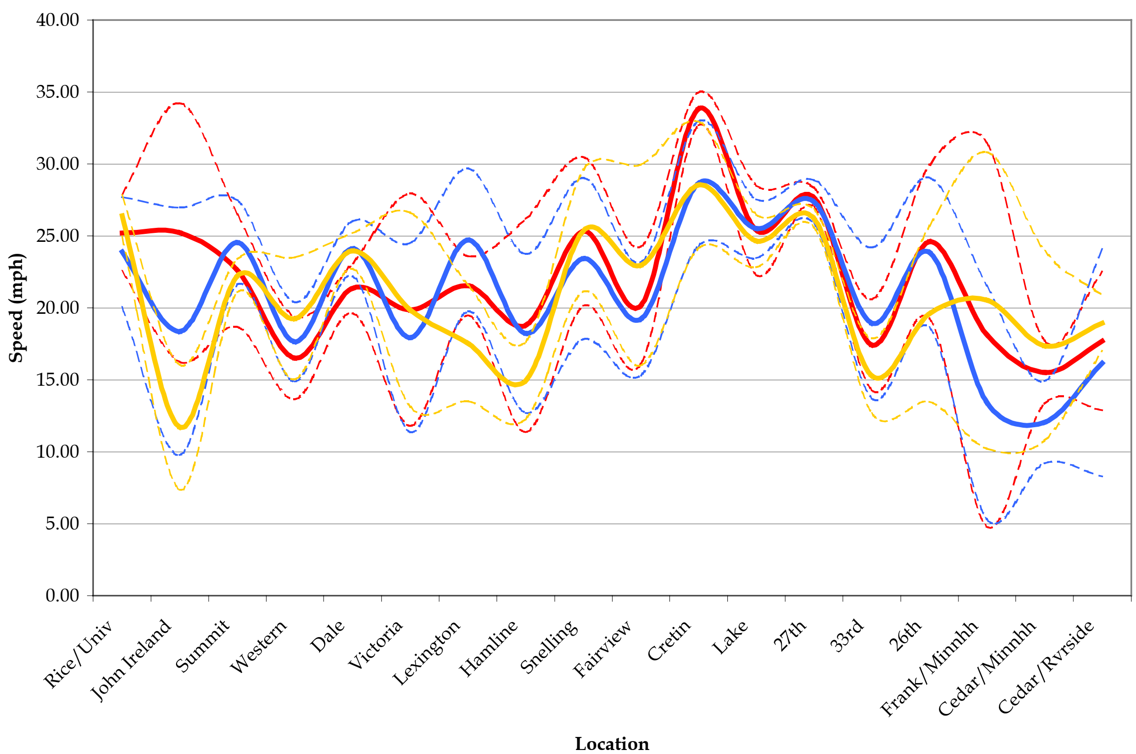
I-94 Marsh EB P.M. Peak (With)



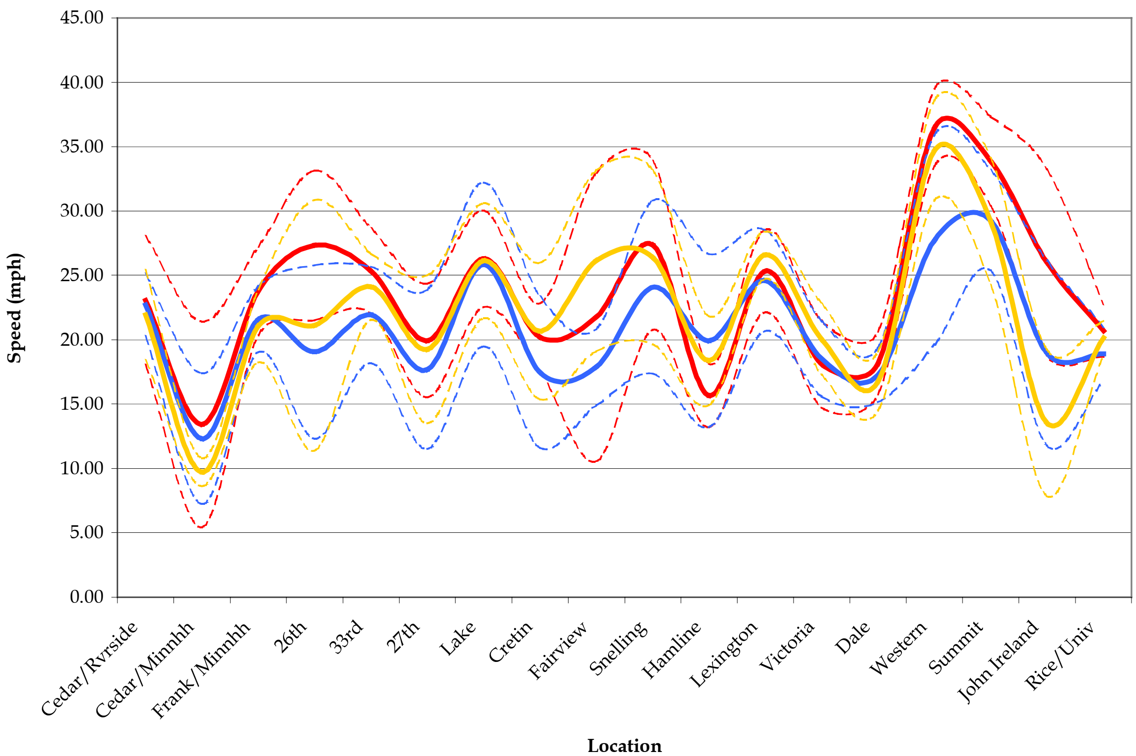
I-94 Marsh WB A.M. Peak (With)



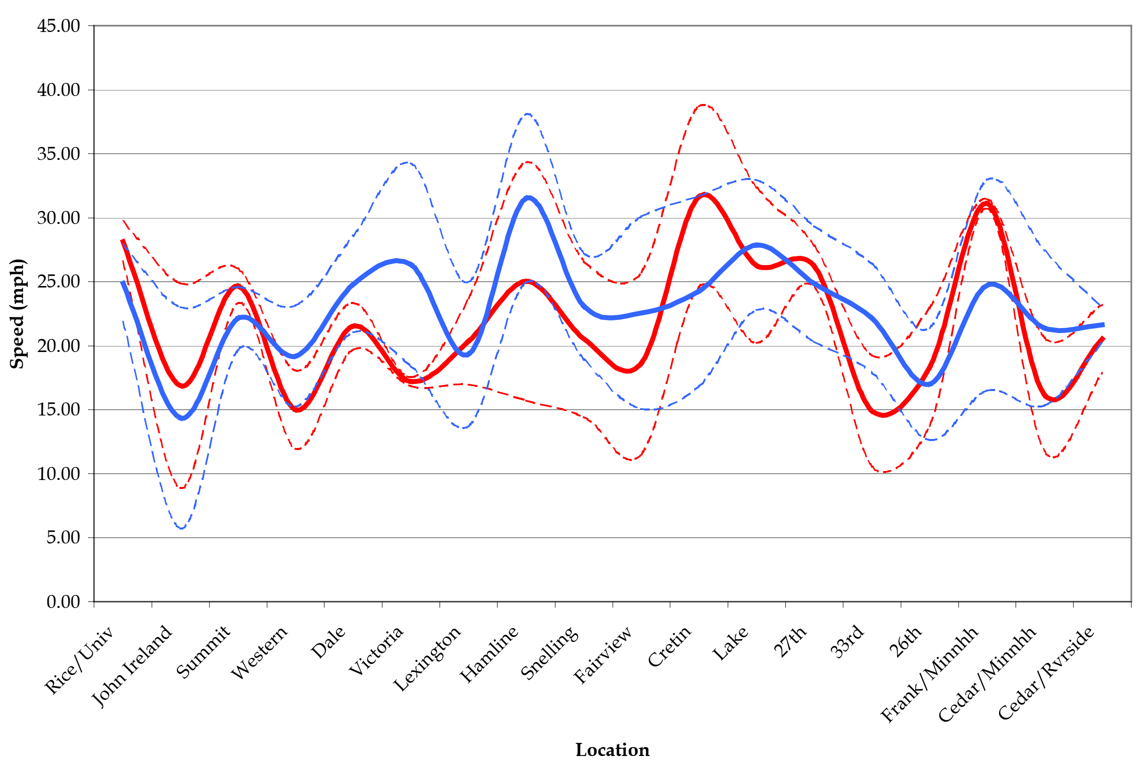
I-94 Marsh WB P.M. Peak (With)



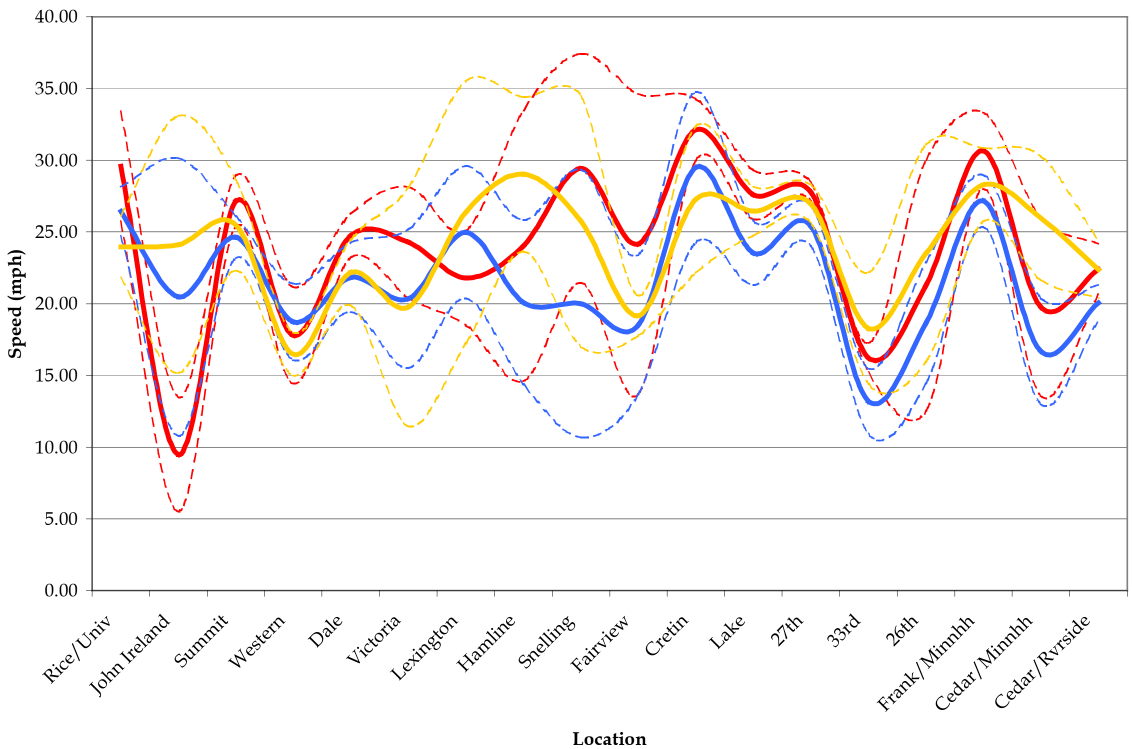
I-94 Marsh EB P.M. Peak (Without)



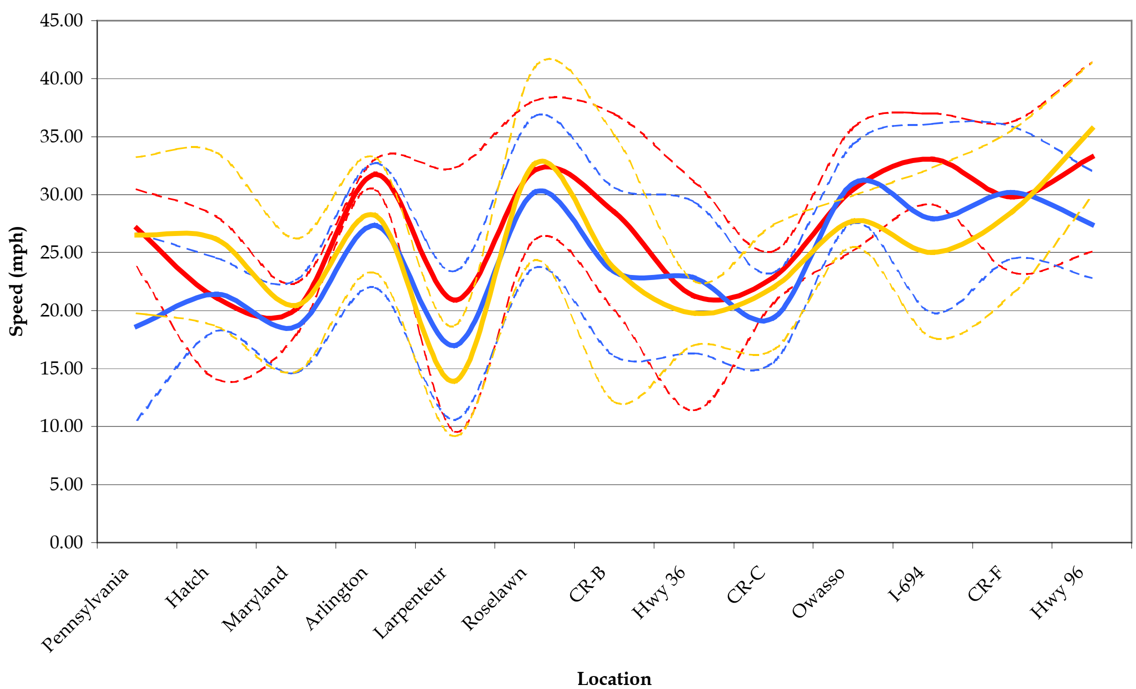
I-94 Marsh WB A.M. Peak (Without)



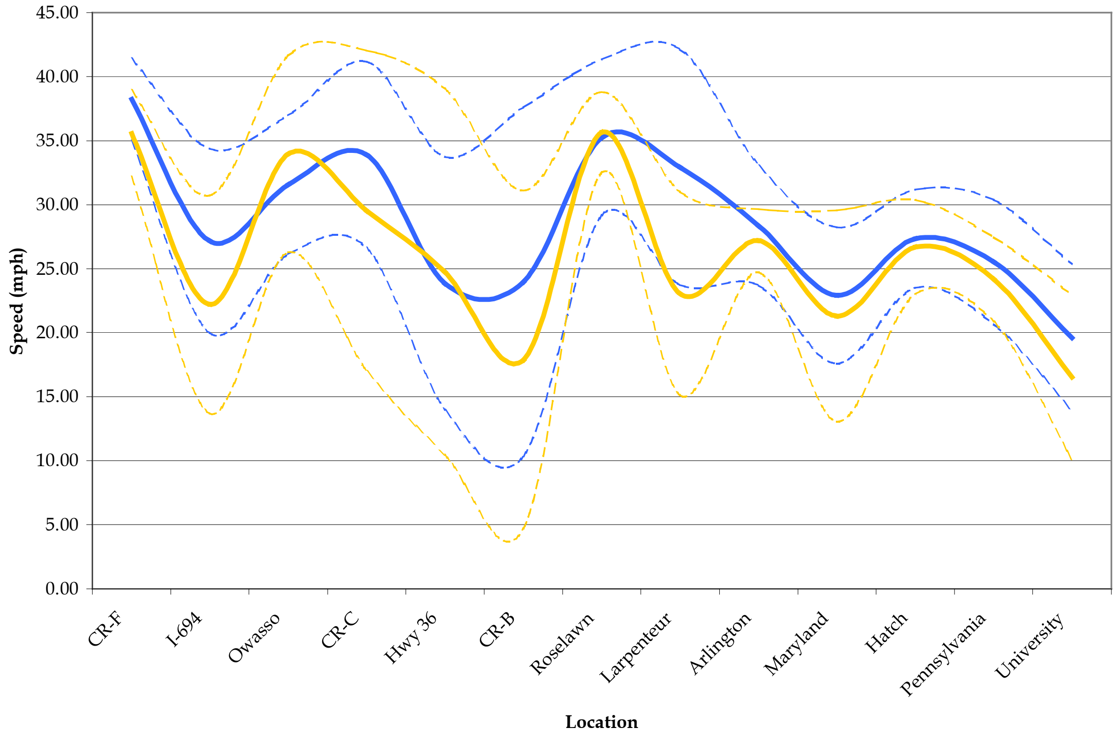
I-94 Marsh WB P.M. Peak (Without)



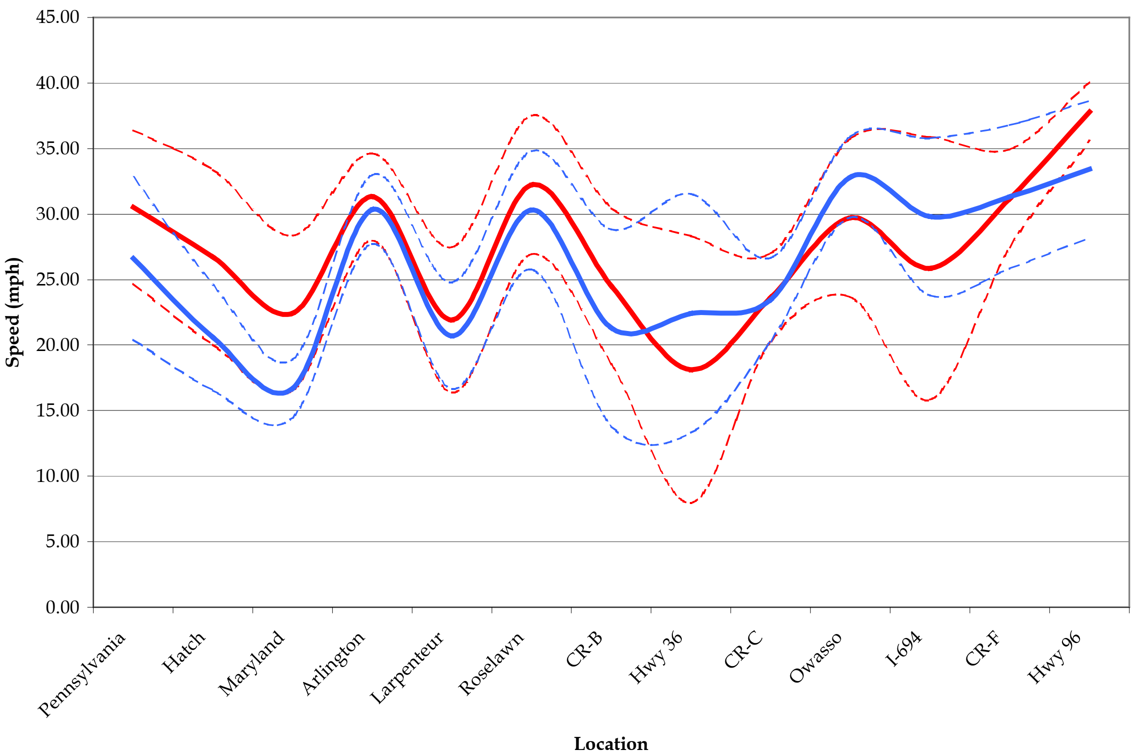
I-35E Rice NB P.M. Peak (With)



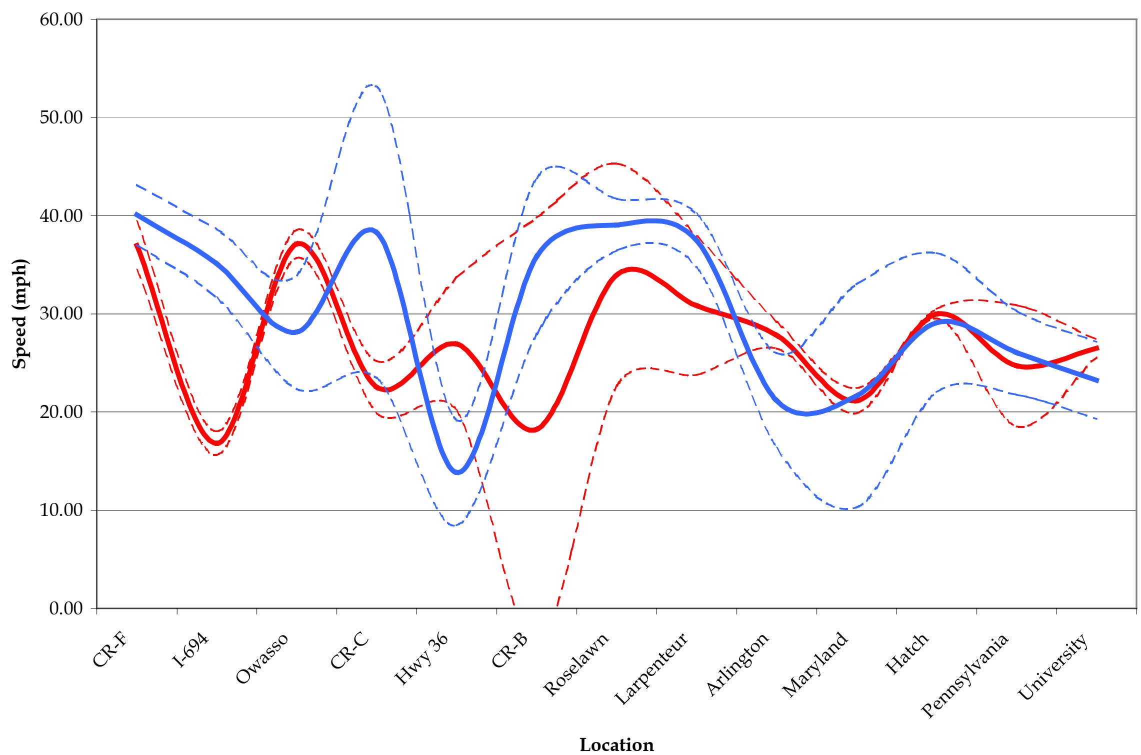
I-35E Rice SB A.M. Peak (With)



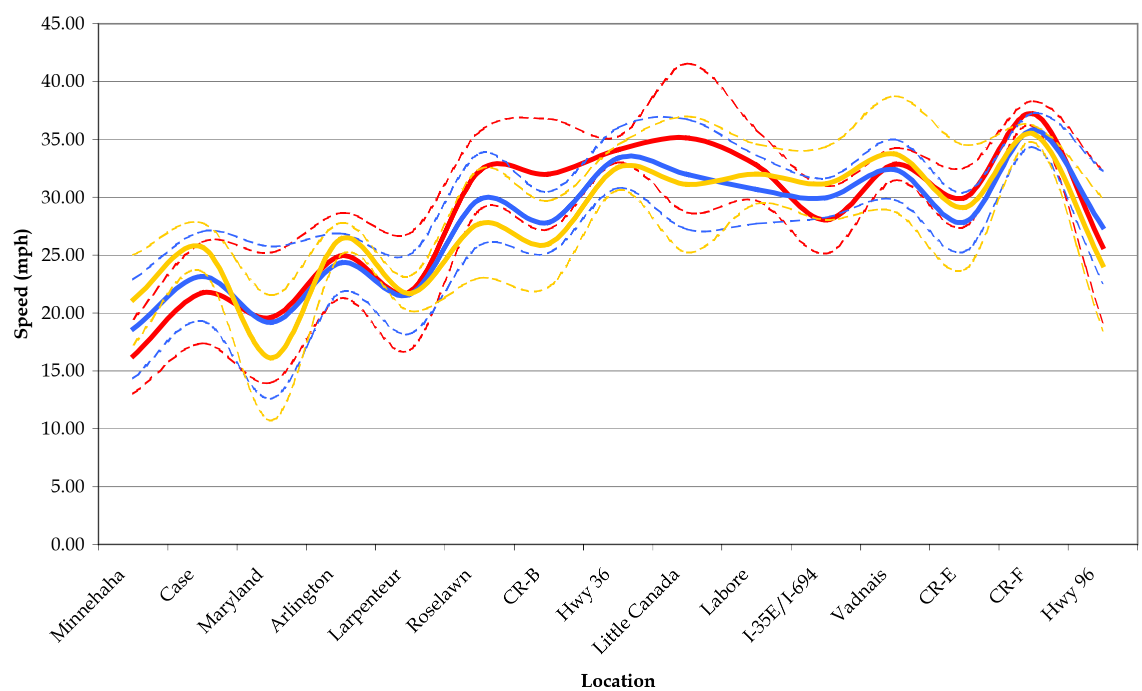
I-35E Rice NB P.M. Peak (Without)



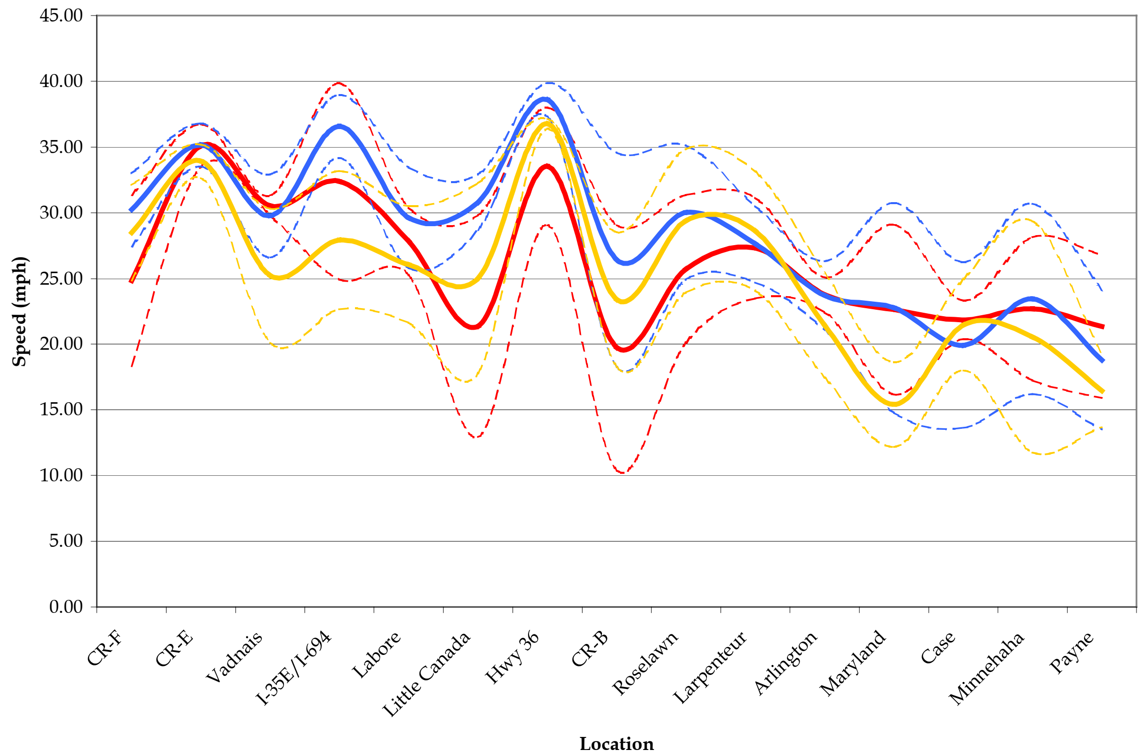
I-35E Rice SB A.M. Peak (Without)



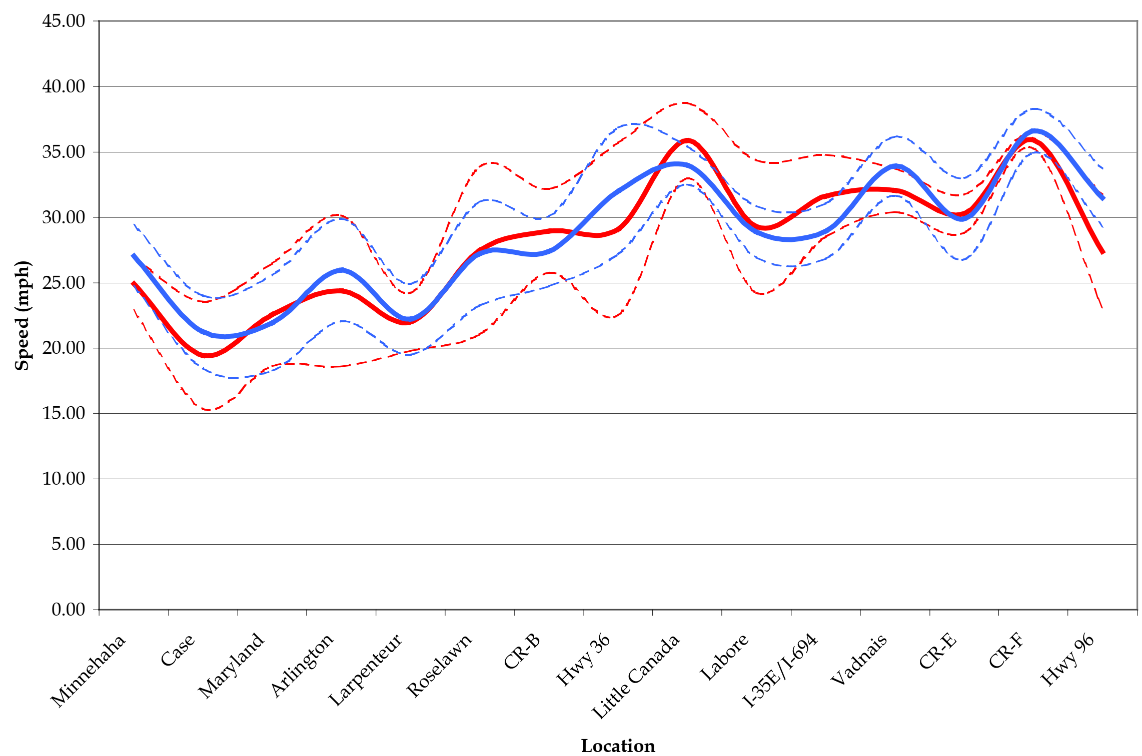
I-35E Edge NB P.M. Peak (With)

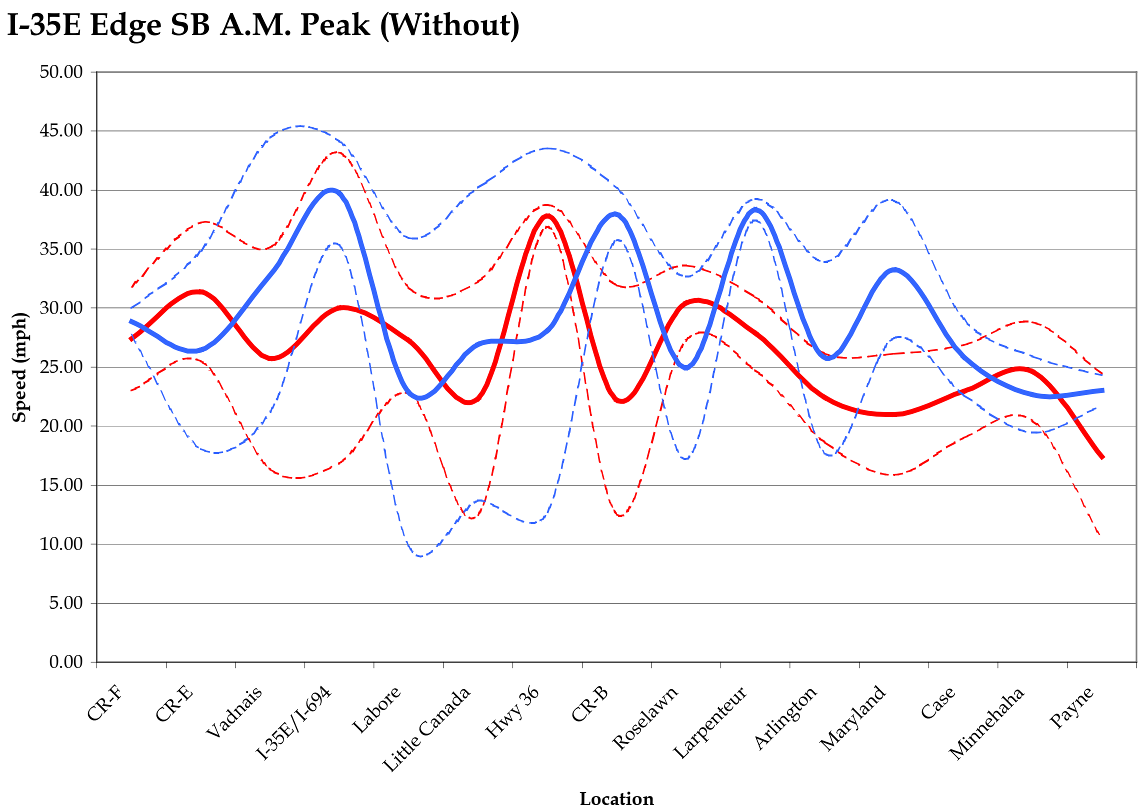


I-35E Edge SB A.M. Peak (With)



I-35E Edge NB P.M. Peak (Without)

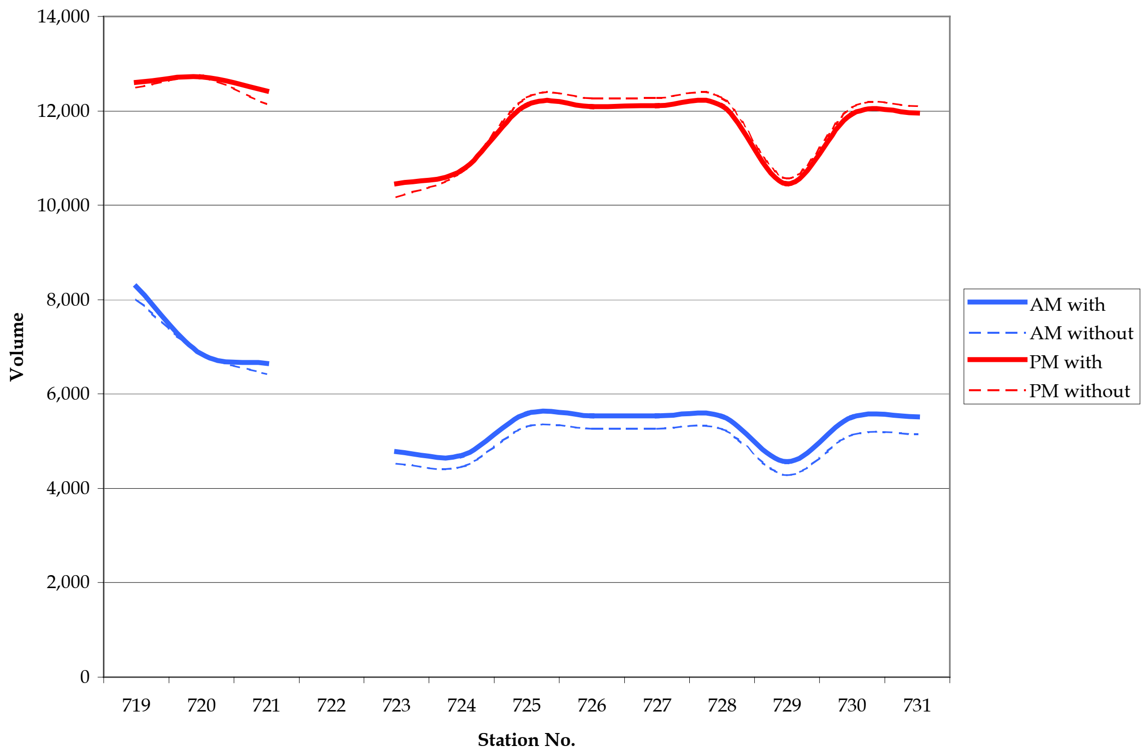



I-35E Edge SB A.M. Peak (Without)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Speed (mph)
CR-F
CR-E
Vadnais
I-35E/I-694
Labore
Little Canada
Hwy 36
CR-B
Roselawn
Larpenteur
Arlington
Maryland
Case
Minnehaha
Payne
Location

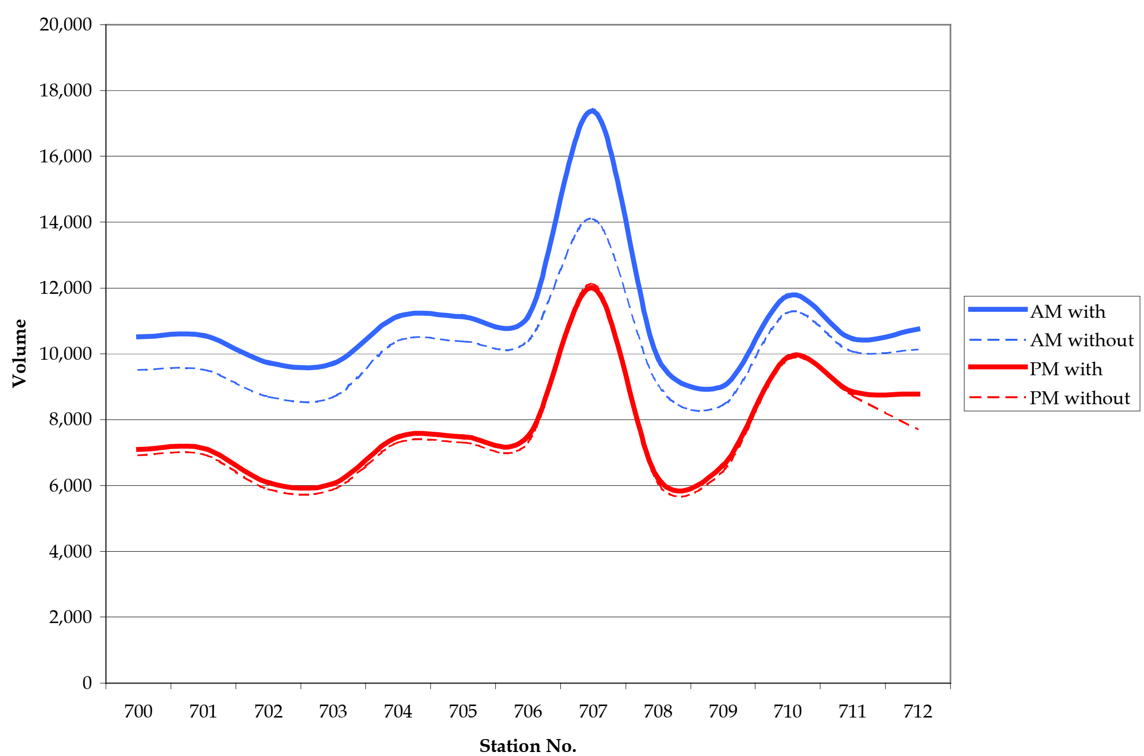
Appendix C

Summary of Field Data: Freeway and Arterial Traffic Volumes

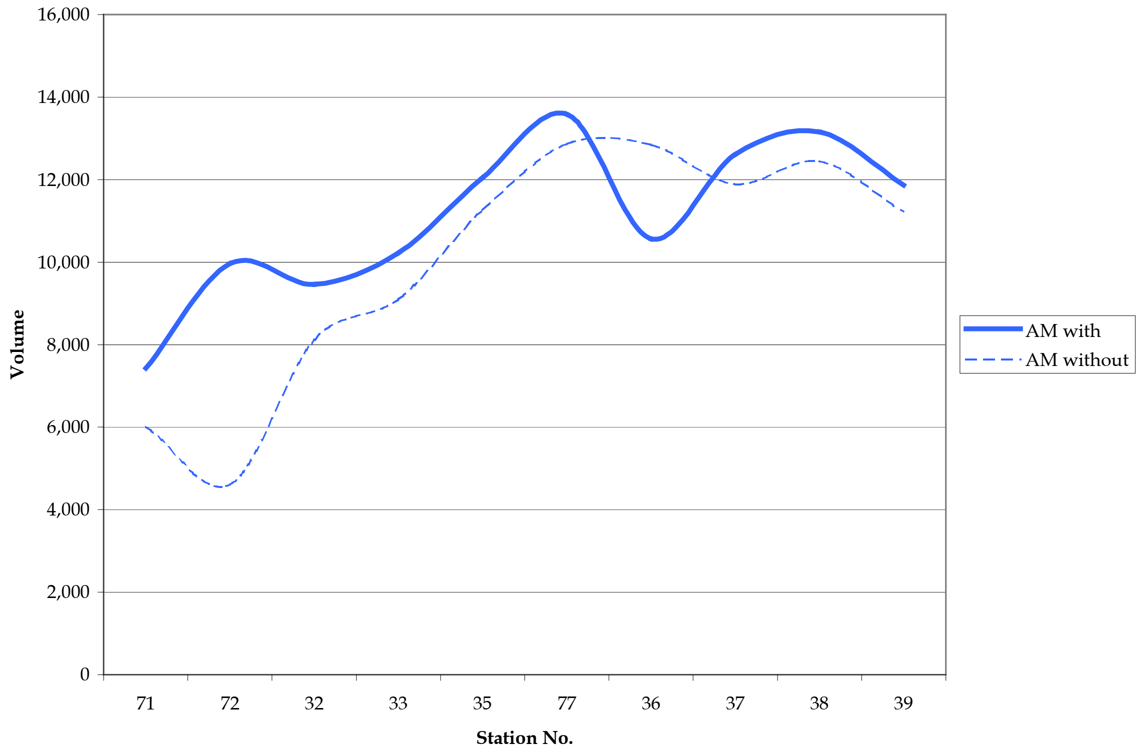
I-494 NB



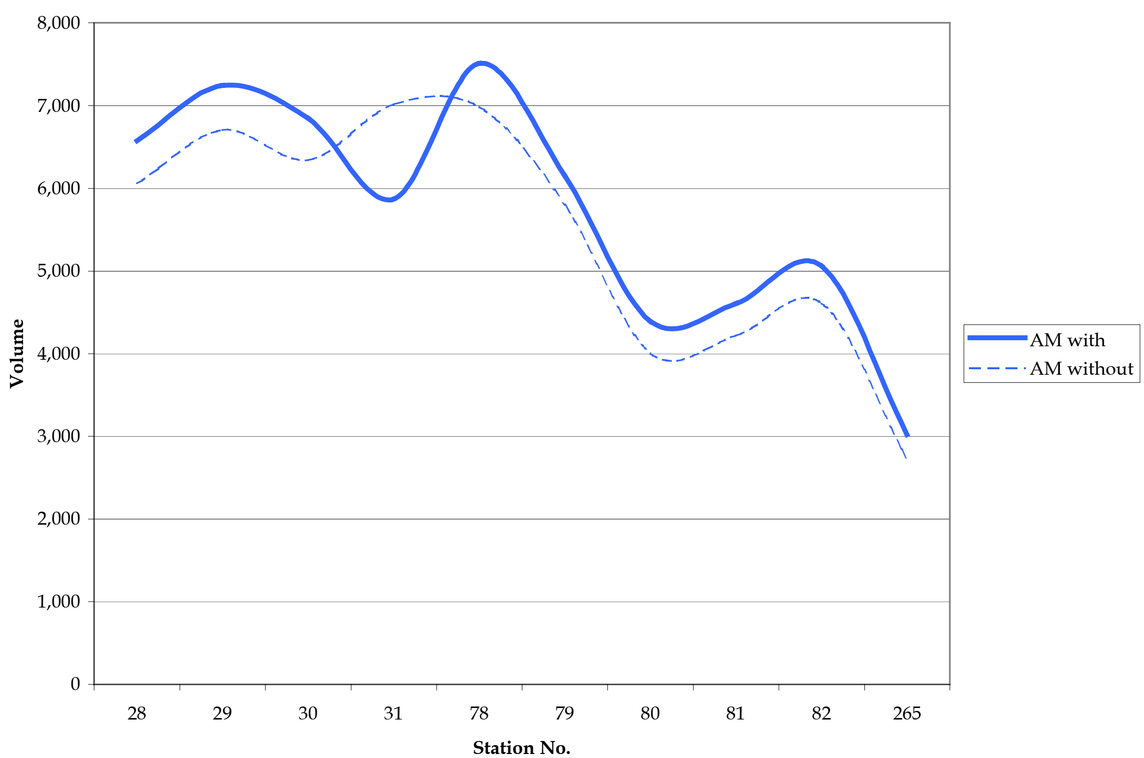
I-494 SB



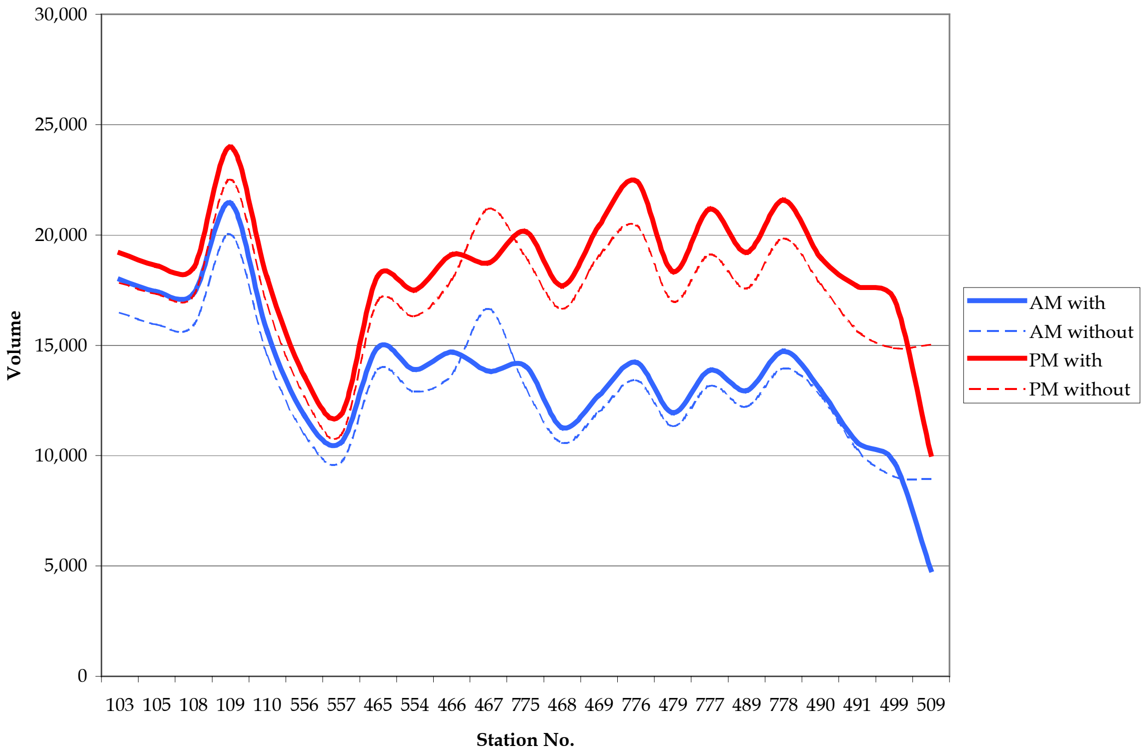
I-35W NB



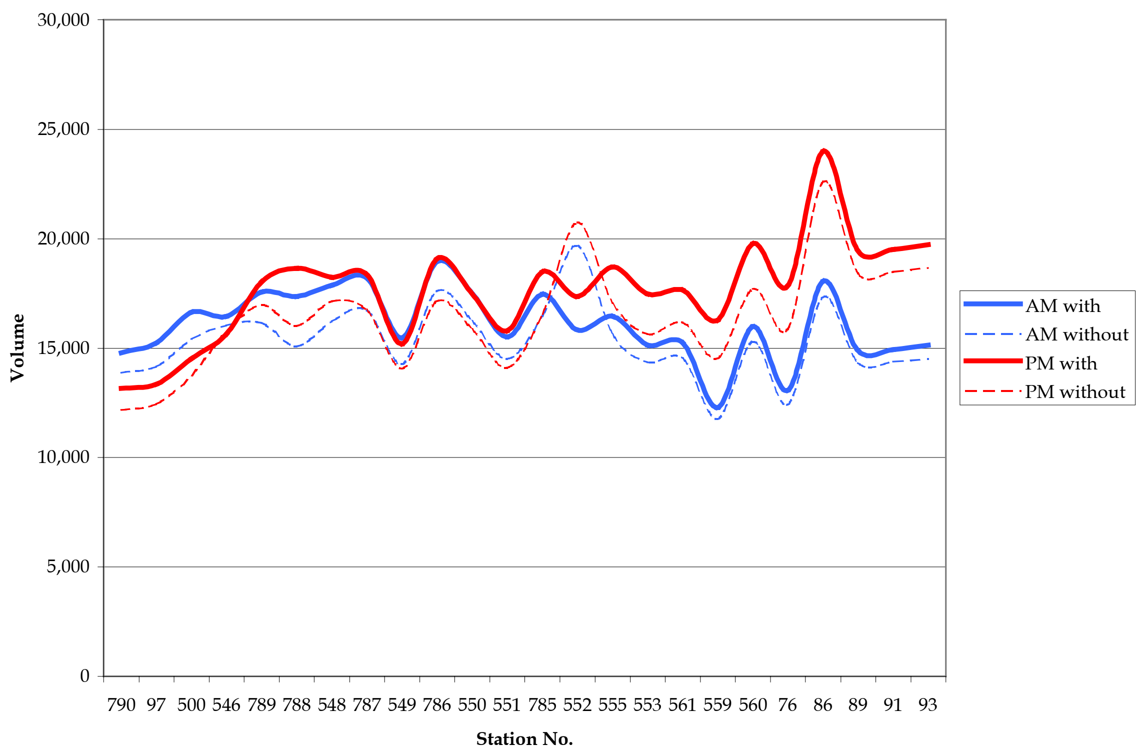
I-35W SB



I-94 EB


30,000
25,000
20,000
15,000
10,000
5,000
0
Volume
103 105 108 109 110 556 557 465 554 466 467 775 468 469 776 479 777 489 778 490 491 499 509
Station No.
AM with
AM without
PM with
PM without

I-94 WB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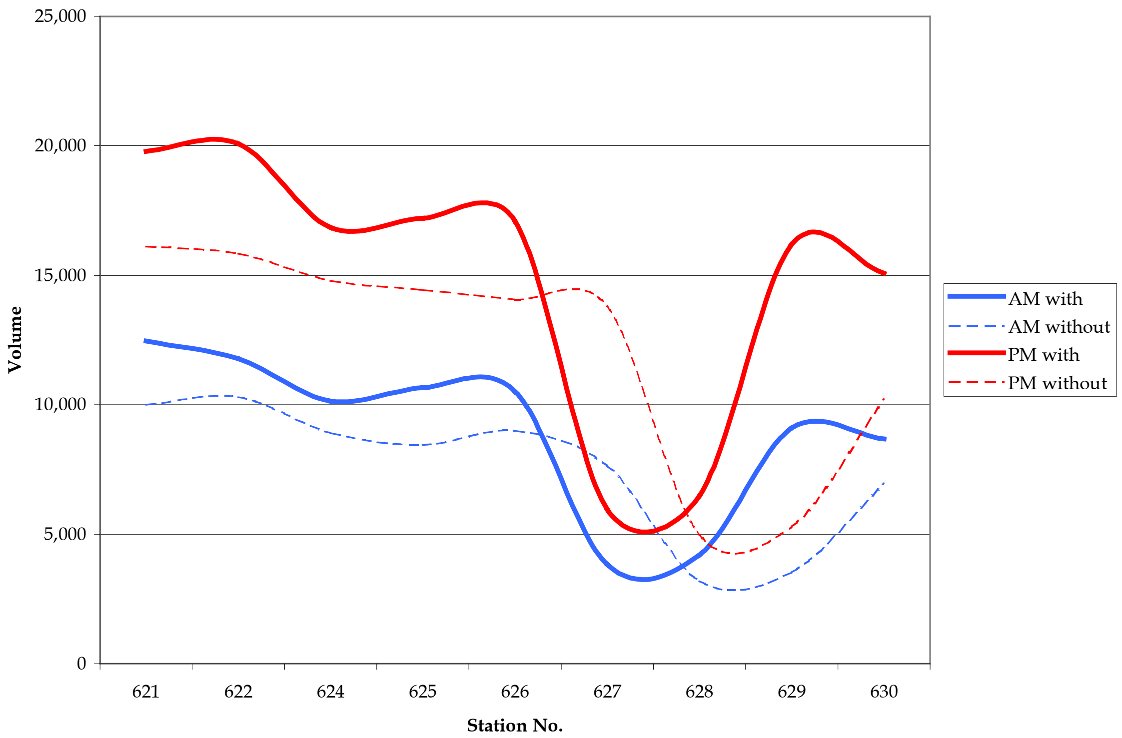

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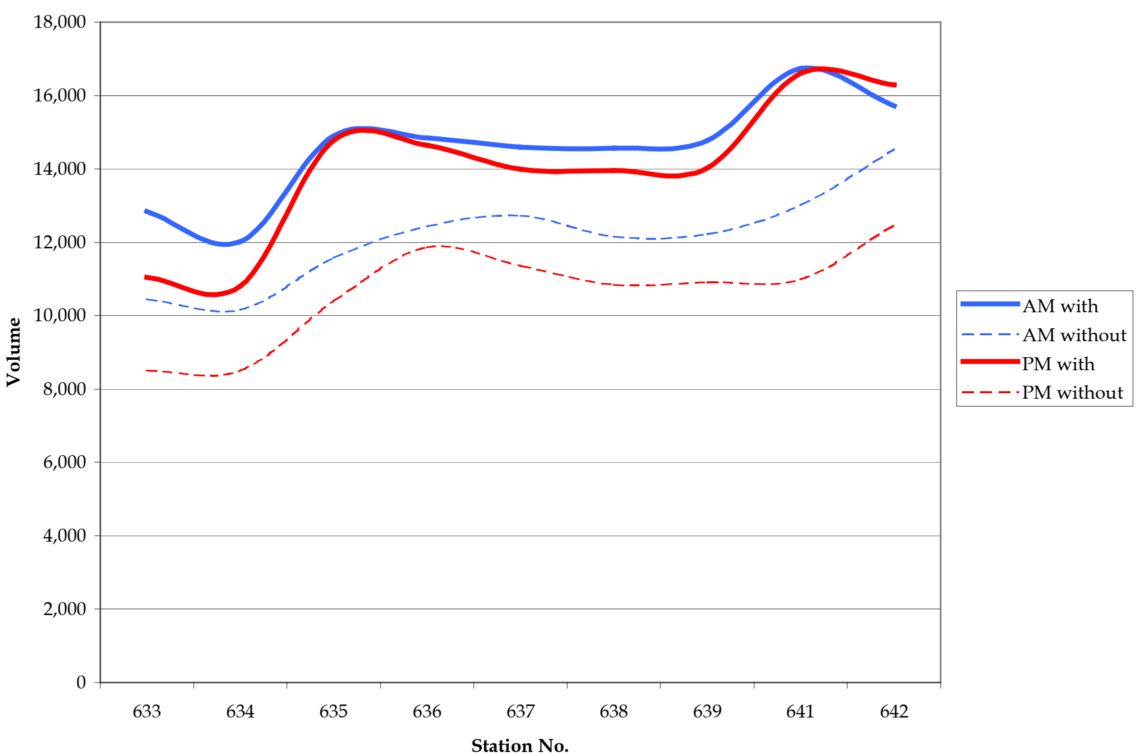

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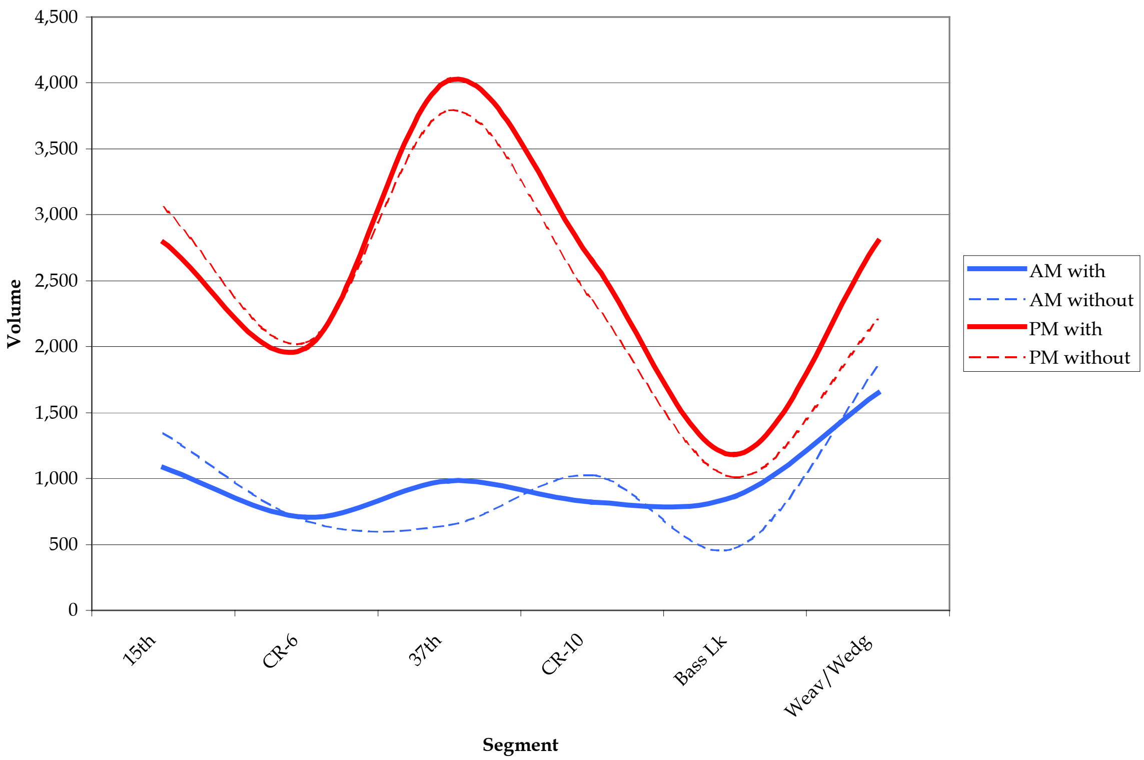

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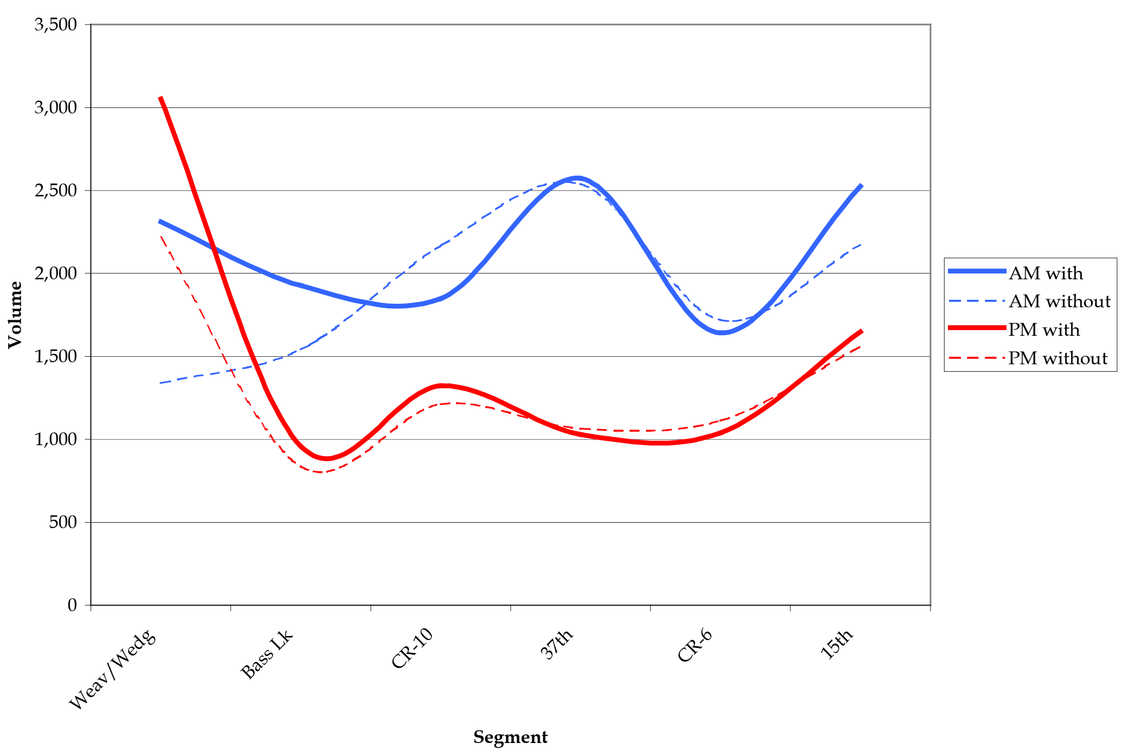

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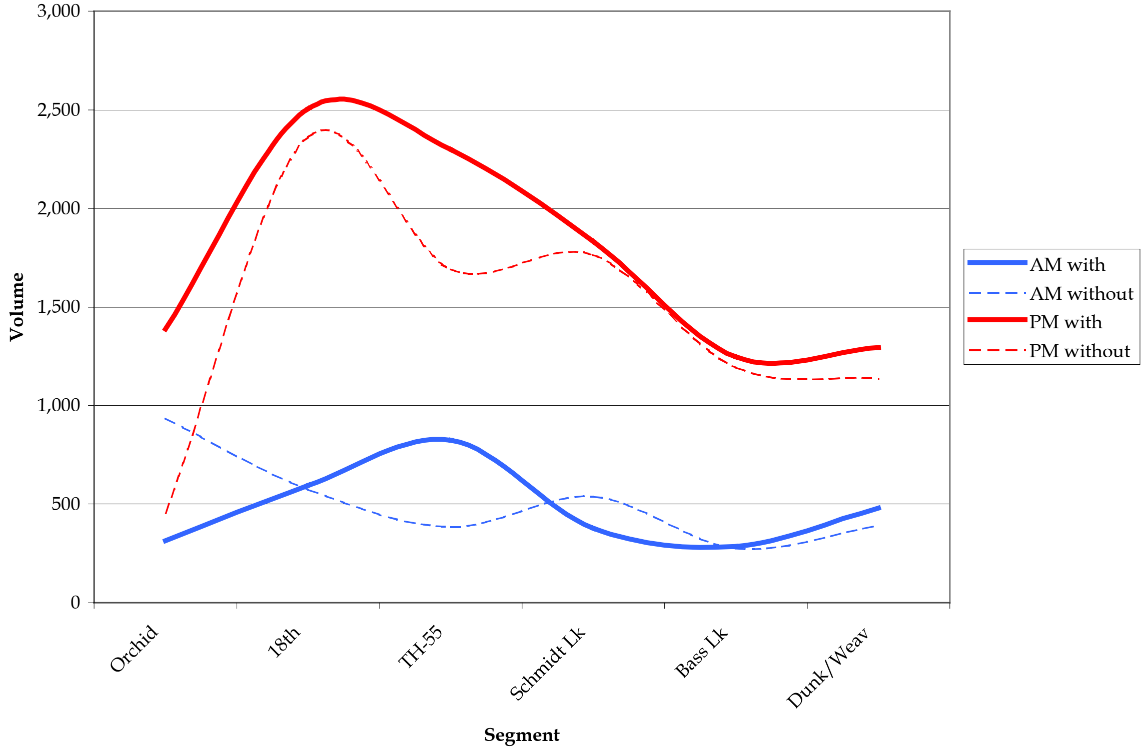

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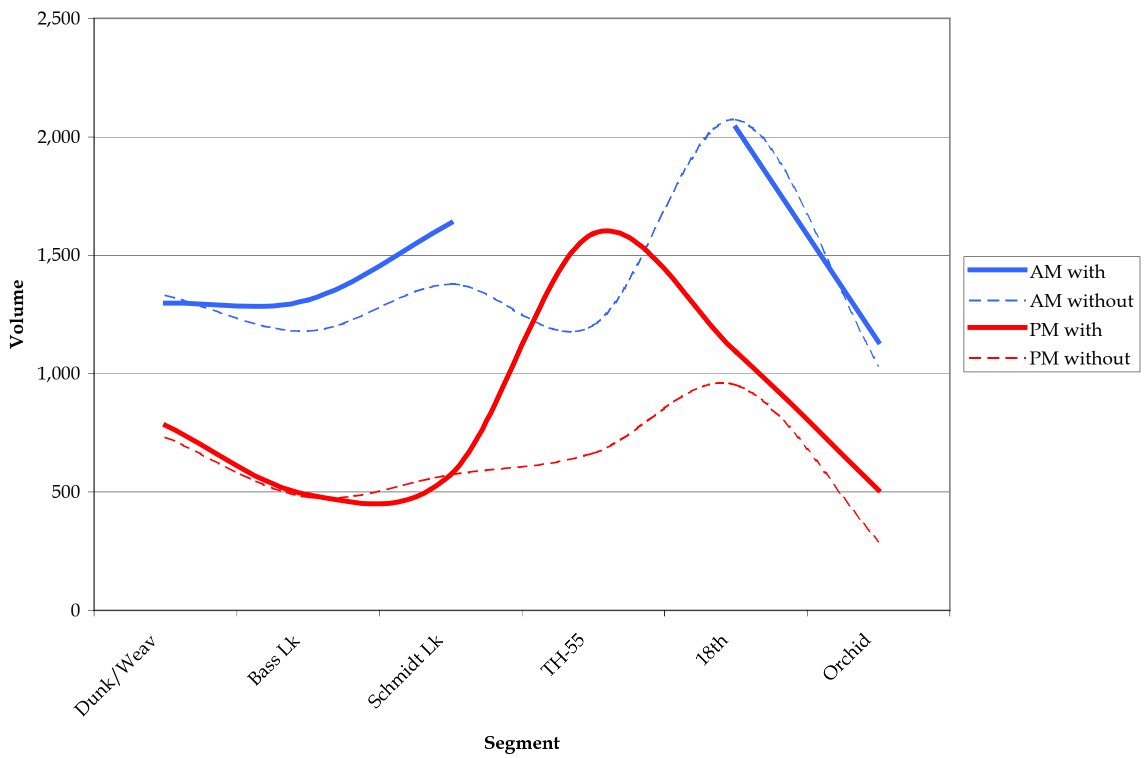

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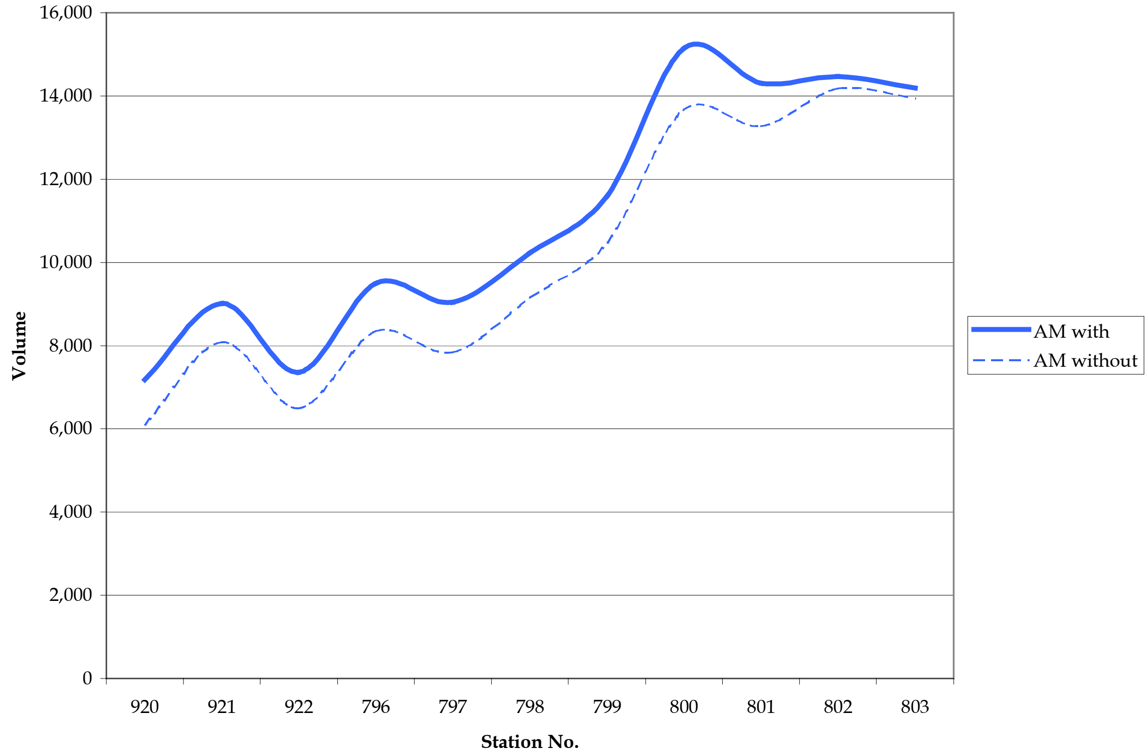

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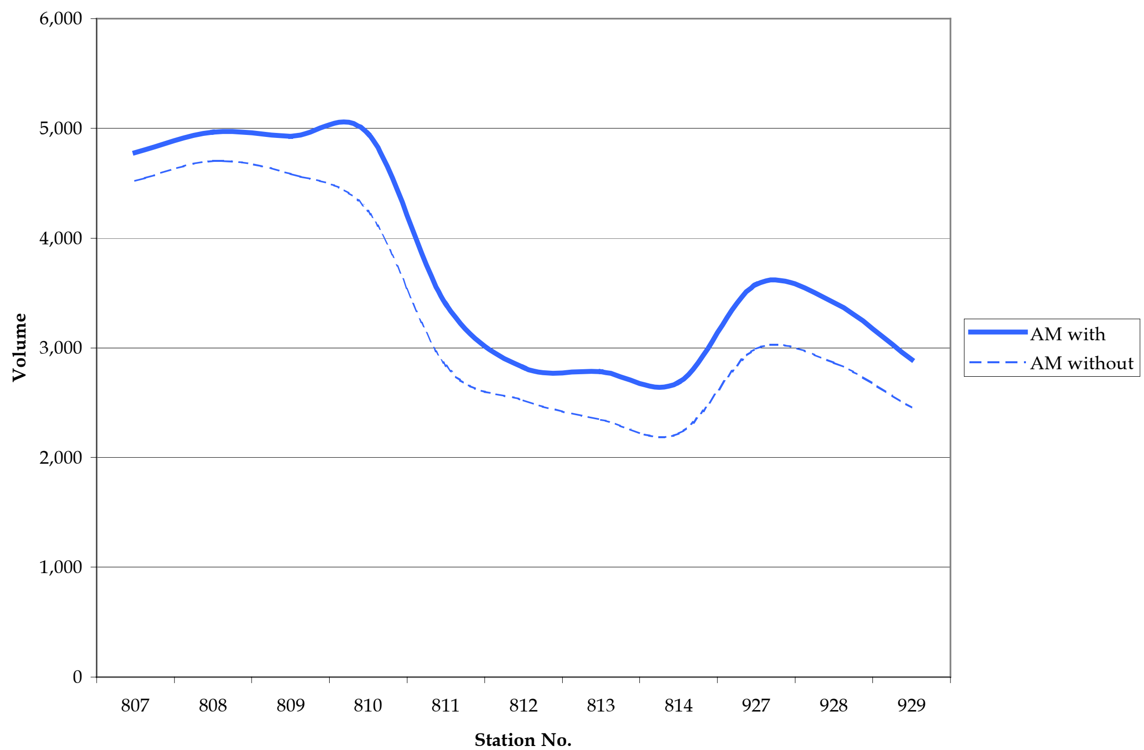

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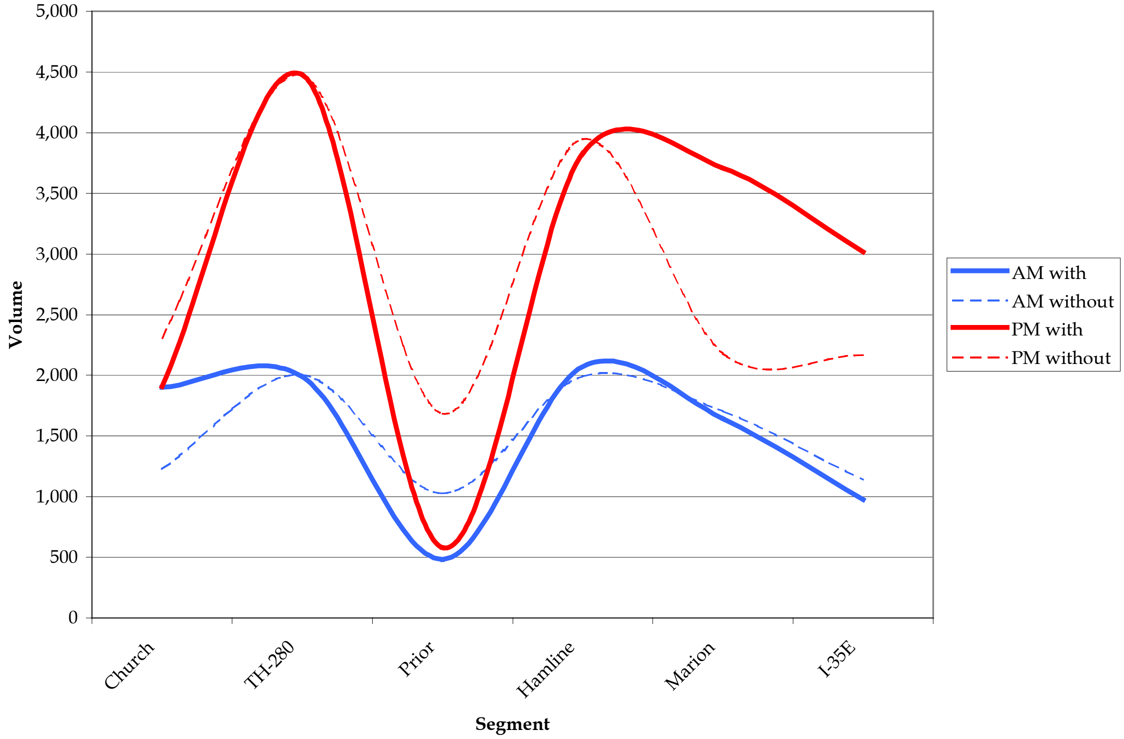

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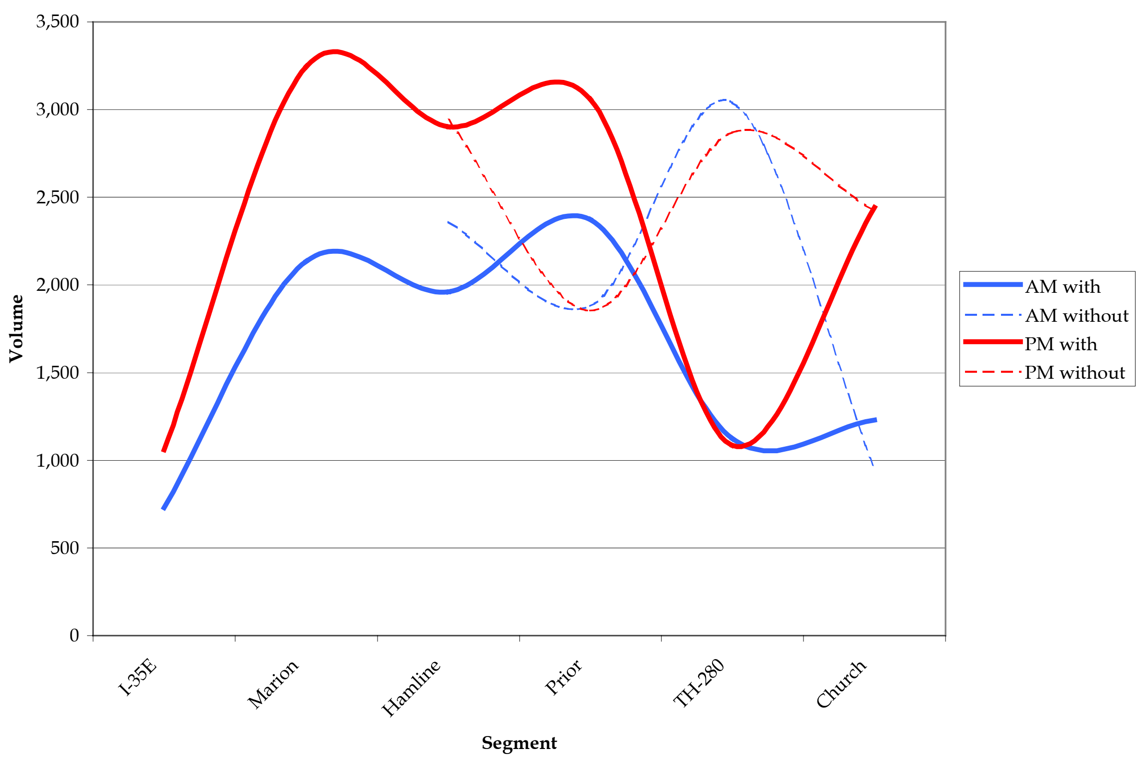

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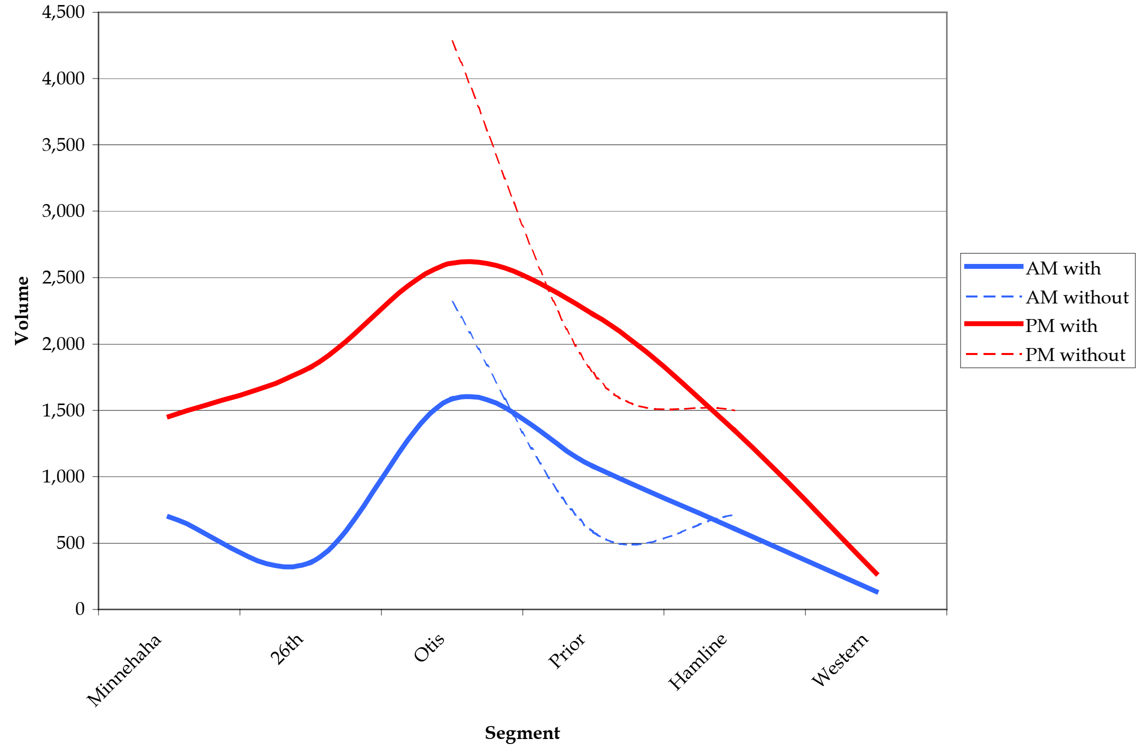

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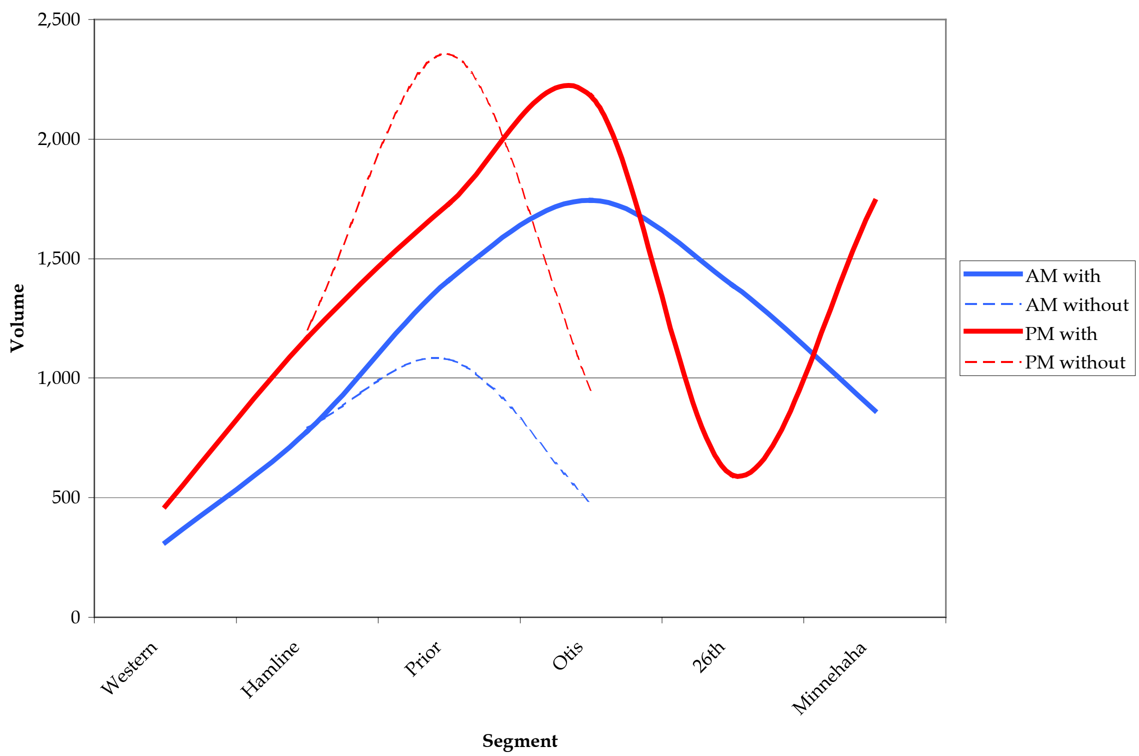

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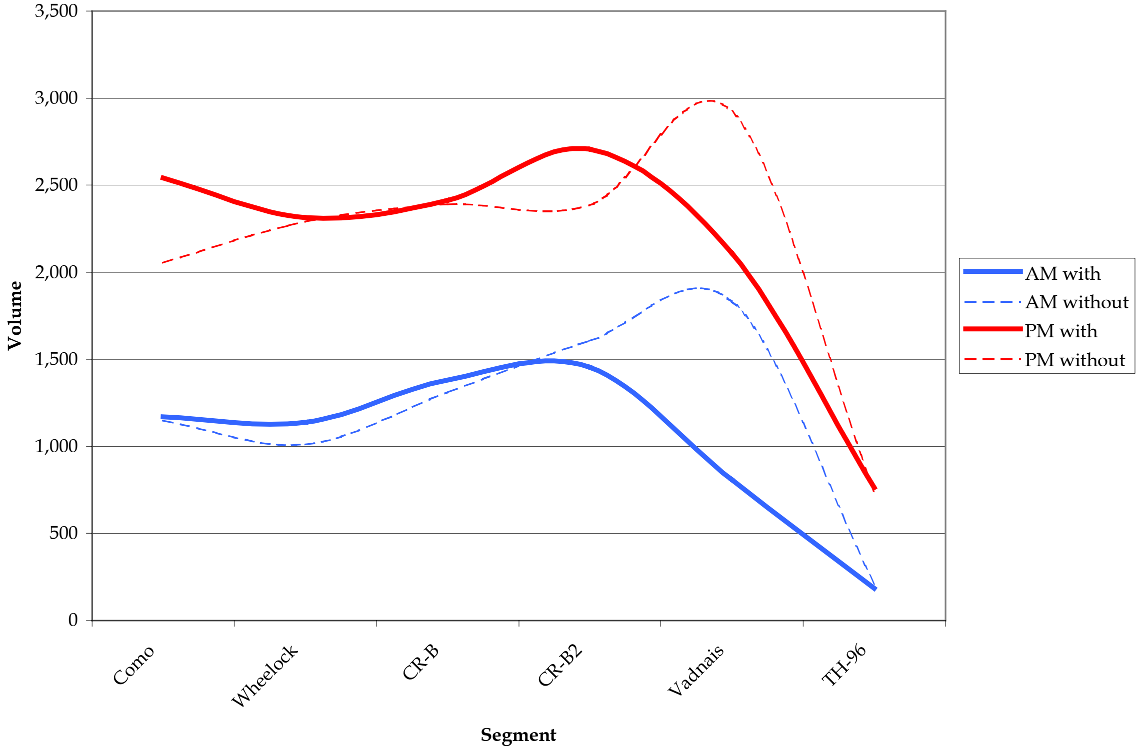

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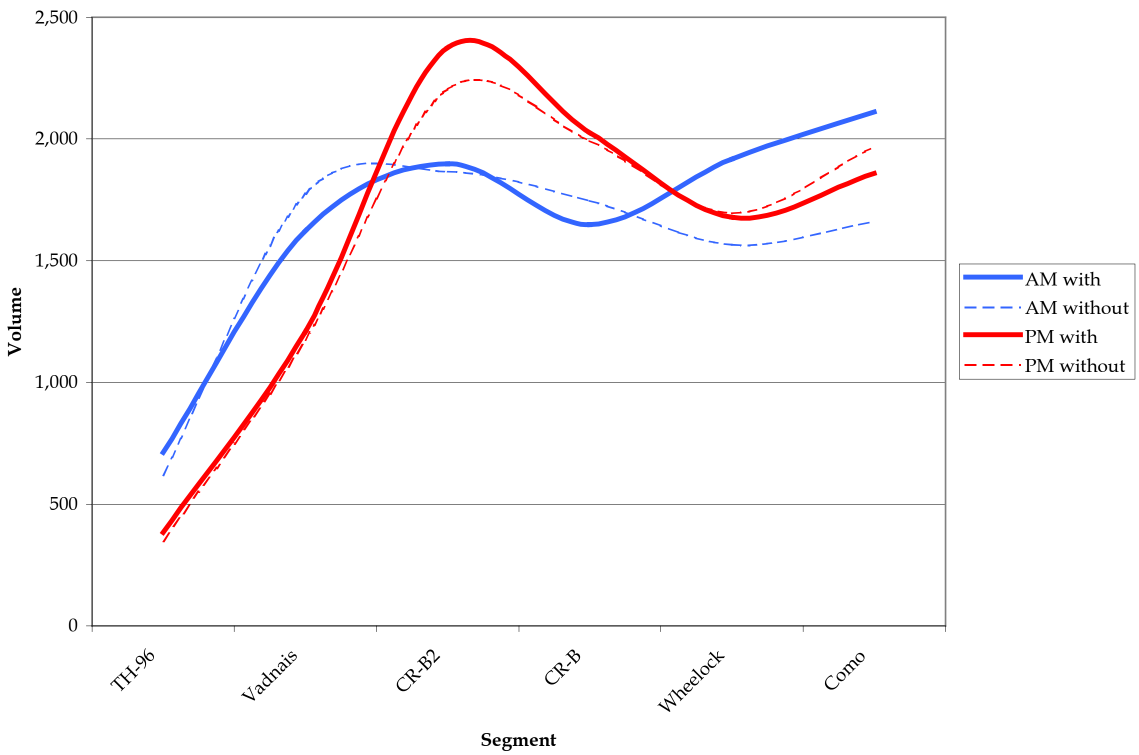

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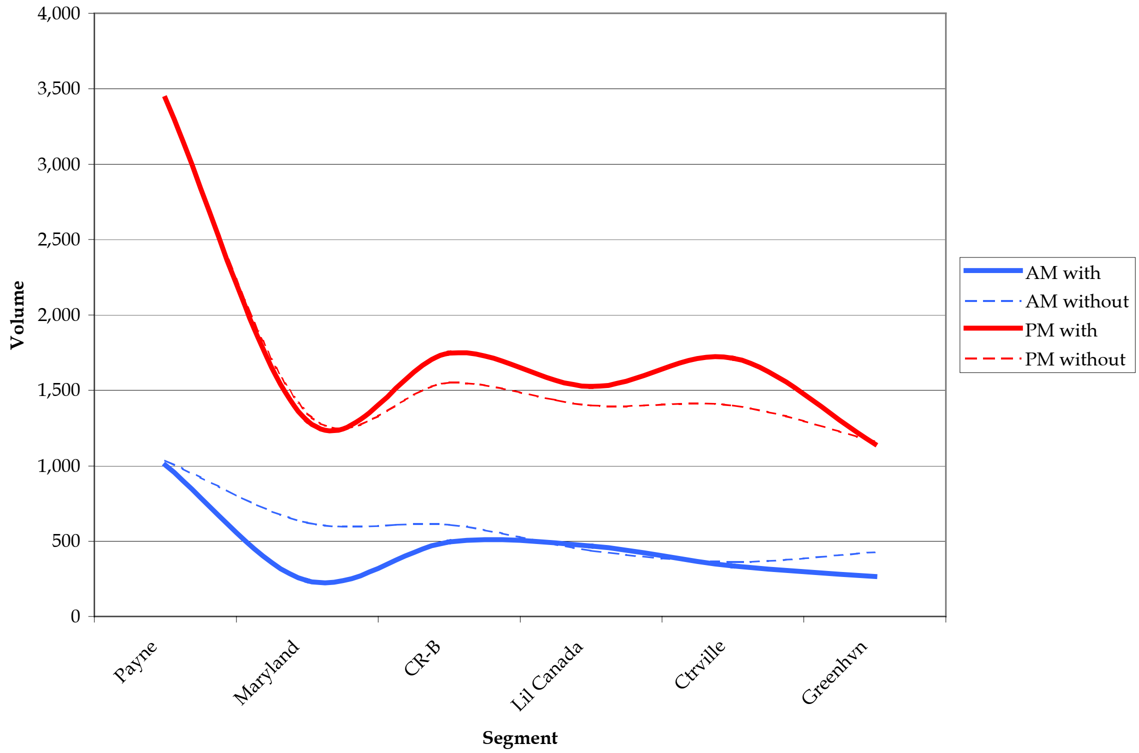

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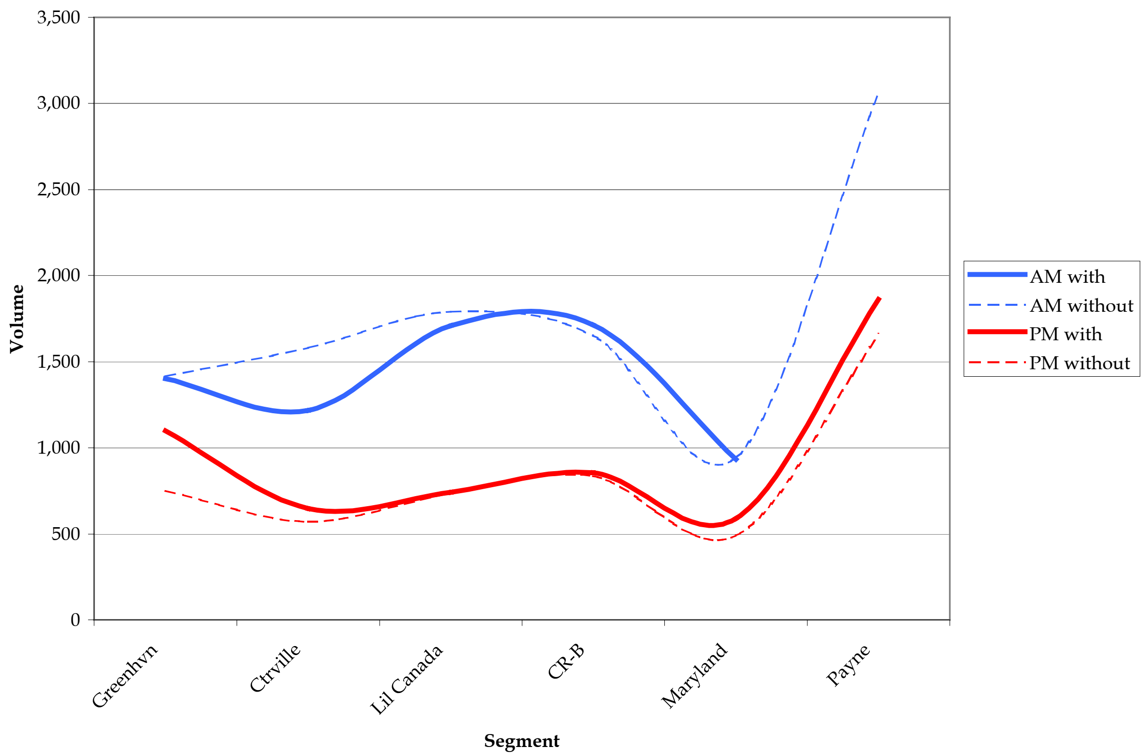

Appendix D

Ramp Volumes

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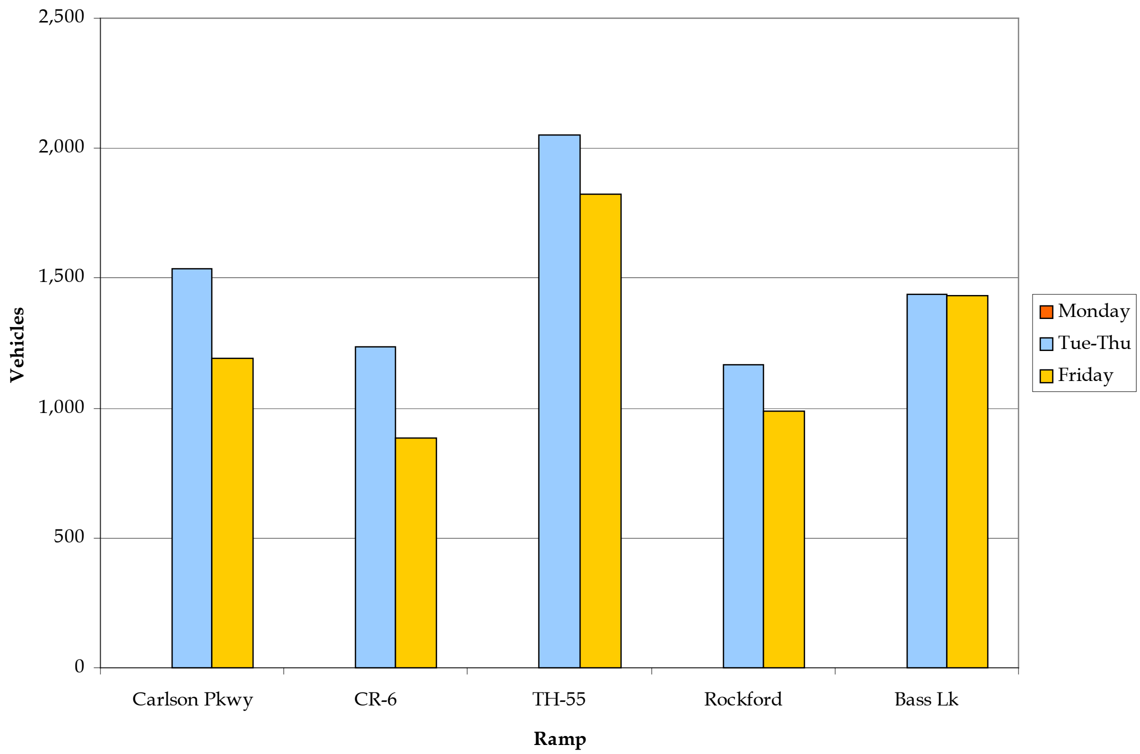

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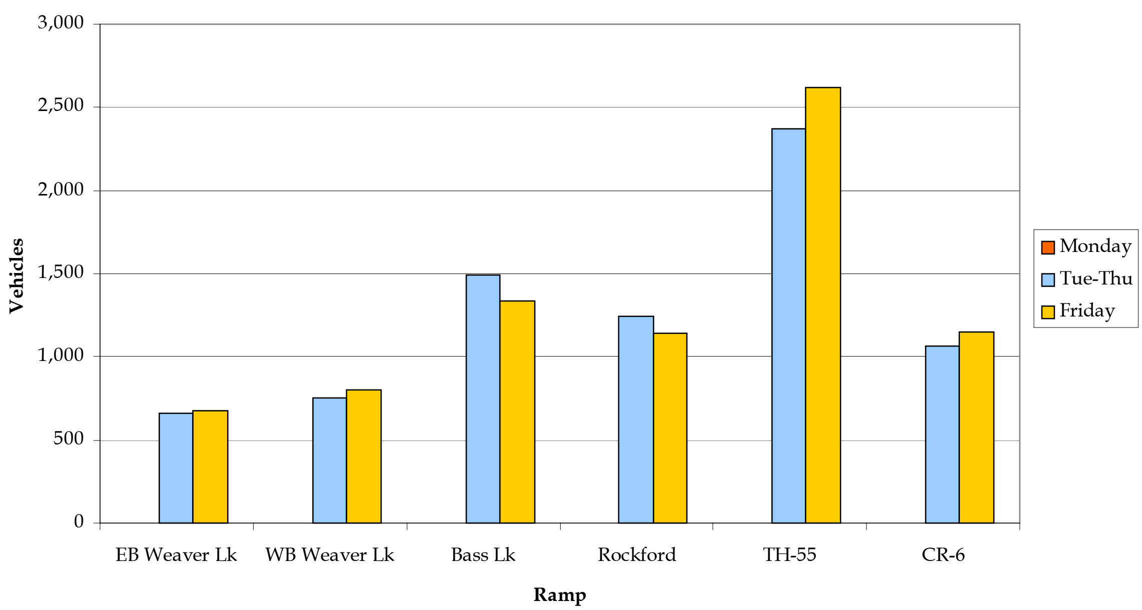

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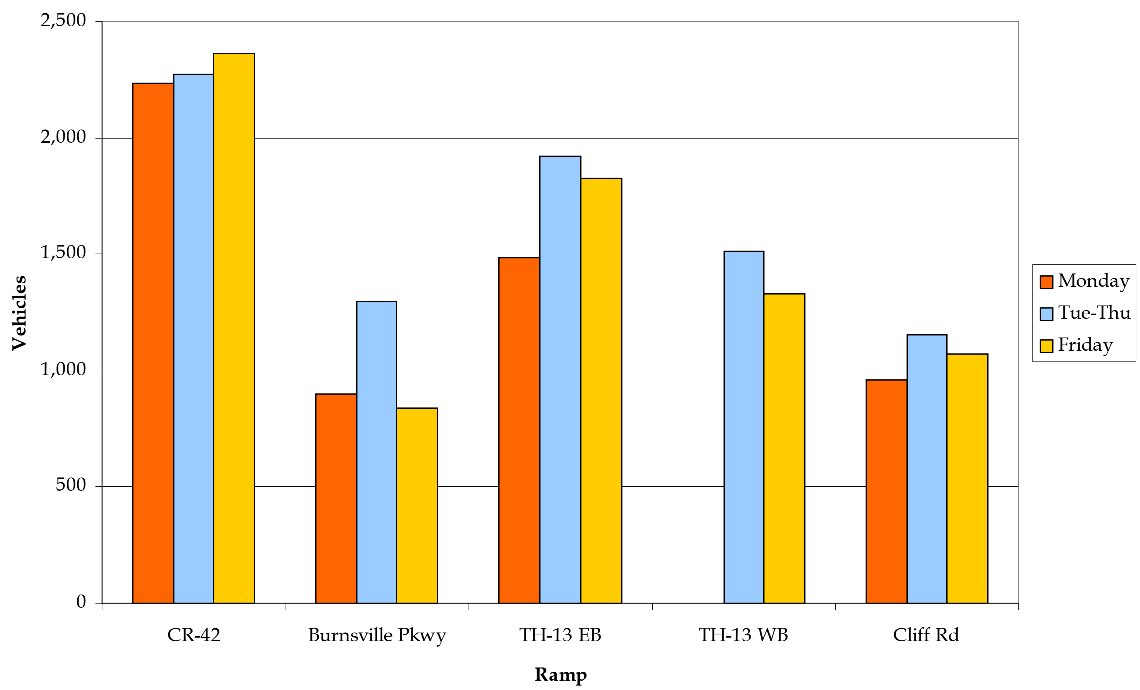

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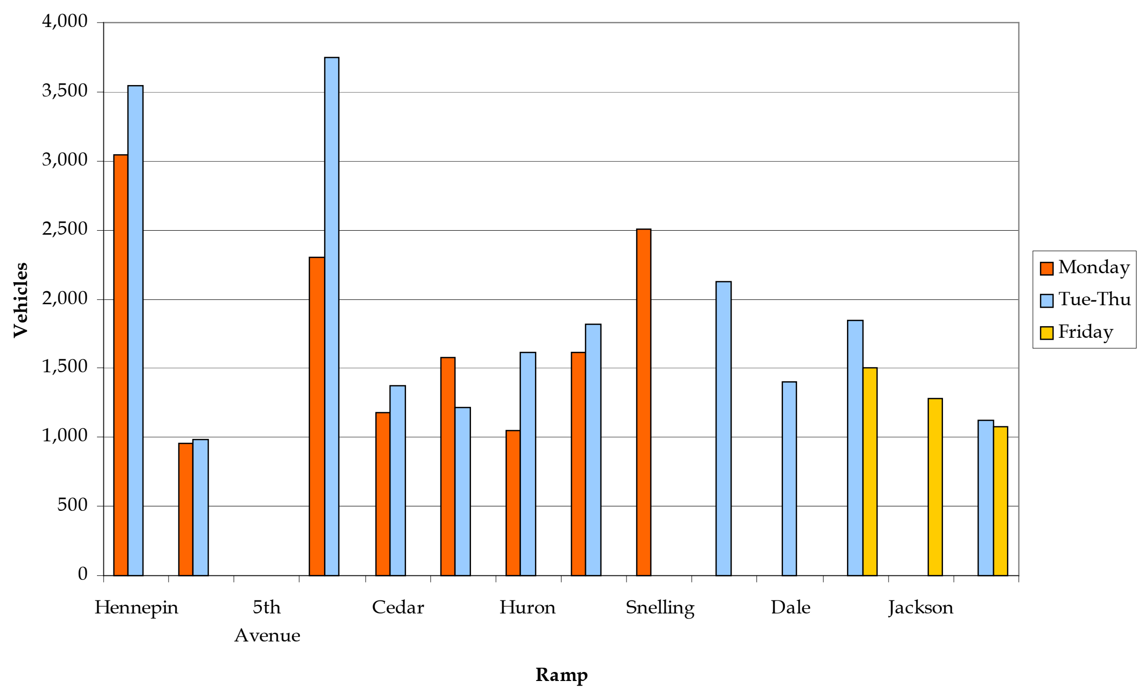

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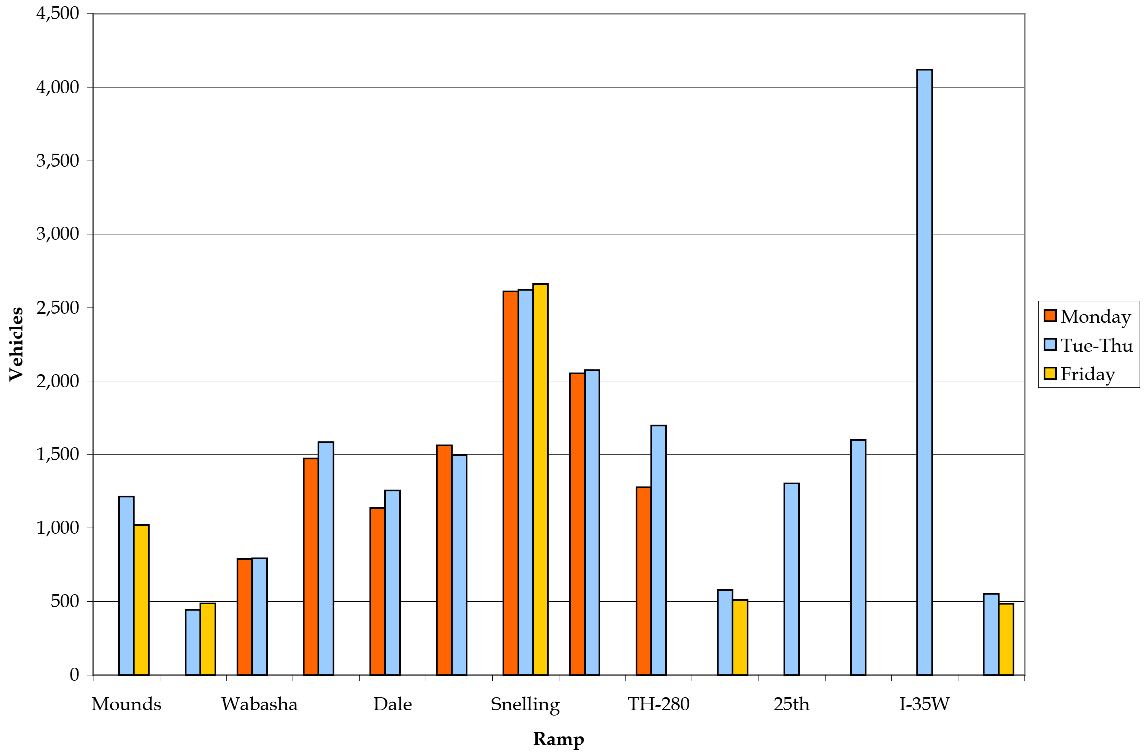

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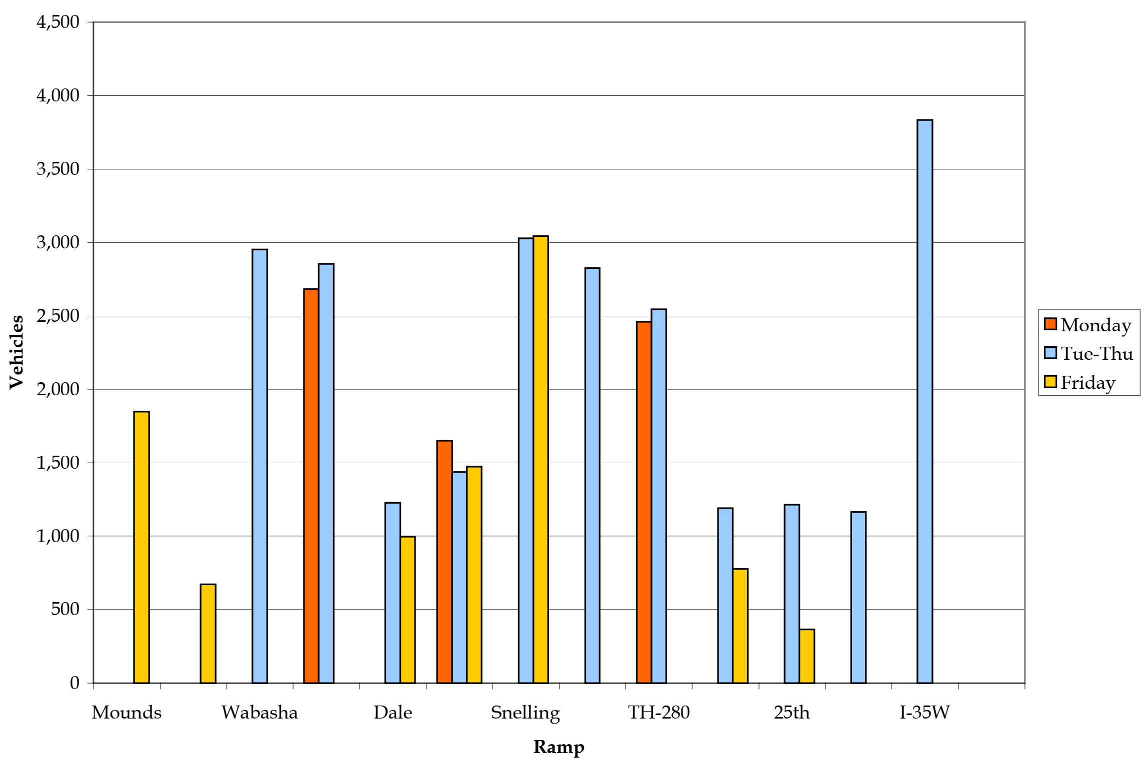

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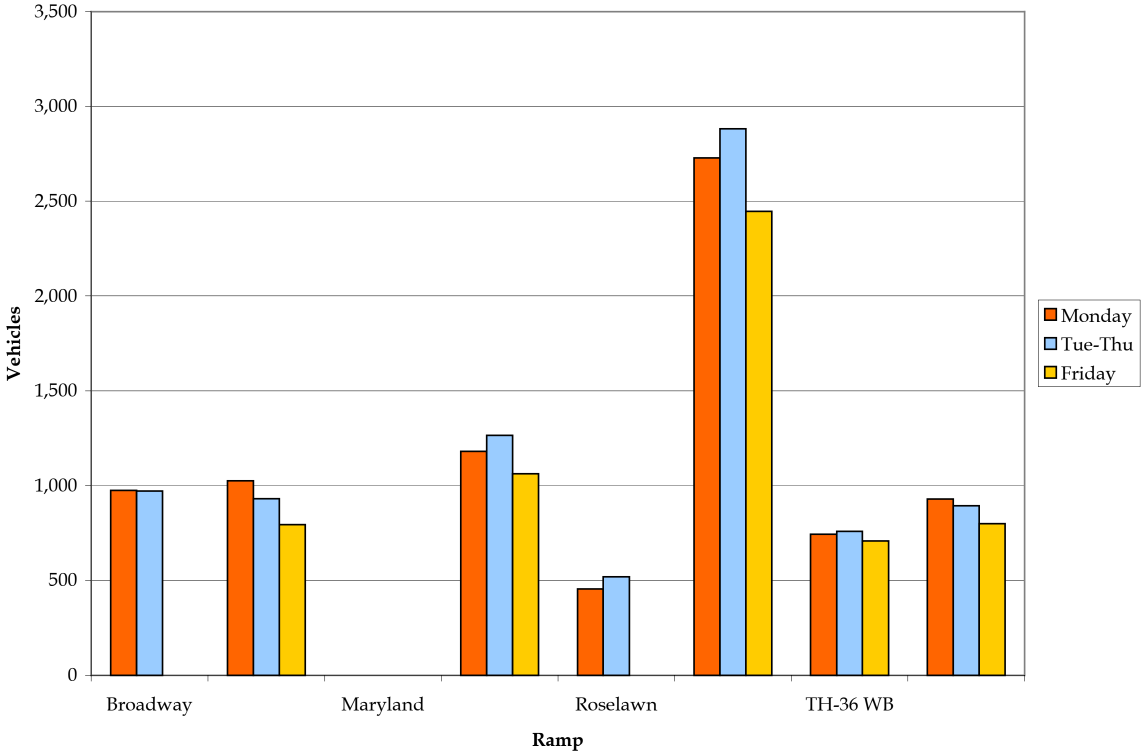

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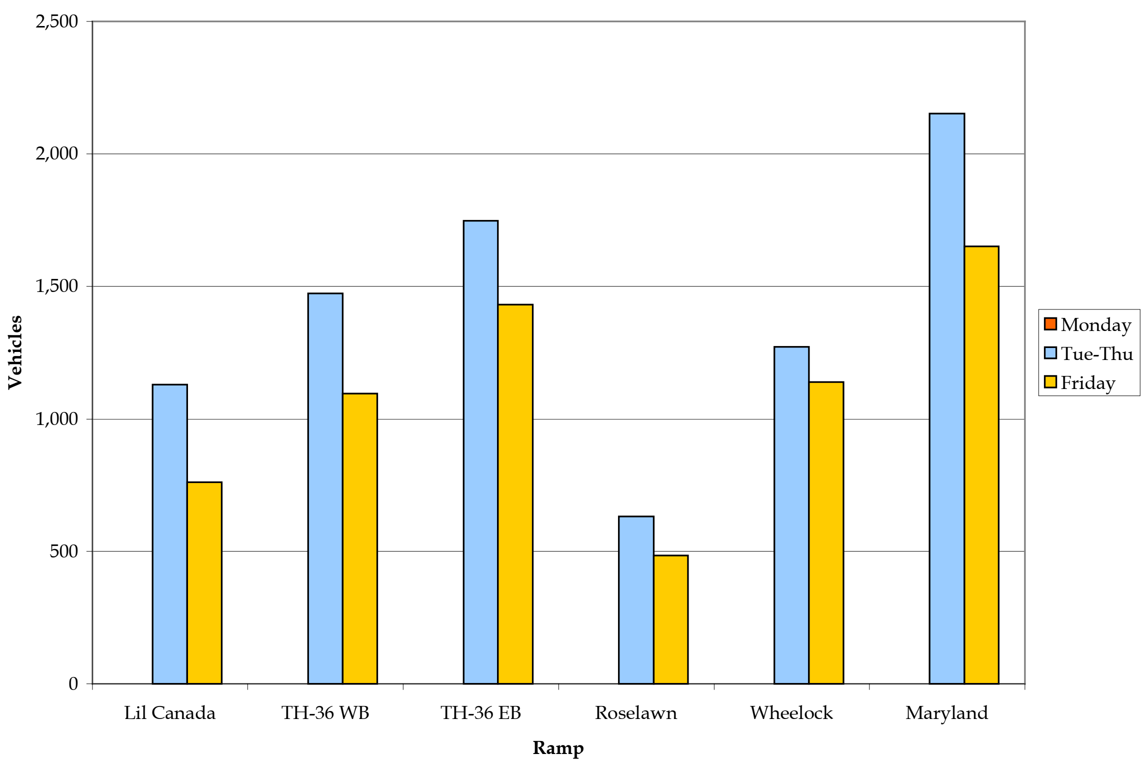

Appendix E

Socioeconomic Distribution of Market Research Samples

Appendix E Socioeconomic Distribution of Market Research Samples

Table E.1 Gender Distribution for "Before" and "After" Random Samples

	"Before" Shutdown		"After" Shutdown	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Males	126	49.8%	126	50.0%
Females	127	50.2%	126	50.0%
Total	**253**	**100.0%**	**252**	**100.0%**

Table E.2 Age Distribution for "Before" and "After" Random Samples

	"Before" Shutdown		"After" Shutdown	
	Frequency	**Percentage**	**Frequency**	**Percentage**
18 to 29 years	42	16.7%	45	18.0%
30 to 39 years	61	24.2%	57	22.8%
40 to 49 years	70	27.8%	73	29.2%
50 to 59 years	42	16.7%	39	15.6%
60 to 69 years	25	9.9%	22	8.8%
70 or more years	12	4.8%	14	5.6%
Total	**252**	**100.0%**	**250**	**100.0%**

Table E.3 Car Ownership for "Before" and "After" Random Samples

	"Before" Shutdown		"After" Shutdown	
	Frequency	Percentage	Frequency	Percentage
1 vehicle	52	20.7%	38	15.1%
2 vehicles	120	47.8%	145	57.5%
3 vehicles	47	18.7%	44	17.5%
4 or more vehicles	32	12.7%	25	9.9%
Total	251	100.0%	252	100.0%

Table E.4 Income Distribution for "Before" and "After" Random Samples

	"Before" Shutdown		"After" Shutdown	
	Frequency	Percentage	Frequency	Percentage
Under $20,000	6	2.6%	8	3.9%
$20,000 to $34,000	39	17.2%	19	9.3%
$35,000 to $49,000	36	15.9%	25	12.2%
$50,000 to $64,000	42	18.5%	47	22.9%
$65,000 to $79,000	37	16.3%	45	22.0%
$80,000 to $99,000	22	9.7%	27	13.2%
$100,000 to $149,000	34	15.0%	24	11.7%
$150,000 or more	11	4.8%	10	4.9%
Total	227	100.0%	205	100.0%

Table E.5 Education Levels for "Before" and "After" Random Samples

	"Before" Shutdown		"After" Shutdown	
	Frequency	Percentage	Frequency	Percentage
High School or less	43	17.0%	44	17.5%
Technical/vocational school	29	11.5%	23	9.1%
Some college	59	23.3%	59	23.4%
College graduate	75	29.6%	75	29.8%
Post-graduate studies	47	18.6%	51	20.2%
Total	253	100.0%	252	100.0%

Table E.6 Household Size for "Before" and "After" Random Samples

	"Before" Shutdown		"After" Shutdown	
	Frequency	**Percentage**	**Frequency**	**Percentage**
One-person household	44	17.4%	31	12.3%
Two-person household	91	36.0%	100	39.7%
Three-person household	49	19.4%	47	18.7%
Four-person household	51	20.2%	49	19.4%
Five-person or larger household	18	7.1%	25	9.9%
Total	253	100.0%	252	100.0%

Appendix F

Geocoding of Respondents' Origin-Destination Trips

Appendix F
Geocoding of Respondents' Origin-DestinationTrips

Each of the 760 "with meters" surveys and 760 "without meters" surveys contain geographic data describing the origins and destinations of the respondents' trips. The surveys also contain the respondents' home zip codes. Cambridge Systematics geocoded these geographic data to examine the similarity of the "with meters" and "without meters" samples, and to analyze whether geography plays a role in determining opinions about ramp meters. The process of geocoding entails converting textual data describing locations to pairs of geographic coordinates that can be represented as points on a map. The objective of geocoding information about the ramp meter surveys is to assign a latitude, longitude coordinate pair to each respondent's home, trip origin, and trip destination, so that each of these locations can be used as points in a GIS (Geographic Information System). Each point in a GIS is a record in a database table that has a unique id associated with the particular survey respondent. The unique ids facilitate the joining of the rest of the survey data with the points.

Subsequently, the survey data can be examined and described geographically through maps. For example, each trip origin point could be colored according to its respondent's opinion of whether the ramp meter system should be modified or not. In addition, geocoding allows for spatial querying and aggregation of the data. For example, all of the trip origins could be aggregated to the county level to see if the average opinion of the ramp meters differs from county to county. Spatial aggregation in a GIS is a quick and efficient way to discern whether geographic patterns exist in the data.

GIS was also used in this study to create variables for the ANOVA analysis. First, the study area was divided into groups of zip codes. Then each respondent was allocated into one of these groups based on its home zip code point, trip origin point, and destination point. Categorical variables were created to store this general information about the respondent's location. These variables allowed the study of whether the nature of the respondent's trip affects their view of the ramp meters, or whether the respondent's home location affects or colors their experiences with the ramp meters along with the other variables in the ANOVA.

Data Preparation

The data originated in text file format. The geographic data were separated and information from each survey was stored in a series of lines. The first line states the case id, the unique id representing the respondent. The second line has the respondent's home zip code; and the next three lines contain information about the intersection where the respondent's trip started in the form of "street one," "street two." The final three lines contain information about the intersection where the respondent's trip ended in the form of "street one" and "street two."

```
Pre-Wave Case ID:  5001

Zip Code:  55427

Q3d. Intersection where started trip

Street1:  Plymouth Ave
Street2:  Napor Ave

Q3h. Intersection where ended trip

Street1:  94th Ave
Street2:  James Ave
```

A program was written in ArcView's Avenue language to parse the intersection and zip code data into a database format. The resulting database represents each survey's information in a record where the first column or key field contains the unique case id. The second column contains street 1 of intersection 1, the third column contains street 2 of intersection 1, the fourth column contains street 1 of intersection 2, and the fifth column contains street 2 of intersection 2. The database tables are stored in an ArcView GIS.

There were many obvious misspellings and even miswordings evident in the data, so each record in the database was coarsely edited manually to correct such obvious errors. After the initial data cleaning was completed, two new fields were created in the database, which concatenated the two streets in each intersection into one field and separated them with an "&." For example, if "Street1" were Plymouth Ave and "Street2" were Napor Ave, the new field would contain "Plymouth Ave & Napor Ave." This was done to format the data for automatic geocoding as described below.

In order to automatically geocode or pinpoint locations in a GIS environment, a detailed basemap must be used that contains address precision. The dataset used by Cambridge Systematics for this task is The Lawrence Group (TLG) Street Centerline Data. The dataset or layer was developed by The Lawrence Group for the express purpose of facilitating automated routing and address matching applications. This street data layer was brought into ArcView and spatially indexed by ArcView in preparation for geocoding the intersection data.

Geocoding results in layers of points that have pinpoint precision. However, the points will only be as accurate as the original data. The best and most precise geocoding is done with address data. However, since the survey collected intersection data, it was assumed that the intersections represent a precise point in space and that point is indeed one of their trip ends. The data were obtained through telephone surveyors asking the respondent to identify the trip end intersections. Since not all respondents are expected to know the exact intersection where they began and ended their trips, the respondents gave information that describes the general area they began or ended their trip. In the process of geocoding, the general intersection descriptions of varying accuracy were assigned a precise point in space.

Geocoding Methodology

ArcView's automated geocoding function is called, "Geocode Addresses." It requires the user to specify the table where the location data are stored and the field where the address to locate is. In this case, the database table created that stores the intersection data and the field we created with the streets of each intersection separated by the "&" sign were selected. ArcView's function goes through each record in the table and looks for a point on the basemap that matches the intersection. The user is allowed to loosen spelling sensitivity so that, if the street name is spelled wrong in the data, a match can still be made.

ArcView's geocoding function was only able to automatically match between 40 and 50 percent of each survey's origins and destinations (see Table 6C.1). ArcView allows interactive geocoding of the remaining unmatched surveys. For each, it allows the user to choose from a list of possible intersections. However, the user is not allowed to see the intersections on a map. Because of this, only another 22 to 30 percent more could be geocoded semi-automatically. The remaining unmatched intersections were geocoded by hand using a combination of paper and electronic maps. Each origin and destination were located on a map, and then a point was created in ArcView at that location. After this effort, there were still some intersections that could not be geocoded, because the respondent didn't know or wasn't sure where their trip started and/or ended. In the end, about 92 percent of all trip origins and destinations were geocoded.

Table F.1 Summary of Geocoding Effort and Resulting Database

Geocoding Results	Number of Surveys	Automatically Matched	Semi-Automatically Matched	Manually Matched	Unmatched	Total Match Percentage
"With meters" Survey Origins	760	343	205	169	43	94.3%
"With meters" Survey Destinations	760	380	171	136	73	90.4%
"Without meters" Survey Origins	760	366	174	150	70	90.8%
"Without meters" Survey Destinations	760	309	238	148	65	91.5%
Total						**91.7%**

Appendix G

Evaluation Plan

Twin Cities Ramp Meter Evaluation

evaluation plan

prepared for

Minnesota Department of Transportation

prepared by

Cambridge Systematics, Inc.

with

SRF Consulting Group, Inc.
N.K. Friedrichs Consulting, Inc.

September 25, 2000

evaluation plan

Twin Cities Ramp Meter Evaluation

prepared for

Minnesota Department of Transportation

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Cambridge Systematics, Inc.
1300 Clay Street, Suite 1010
Oakland, California 94612

September 25, 2000

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1.0 Project Background

1.0 Project Background

The Minnesota Department of Transportation (Mn/DOT) uses ramp meters to manage freeway access on approximately 210 miles of freeways in the Twin Cities metropolitan area. Mn/DOT first tested ramp meters in 1969 as a method to optimize freeway safety and efficiency in the metro area. Since then, approximately 430 ramp meters have been installed and used to help merge traffic onto freeways and to help manage the flow of traffic through bottlenecks.

While ramp meters have a long history of use by Mn/DOT as a traffic management strategy, some members of the public have recently questioned the effectiveness of the strategy. A bill passed in the past session by the Minnesota Legislature requires Mn/DOT to study the effectiveness of ramp meters in the Twin Cities Region by conducting a shutdown study before the next legislative session.

The study is scheduled to occur in the fall of 2000, with the results to be presented to the Legislature and the public by February 1st, 2001. The goal of the study is to evaluate and report any relevant facts, comparisons, or statistics concerning traffic flow and safety impacts associated with deactivating system ramp meters for a predetermined amount of time.

In response to the Legislative mandate, Mn/DOT has formed two committees to represent the public and ensure the credibility/objectivity of the study, including:

- **Advisory Committee –** Provides policy oversight and input into the consultant selection process, the proposed study work plan, measures of effectiveness and evaluation measures.

- **Technical Committee –** Provides technical guidance, expertise, and quality control. Also provides technical input to the consultant selection process, proposed study work plan, measures of effectiveness and evaluation measures.

On June 19th, 2000, Mn/DOT issued a Request for Proposals (RFP) to study and report on the traffic flow and safety results of deactivating ramp meters in the Twin Cities Region. Members of both the Advisory Committee and the Technical Committee served on a selection committee to design and approve consultant selection criteria and evaluate proposals from consultants received in response to the RFP. A consultant team led by Cambridge Systematics, Inc. was selected to conduct the ramp meter evaluation. Joining Cambridge Systematics on the evaluation team are SRF Consulting Group, N.K. Friedrichs Consulting, and a panel of nationally recognized experts in the field of ramp metering and transportation evaluations.

This document represents the Evaluation Plan developed for the study by the Cambridge Systematics (CS) team with significant input from the Technical and Advisory Committees. This Evaluation Plan identifies:

- Evaluation team members and organizational hierarchy (Section 2);
- Evaluation objectives (Section 3);
- Performance measures and evaluation methodologies (Section 4);
- Technical approach for field data collection (Section 5);
- Technical approach for market research tasks (Section 6);
- Technical approach for conducting the benefit/cost analysis (Section 7);
- Technical approach for conducting secondary research (Section 8); and
- Evaluation schedule, meetings and deliverables (Section 9).

This Evaluation Plan will serve as the guideline for conducting the ramp metering evaluation. As such, this document is intended to be sufficiently detailed to provide valuable guidance to the evaluators; however, the plan also maintains flexibility to address project contingencies that may arise.

2.0 Evaluation Team

2.0 Evaluation Team

The evaluation team assembled for this study is knowledgeable and experienced in the evaluation of traffic management strategies, such as ramp metering. The evaluation team has been carefully selected and structured to provide an independent, credible and objective study.

Two committees have been formed to represent the public in the implementation of the study. The Advisory Committee is comprised of legislators, legislative staff, local government representatives, researchers, industry representatives, and stakeholder representatives. The Advisory Committee provides policy oversight, input and guidance to the study. The Advisory Committee is chaired by David Jennings, President of the Greater Minneapolis Chamber of Commerce. Other organizations represented on the Advisory Committee include:

- Association of Minnesota Counties;
- Department of Public Safety – Minnesota State Patrol;
- Hennepin County Community Health Department;
- Southwest Metro Transit Commission;
- State Legislators (4);
- Federal Highway Administration (FHWA);
- Murphy Warehouse Company;
- American Automobile Association (AAA);
- Metropolitan Council;
- Minnesota Department of Transportation (Mn/DOT);
- Citizens League;
- Metro Transit; and
- City of Eagan.

The Advisory Committee is assisted in the day-to-day technical oversight and project quality control by a qualified Technical Committee. The Technical Committee is chaired by James Grube, Director of the Hennepin County Transportation Department. Other organizations represented on the Technical Committee include:

- Pollution Control Agency;
- Dakota County Highway Department;
- City of Ramsey;

- City of St. Paul;
- Mn/DOT – Metro Division;
- Mn/DOT – Office of Investment Management;
- Metropolitan Council;
- City of Minneapolis;
- Metro Transit;
- Ramsey County Department of Public Works; and
- Federal Highway Administration.

The relation of the Advisory and Technical Committee to the overall evaluation team is shown in Figure 2.1.

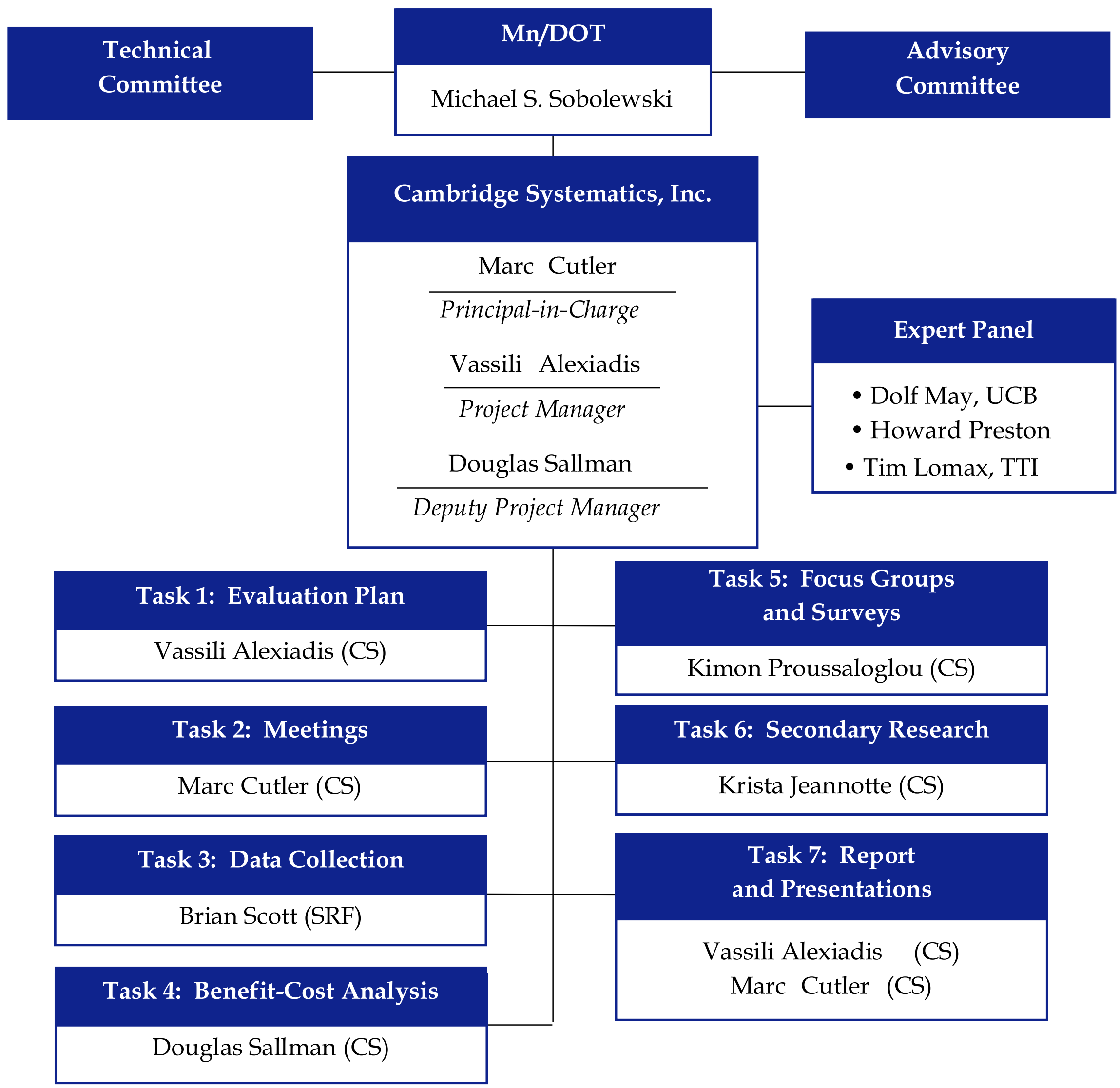
Michael Sobolewski is the Mn/DOT Project Manager selected to provide day-to-day management of the project and provide coordination between the Advisory and Technical Committees and the consultant team.

The consultant team conducting the study is led by Cambridge Systematics, which is responsible for overall project management, as well as the conduct of several specific work tasks (including the development of the evaluation plan, the design and implementation of focus groups and survey market research, the conduct of the benefit/cost analysis, and research of secondary data sources). SRF Consulting is assisting Cambridge Systematics in the traffic data collection design and implementation tasks. N.K. Friedrichs Consulting is assisting with the market research tasks.

Marc Cutler of Cambridge Systematics is serving as the Principal in Charge for the consultant team providing technical direction and quality control of the study. Vassili Alexiadis of Cambridge Systematics functions as the project manager for the consultant team providing day-to-day management of all aspects of the study progress. He is assisted by a Deputy Project Manager and individual Task Managers. These Task Managers provide focused expertise on individual aspects of the work scope. This management approach was developed to adequately support the diverse tasks required of the study while meeting the rigid time schedule presented by the legislative mandate.

The consultant team is also assisted by an expert panel consisting of individuals selected by the consultant team and by the Advisory and Technical Committees. These nationally-recognized experts provide technical input to the study approach, provide critical review of deliverables, and help to ensure a credible and objective evaluation.

Figure 2.1 Evaluation Team



3.0 Evaluation Objectives

3.0 Evaluation Objectives

The goals and objectives of conducting the evaluation of ramp meter effectiveness in the Twin Cities Metropolitan Region were designed to meet the mandate of the legislature's bill. Three evaluation goals for the Ramp Meter Study were identified including:

1. Evaluate whether the benefits of ramp metering outweigh the impacts and associated costs;

2. Identify other ramp metering impacts on surface streets and transit operations; and

3. Identify how the Twin Cities' ramp metering system compares and contrasts with other national and international ramp meter systems in terms of ramp meter operation strategy employed and ramp configuration strategy.

For each of the broad evaluation goals, several detailed evaluation objectives were identified. These evaluation objectives provide the framework for conducting the evaluation. Table 3.1 presents the evaluation objectives as they relate to each of the evaluation goals.

The following sections describe in greater detail the tasks required to fulfill each of the evaluation's three main goals and associated objectives.

Table 3.1 Evaluation Goals and Objectives

Evaluation Goal	Evaluation Objective
Evaluate whether the benefits of ramp metering outweigh the impacts and associated costs.	• Quantify ramp metering safety impacts/benefits (positive and negative) for selected corridors. • Quantify ramp metering traffic flow impacts/benefits (positive and negative) for selected corridors. • Extrapolate ramp metering safety impacts/benefits (positive and negative) to the entire system. • Estimate ramp metering impacts/benefits (positive and negative) on energy consumption and the environment. • Extrapolate ramp metering traffic flow impacts/benefits (positive and negative) for the entire system. • Compare the systemwide ramp metering benefits with the associated impacts and costs. • Identify (both quantitatively and qualitatively) public attitudes toward ramp metering for both the selected corridors and the region as a whole.
Identify other ramp metering impacts on surface streets and transit operations.	• Identify ramp metering impacts on local streets. • Identify ramp metering impacts on transit operations. • Document additional ramp metering benefits/impacts observed during the study.
Identify how the Twin Cities' ramp metering system compares and contrasts with other national and international ramp meter systems.	• Identify similarities and differences between the Twin Cities' ramp metering system and other metropolitan areas in terms of ramp meter operation strategy employed and ramp configuration strategy. • Identify national and international trends regarding the use of ramp metering as a traffic management strategy. • Identify benefits/impacts of ramp metering systems documented in other national and international studies.

4.0 Performance Measures and Evaluation Methodologies

4.0 Performance Measures and Evaluation Methodologies

The evaluation goals and objectives presented in the previous section provide the framework for the evaluation. This section presents the particular measures of effectiveness that will be evaluated during the study. These evaluation measures build on the evaluation objectives and are designed to provide for a comprehensive analysis of the evaluation goals. This section also presents an overview of the methodologies that will be employed to collect and analyze data for the study.

4.1 Evaluation Measures

For each of the evaluation objectives identified in Section 3.0, one or more measures of effectiveness have been identified to provide an assessment of the objective. Where possible, these evaluation measures are expressed in quantitative terms; however, many of the measures are more appropriately expressed in qualitative terms.

The evaluation measures selected for each evaluation objective are presented in Table 4.1. The measures of effectiveness are focused on the incremental change observed between the two evaluation scenarios – "with" (meters on) and "without" (meters off). By focusing on the change occurring between the two scenarios, the evaluation team will be better able to isolate the particular benefit/impact. The measures of effectiveness are not mutually exclusive and in some cases the same measure is used to test several objectives. The evaluation measures are also designed to be "neutral" and not presuppose any outcome of the ramp meter test. In all cases, the outcome of the particular measure may be either positive or negative depending on the impacts observed during the two scenarios. Outcomes may also be *both* positive and negative in that results may vary geographically across the selected corridors, market segments, or timeframes.

Appropriate data will be collected related to each of these measures to provide the opportunity for assessment against the evaluation objectives and goals. Section 4.2 presents an overview of the methodology that will be employed in evaluating these measures. The remaining sections of this document provide greater detail on the data collection and analysis methodologies.

Table 4.1 Evaluation Measures

Evaluation Objective	Measures of Effectiveness
1. Quantify ramp metering safety impacts for selected corridors.	• Change in the number of crashes occurring in selected corridors. • Change in the severity of crashes occurring in selected corridors. • Change in the number of traffic conflicts (non-crashes) occurring at specific corridor locations (ramp merge and adjacent intersections). • Change in HOV lane violations. • Perceived change in safety of travel in selected corridors.
2. Quantify ramp metering traffic flow and travel time impacts for selected corridors.	• Change in travel time for primary travel route in selected corridors. • Change in travel time for alternative travel routes in selected corridors. • Change in travel speed for primary travel route in selected corridors. • Change in travel speed for alternative travel routes in selected corridors. • Change in traffic volume for primary travel route in selected corridors. • Change in traffic volume for alternative routes in selected corridors. • Change in travel time reliability for selected corridors. • Change in traffic volume, travel time, travel speed, and travel time reliability for on-ramps in selected corridors. • Perceived change in travel time for selected corridors. • Perceived change in travel time reliability for selected corridors.
3. Extrapolate ramp metering safety impacts to the entire system.	• Change in the number of crashes occurring systemwide. • Change in the severity of crashes occurring systemwide. • Estimated change in the regional crash rate for different facility types. • Estimated regional change in vehicle miles traveled for different facility types. • Estimated change in regional volume to capacity (v/c) ratios. • Perceived change in systemwide safety of travel.
4. Estimate ramp metering impacts/ benefits (positive and negative) on energy consumption and the environment.	• Estimated regional change in emissions by pollutant and by facility type. • Estimated regional change in fuel consumption by facility type.

Table 4.1 Evaluation Measures (continued)

Evaluation Objective	Measures of Effectiveness
5. Extrapolate ramp metering traffic flow impacts/benefits (positive and negative) for the entire system.	• Estimated regional change in travel time. • Estimated regional change in vehicle miles traveled for different facility types. • Estimated regional change in travel speed for different facility types. • Estimated regional change in travel time reliability. • Perceived regional change in travel time. • Perceived regional change in travel time reliability.
6. Compare the systemwide ramp metering benefits with the associated impacts and costs.	• Change in the number and severity of crashes occurring systemwide. • Change in systemwide travel times. • Change in the total number of trips. • Change in travel time reliability. • Change in fuel use and other user paid costs. • Change in vehicle emissions levels. • Estimated change in DOT operating costs. • Estimated change in operating costs of other agencies (e.g., State Patrol, transit agencies, local jurisdictions, etc.) • Capital cost of ramp metering system.
7. Identify ramp metering impacts on local streets.	• Change in traffic volumes on local streets in selected corridors. • Change in the length and severity of ramp queue spillover onto adjacent intersections in selected corridors.
8. Identify ramp metering impacts on transit operations.	• Change in transit travel times for selected corridors. • Change in transit ridership levels for selected corridors. • Estimated change in operating costs for transit providers.
9. Document additional ramp metering benefits/impacts observed during the study.	• Documentation only.
10. Identify similarities and differences between the Twin Cities' ramp metering system and other metropolitan areas in terms of ramp meter operation strategy employed and ramp configuration strategy.	• Documentation only.
11. Identify national and international trends regarding the use of ramp metering as a traffic management strategy.	• Documentation only.
12. Identify benefits/impacts of ramp metering systems documented in other national and international studies.	• Documentation only.

4.2 Overview of Evaluation Methodologies

Data related to the measures of effectiveness will be collected during two periods during the fall of 2000. The first data collection period will be used to assess the baseline or "with ramp meters" scenario. In this scenario, the ramp meters will be operated according to established operating practices. These data will be used to establish a baseline for the purpose of identifying the incremental change occurring in the "without ramp meters" scenario.

A second data collection period will be conducted to evaluate the "without ramp meters" scenario. In this scenario, *all ramp meters will be deactivated systemwide*. The deactivated ramp meters will be set to "flashing yellow" mode – consistent with their normal operation during off-peak periods. Although all ramp meters throughout the system will be deactivated during the test, the data collection effort will be focused on four selected corridors. These corridors were selected as representative of other corridors throughout the metropolitan region. Section 5.0 identifies the selected corridors and provides additional detail on the criteria used to select the corridors. Other systemwide data will be collected during this period to allow for the normalization of data collected in the selected corridors.

In parallel with the field traffic data collection, a series of market research tasks will be conducted. This effort will include both focus groups and surveys conducted during both the "with" and "without" scenarios.

Data collection will occur over a four- to six-week period during both the "with" and "without" scenarios. "With ramp meter" data collection will occur between September 11th (following the Labor Day holiday and the return of normal fall business and school activity) and October 15th, 2000. The public will be informed on October 9th that the ramp meters will be deactivated the following Monday, October 16th. Most of the public knows that this will be occurring sometime in the fall. The goals of the schedule are: 1) to provide adequate time for the collection of the "before deactivation" data; 2) to provide the public with adequate notice of the impending change in traffic operations such that they have time to plan changes in their travel routines should they be interested in doing so; and 3) to not provide so much advance notice that the resulting induced behavioral change would in some way taint the "before deactivation" data collection. It is the intention of the plan to collect the vast majority of data prior to the October 9th public notification, using the final week primarily for contingency purposes. It should be noted that the public will not be formally notified of the selected test corridors; however, it is likely that many travelers will observe the data collection activities in progress on these corridors.

The ramp meters will remain deactivated from October 16th through November 17th, thereby concluding prior to the Thanksgiving Holiday and the onset of the Christmas shopping season. This five-week test period will also enable the evaluation to assess changes over time in travel behavior as travelers adjust to new operating conditions and congestion patterns.

Following the conclusion of the "without" scenario test, the ramp meters will most likely be turned on to operate in their pre-test mode absent a policy decision by Mn/DOT to the contrary. Data analysis will be conducted to isolate the incremental impact observed between the two scenarios during this time. These incremental impacts will then be extrapolated and combined with other data to support the regionwide analysis of ramp meter effectiveness.

To support the evaluation, several individual test plans have been developed to guide the collection and analysis of different types of data. Each test plan provides detailed instructions for conducting a specific aspect of the study. Yet, all the individual test plans have been carefully linked to provide coordination between the different analysis efforts. The individual test plans developed for this study include:

- **Field Data Collection Plan for Selected Corridors –** Defines corridor selection criteria, selected corridors, and the field data to be collected and analyzed for the selected corridors (Section 5.0);

- **Market Research Test Plan –** Defines the focus group and survey data collection tasks to be performed and presents the methodology to be used (Section 6.0);

- **Benefit/Cost Analysis Test Plan –** Identifies how the data collected for the selected corridors will be extrapolated to develop estimates of regionwide impacts and presents candidate methodologies for performing the methodology (Section 7.0); and

- **Secondary Research Test Plan –** Identifies the secondary research to be performed to compare and contrast the ramp metering system in the Twin Cities with systems in other national and international locations (Section 8.0).

The following sections present the various individual test plans that provide specifics on the conduct of the various evaluation tasks.

5.0 Test Plan for Field Data Collection

5.0 Test Plan for Field Data Collection

Ramp meters throughout the entire system will be deactivated during the test. Collecting field data on the entire transportation system would require an extraordinary amount of resources. However, in order to make better use of evaluation resources and meet the demanding schedule requirements of the project, the evaluation team will instead focus field data collection on several select corridors that are representative of other corridors throughout the entire system. This data will then be extrapolated to the entire system.

The objective of the field data collection portion of this study is to measure the impacts of ramp metering on a host of transportation variables over different types of freeway corridors. The results of the information from this data collection will then be analyzed and applied to the entire metropolitan transportation system to derive the systemwide impacts of ramp metering. The results of the corridor-specific data collection and analysis will also be used to directly report the statistically valid effects of ramp metering on each corridor studied.

5.1 Corridor Selection Process

The key to the approach of the evaluation is to select study corridors that are representative of most of the freeway corridors in the Twin Cities Metropolitan Area so that the results can be extrapolated to the entire freeway system. The first task in the corridor selection is to classify the Twin Cities Metropolitan Area freeways into four corridor types. Each freeway corridor type represents a number of freeway sections within Twin Cities Metropolitan Area. This "categorization" of freeway sections allows the CS team to extrapolate the measured impacts of the four study corridors to the rest of the Twin Cities Metropolitan Area freeway system to provide systemwide evaluation results.

The four basic types of freeway corridors are defined as follows:

- **Type A –** Freeway section representing the I-494/I-694 beltline, which has a high percentage of heavy commercial and recreational traffic. The commuter traffic on the corridor type is generally suburb-to-suburb commuters.

- **Type B –** Radial freeway outside the I-494/I-694 beltline with a major geographic constraint that does not allow for alternate routes (i.e., major freeway river crossing).

- **Type C –** Intercity connector freeway corridor that carries traffic moving between major business and commercial zones. This type of freeway has a fairly even directional split of traffic throughout the a.m. and p.m. peak periods.

- **Type D –** Radial freeway inside the I-494/I-694 beltline that carries traffic to/from a downtown or suburban work center.

Next, a three-step process is used to select the four study corridors. Process steps are listed below and defined in greater detail in the following pages:

1. Identify the corridor selection criteria;
2. Identify candidate corridors; and
3. Apply corridor selection criteria and select corridors to be studied.

5.1.1 Identify the Corridor Selection Criteria

In coordination with the Technical and Advisory Committees the CS team developed the criteria for corridor selection. The criteria account for the types of freeway corridors, philosophy for metering the different types of freeway corridors, variations in traffic demand on the corridors, lane drops, interchange or geometric constraints, ease of data collection, HOV facilities and transit services in the corridor, unmetered ramps along corridor, etc. The corridor selection criteria were ranked as shown in the following list, with the first four criteria being the primary criteria used for the initial corridor screening:

- Availability and type of alternate routes,
- Level of congestion,
- Geographic representation,
- Construction activity on freeway and alternate routes,
- HOV lanes and bypass ramps,
- Transit service on corridor,
- Geographic balance within the Twin Cities Metropolitan Area,
- Geometric constraints,
- Market segments,
- Geometric constraints, and
- Representative corridor length.

5.1.2 Identify Candidate Corridors

Mn/DOT had identified four sample test corridors in the project Request for Proposals (RFP). These corridors represented a good variation of traffic characteristics and ramp meter locations. The CS team applied the corridor selection criteria to freeway sections throughout the Twin Cities Metropolitan Area and identified an initial list of 11 freeway corridors that adequately met the primary selection criteria. These initial corridors are shown in Table 5.1.

Next, the CS team gathered detailed information on the 11 candidate corridors and applied the remaining corridor selection criteria to these corridors, resulting in the presentation of nine candidate freeway corridors for review by the Technical and Advisory Committees. The nine candidate corridors are shown in the map on Figure 5.1, and the attributes of the corridors are shown in Table 5.2.

5.1.3 Apply Corridor Selection Criteria and Select Corridors To Be Studied

The CS team presented the candidate corridors to the Technical and Advisory Committees and facilitated the discussion and final selection of the four corridors to be studied in detail. The four corridors selected for the study provide geographic balance with the Twin Cities Metropolitan Area. The four corridors selected for the study are shown in Figure 2 and described as follows:

1. **I-494 Corridor –** This corridor serves traffic from outside the Twin Cities Metropolitan Area and commuter traffic between the residential area north of the corridor and employment destinations to the south.

2. **I-35W Corridor –** This corridor serves commuter traffic between the residential communities south of the Minnesota River (e.g., Burnsville and Lakeville) and employment destinations north of the river.

3. **I-94 Corridor –** This corridor serves traffic demand between downtown Minneapolis and downtown St. Paul.

4. **I-35E Corridor –** This corridor serves commuter traffic between the northern residential communities and various employment destinations further south.

■ 5.2 Field Data Collection Plan

The premise of the field data collection test plan is to measure the transportation system impacts of the ramp metering system in the Twin Cities Metropolitan Area. This task involves an extensive "with ramp metering" and "without ramp metering" traffic data collection program to address the impacts on traffic operations and safety by means of on-the-ground collection of empirical data about the metered and non-metered systems. To accomplish this, field data will be collected and evaluated with and without the ramp metering system in operation.

Traffic data will be collected at specific ramps and along selected corridors within the region over several weeks for both the "with" and "without" ramp metering evaluation scenario. Data collection will occur during a.m. and p.m. peak periods from Monday

Table 5.1 Candidate Corridors for Ramp Meter Evaluation

#	Type	Corridor	From	To	Length (miles)	Alternate Routes	Level of Congestion	Geographic Area
1	A	I-494 (NB)	Carlson Parkway	Weaver Lake Road	8	Vicksburg CR 61	H - L	N.W.
		I-494 (SB)	Weaver Lake Road	Carlson Parkway	8	Vicksburg CR 61	M - L	
2	A	I-694 (WB)	I-35W	TH 252	4.5		M - L	North Central
		I-694 (EB)	TH 252	I-35W	4.5		M - L	
3	B	TH 77 (NB) (a.m. only)	140th St.	Old Shakopee Road	6.8	I-35W	H - L	South
4	B	I-35W (NB) (a.m. only)	Cty. Road 42	98th St.	5	TH 77	High	South
5	C	I-94 (WB)	I-35E	I-394	10.9	Univ. Ave. TH 36 Franklin Ave. Lake St. – Marshall Ave.	H - L	Central
		I-94 (EB)	I-394	I-35E	10.9	Univ. Ave. TH 36 Franklin Ave. Lake St. - Marshall Ave.	H - L	
6	D	I-394 (WB)	TAD	TH 101	11	TH 55	H - L	West Central
		I-394 (EB)	TH 101	TAD	11	TH 55	H - L	
7	D	I-35E (NB)	I-694	I-94	5.4	Rice St. (TH 49) Edgerton Ave.	M - L	East Central
		I-35E (SB)	I-94	I-694	5.4	Rice St. (TH 49) Edgerton Ave,	H - L	
8	D	I-35W (NB)	TH 36	TH 10	7.4	CR 77	H - L	North Central
		I-35W (SB)	TH 10	TH 36	7.4	CR 77	H - L	

Table 5.1 Candidate Corridors for Ramp Meter Evaluation (continued)

#	Type	Corridor	From	To	Length (Miles)	Alternate Routes	Level of Congestion	Geographic Area
9	C	TH 100 (NB)	I-494	I-394 (Glenwood)	8	France Ave. TH 169	H - L	S.W.
		TH 100 (SB)	I-394 (Glenwood)	I-494	8	France Ave. TH 169	H - L	
10	D	I-94 (WB)	I-394	I-694	6.4	Lyndale Central	Low	North Central
		I-94 (EB)	I-694	I-394	6.4	Lyndale Central	Low	
11	C	I-494 (EB)	TH 212	I-35W	7	TH 62	High	S.W.
		I-494 (WB)	I-35W	TH 212	7		High	

Key:

Freeway Type	Attributes
A	Freeway section representing the I-494/I-694 beltline, commuter, heavy commercial and recreational traffic (suburb-to-suburb).
B	Radial freeway outside the beltline, major geometric constraint (e.g., river bridge) presenting limited alternate routes.
C	Intercity connector.
D	Radial freeway.

Figure 5.1 Candidate Corridors for Ramp Meter Evaluation

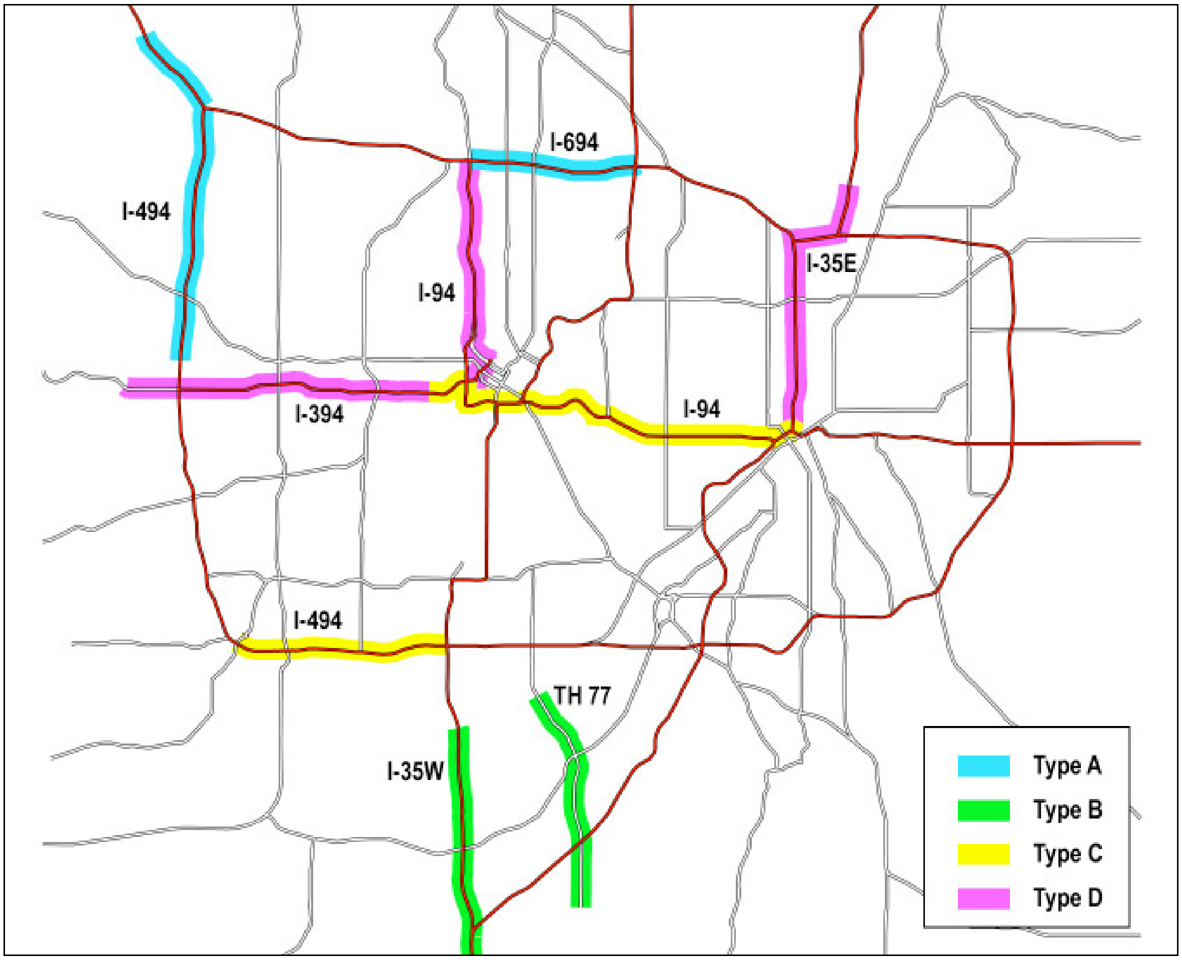


Table 5.2 Candidate Corridors for Ramp Meter Evaluation Versus Selection Criteria

No.	Type	Corridor	From	To	Length (Miles)	Alternate Routes	Level of Congestion	Geographic Area
1	A	I-494 (NB)	Carlson Parkway	I-94/C.R. 30	9	Vicksburg CR 61	H - L	N.W.
		I-494 (SB)	I-94/C.R. 30	Carlson Parkway	9	Vicksburg CR 61	M - L	
2	A	I-694 (WB)	I-35W	TH 252	4.5		M - L	North Central
		I-694 (EB)	TH 252	I-35W	4.5		M - L	
3	B	TH 77 (NB) (a.m. only)	C.R. 38 – 140th St.	Old Shakopee Road	6.8	I-35W	H - L	South
4	B	I-35W (NB) (a.m. only)	C.R. 46	98th St.	6	TH 77	High	South
5	C	I-94 (WB)	I-35E & Mounds	I-394/Penn.	12	Univ. Ave. Lake-Marshall	H - L	Central
		I-94 (EB)	I-394/Penn.	I-35E & Mounds	12	Univ. Ave. Lake-Marshall	H - L	
6	C	I-494 (EB)	TH 212	I-35W	7	TH 62	High	S.W.
		I-494 (WB)	I-35W	TH 212	7		High	
7	D	I-394 (WB)	TAD	C.R. 101	11	TH 55 TH 7	H - L	West Central
		I-394 (EB)	C.R. 101	TAD	11	TH 55 TH 7	H - L	
8	D	I-94 (WB)	I-394	I-694	6.4	Lyndale Central	Low	North Central
		I-94 (EB)	I-694	I-394	6.4	Lyndale Central	Low	
9	D	I-35E (NB)	C.R. 96	I-94	6.5	Rice St. (TH 49) Edgerton Ave.	M - L	East Central
		I-35E (SB)	I-94	I-694	6.5	Rice St. (TH 49) Edgerton Ave,	H - L	

Table 5.2 Candidate Corridors for Ramp Meter Evaluation Versus Selection Criteria (continued)

No.	Type	Corridor	ADT	Traffic Type	No. of Lanes	HOV Lanes/ Ramps	Geometric Constraints	Transit Route	No. of Metered Ramps
1	A	I-494 (NB)	48,500	Commuter Recreational HC (7%)	2	2 Bypass ramps	Steep Grades Auxiliary Lanes	Minor	5
		I-494 (SB)	48,500	Commuter Recreational HC (7%)	2	3 Bypass ramps	Steep Grades Auxiliary Lanes	Minor	5
2	A	I-694 (WB)	80,000	Commuter Recreational HC (7%)	3	Bypass ramps	Auxiliary Lanes	Minor	9
		I-694 (EB)	80,000	Commuter Recreational HC (7%)	3	Bypass ramps	Auxiliary Lanes	Minor	10
3	B	TH 77 (NB) (a.m. only)	48,500	Commuter HC (2.5%)	3	Bypass at every ramp	River Crossing	MVTA Major No AVL Buses	6
4	B	I-35W (NB) (a.m. only)	51,500	Commuter HC (6.7%)	2 + HOV	HOV Lanes + 3 bypasses	River Crossing	Major No AVL Buses	5
5	C	I-94 (WB)	128,500	Commuter HC(5.7%)	3	Bypass ramps	Tunnel River Bridge	Major	13
		I-94 (EB)	128,500	Commuter HC(5.7%)	3	Bypass ramps	Tunnel River Bridge	Major	12
6	C	I-494 (EB)			2 - 3	3 Bypass ramps			10
		I-494 (WB)			2 - 3	2 Bypass ramps			8
7	D	I-394 (WB)	74,000	Commuter HC (3.2%)	2 3	HOV lanes + 5 Ramps	Bottleneck	Major	16
		I-394 (EB)	74,000	Commuter HC (3.2%)	2 3	HOV Lanes + 10 ramps	Bottleneck	Major	13
8	D	I-94 (WB)	63,000	Commuter HC (3.8%)	4	2 Bypass ramps	Auxiliary Lanes	Major	3
		I-94 (EB)	63,000	Commuter HC (3.8%)	4	2 Bypass ramps	Auxiliary Lanes	Major	5

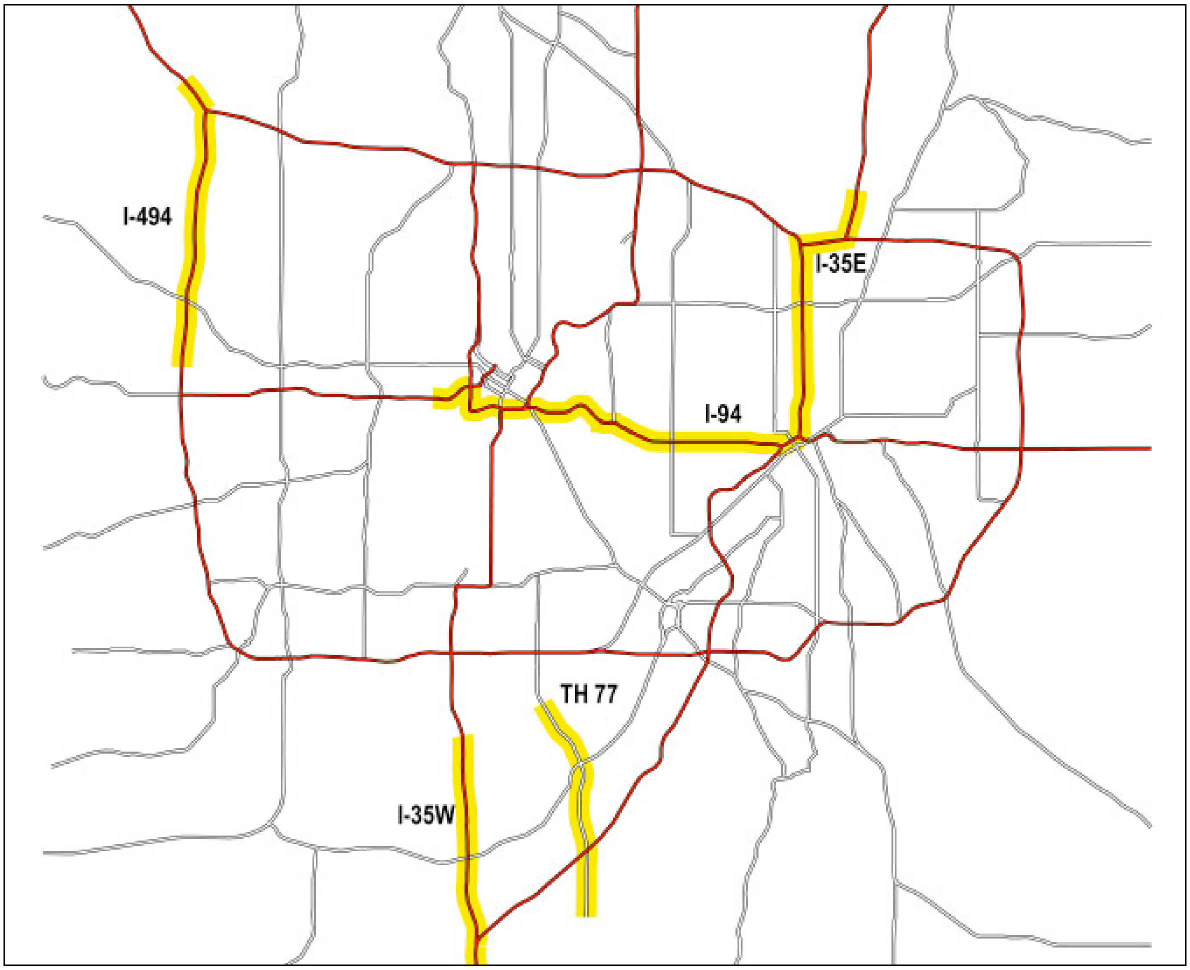
Table 5.2 Candidate Corridors for Ramp Meter Evaluation Versus Selection Criteria (continued)

No.	Type	Corridor	ADT	Traffic Type	No. of Lanes	HOV Lanes/ Ramps	Geometric Constraints	Transit Route	No. of Metered Ramps
9	D	I-35E (NB)	62,500	Commuter HC (4.3%)	3	1 Bypass ramp & shoulder lanes		Minor	9
		I-35E (SB)	62,500	Commuter HC (4.3%)	3	No bypass ramps – shoulder lanes		Minor	6

Key:

Freeway Type	Attributes
A	Freeway section representing the I-494/I-694 beltline, commuter, heavy commercial and recreational traffic (suburb-to-suburb).
B	Radial freeway outside the beltline, major geometric constraint (e.g., river bridge) presenting limited alternate routes.
C	Intercity connector with even directional split.
D	Radial freeway inside the beltline.

Figure 5.2 Twin Cities Corridors Selected for Detailed Evaluation



through Friday of the evaluation period. Subsets will be created for Monday and Friday data and for Tuesday through Thursday data. The Tuesday through Thursday data are the primary data collection days, and will be used to provide statistically valid data. Travel time data will be collected during the morning and afternoon peak periods for approximately 3.5 hours per peak period. Ramp operational studies will be conducted during hours the ramps are metered; this varies depending on the particular ramp.

5.2.1 Field Data Collection Schedule

A preliminary field data collection schedule is shown in Table 5.3. The schedule applies to those elements of the data collection which will be implemented by the consultant team during the course of the evaluation period, including ramp observations in which specific ramps will be monitored, floating car studies in which travel times across specific corridors are measured, and traffic flow data will be collected along alternate routes by means of tube counts. This schedule applies to both the "with" and "without" ramp metering conditions. Other data will be supplied by the routine automated data collection systems used by Mn/DOT to monitor traffic flow, such as freeway loop detectors. These systems are always in operation and Mn/DOT will provide the data from these systems to the consultant team for analysis.

Table 5.3 Field Data Collection Schedule

	Travel Time Data Collection					Volume and Ramp Study
Week of:	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	
Sept. 11	I-494	I-35W	I-494	I-35W	I-494	I-494
Sept. 18	I-35E	I-94	I-35E	I-94	I-35E	I-35E
Sept. 25	I-35W	I-494	I-35W	I-494	I-35W	I-35W
Oct. 2	I-94	I-35E	I-94	I-35E	I-94	I-94
Oct. 9 (1)						
Oct. 16 (2)	I-94	I-94	I-94	I-94	I-94	I-94
Oct. 23	I-494	I-35W	I-494	I-35W	I-494	I-494
Oct. 30	I-35E	I-94	I-35E	I-94	I-35E	I-35E
Nov. 6	I-35W	I-494	I-35W	I-494	I-35W	I-35W
Nov. 13	I-94	I-35E	I-94	I-35E	I-94	I-94

Notes:

1. On October 9 the public will be notified that the ramp meters will be shutoff beginning October 16. No data will be collected this week.
2. On October 16 the ramp meters will be shutoff. Data collection will be concentrated on I-94 during this week, and repeated along this corridor during the last week of the evaluation so that traveler behavioral change over the course of the ramp meter deactivation period can be assessed.

5.2.2 Evaluation Objectives

The following five objectives will be used to evaluate and quantify the transportation system impacts with and without the ramp metering system:

- Assess traffic flow impacts;
- Assess travel time impacts;
- Assess ramp impacts;
- Assess safety impacts; and
- Assess transit impacts.

Specific measures of effectiveness and their corresponding data sources are presented for each of the five evaluation objectives supporting this test plan in the sections that follow.

5.2.2.1 Objective 1: Assess Traffic Flow Impacts

This evaluation objective will examine the traffic flow impacts of the ramp metering system. Traffic volume and occupancy data from freeway mainline detector stations and volume data from alternate routes will be collected. Two different data collection methods will be used including existing freeway loop detectors and portable counting devices (road tubes). Further detail on each type of data and data source is provided below.

5.2.2.1.1 Freeway Mainline Traffic Volume and Occupancy

Data from the Mn/DOT Traffic Management Center (TMC) freeway loop detector stations will be collected along each of the corridors under evaluation. The following information pertains to freeway data:

1. Sample size:
   - Thirty-second traffic volume data per lane, 24-hours per day;
   - Data aggregated to 15-minute periods during the four-hour a.m. and four-hour p.m. peak periods;
   - Four-hour peak periods selected to allow analysis of any peak-period spreading;
   - Data aggregated to daily totals;
   - Five days of data per week (Monday through Friday):
     - Monday and Friday (subset); and
     - Tuesday through Thursday (primary data subset).
   - Data will be collected from the detector stations within the corridor study limits.

2. Assumptions:
   - Mn/DOT TMC detector count data will be available;
   - Mn/DOT Maintenance will have the majority of detectors on study corridors operational at the beginning of the test, and will maintain them in operation throughout the test period;
   - Not all mainline detector counts are needed for the study;
   - Detector data can be downloaded remotely/electronically; and
   - Evaluator will run a daily automated check of the data.
3. Data collection methods and tools:
   - Mn/DOT TMC will download detector data files to SRF FTP site; and
   - Spreadsheet and/or database will be used to process data.

5.2.2.1.2 Alternate Route Traffic Volume – Road tubes will be used to collect traffic volume data along each of the arterial corridors under evaluation. The following information pertains to alternate route data:

1. Sample size:
   - Fifteen-minute volumes per lane during the four-hour a.m. and four-hour p.m. peak periods;
   - Daily volume totals; and
   - Five days of data per week (Monday through Friday):
     - -- Monday and Friday (subset); and
     - -- Tuesday through Thursday (subset).
2. Assumptions:
   - Collect data on arterial routes during the same period as the corresponding freeway route; and
   - Backup data collection will be done via spare portable counters and/or manual counts.
3. Data collection methods and tools:
   - Road tubes; and
   - Spreadsheet and/or database will be used to process data.

5.2.2.2 Objective 2: Assess Travel Time Impacts

This evaluation objective will examine the travel time impacts of the ramp metering system. A statistically significant sample of actual running speeds over the four freeway corridors and corresponding alternate routes will be collected. Travel times and distances will be recorded from probe vehicles driven along the corridor by members of the evaluation team. The floating car method will be used, whereby the probe vehicle driver estimates the median speed of the traffic flow by passing and being passed by an equal number of vehicles.

Four Geographic Positioning System (GPS)-equipped vehicles will be used to capture the travel time profiles at discrete intervals. One GPS-equipped vehicle will be used on each freeway (and alternate route) corridor. Three additional vehicles will be equipped with traditional distance measuring instruments (Jamar) to gain enough travel time data to produce results meeting a 95 percent confidence interval. The specified error will be +/-two mph for freeways, and +/-one mph on the alternate routes. Data will be collected in both directions of travel along the corridor.

The travel time runs for two corridors, I-494 and I-35E, will have a start and end point that represents a "virtual" home to work trip. This will allow the CS team to plot the sample travel time data on a map, providing a useful tool for conveying the travel time data to the public.

In selecting the alternate route travel time, traffic flow patterns were examined to identify routes that would be used during periods of congestion on the freeway. An overview of the travel time routes along each of the corridors is provided below:

- **I-494 Corridor –** This corridor serves traffic coming from outside the Twin Cities Metropolitan Area, as well as commuter traffic between the residential area on the north end of the corridor and employment destinations on the southern end. Travel time runs will be conducted between I-94/County Road 30 in Maple Grove and the Carlson Towers in Minnetonka. Traffic flow has a directional split with southbound congestion occurring in the a.m. peak period and northbound congestion occurring in the p.m. peak period. There are two alternate routes for this corridor. To the west of I-494 Vicksburg Lane, Weaver Lake Road and Dunkirk Lane are used between I-94/County Road 30 and Carlson Parkway. Various roadways (mainly County Road 61) are used for the route primarily to the east of I-494 between I-94/County Road 30 and Carlson Parkway. This corridor is shown in Figure 5.3.

- **I-35W Corridor –** This corridor serves commuter traffic between the residential communities south of the Minnesota River (e.g., Burnsville and Lakeville) and employment destinations north of the river. Travel time runs will be conducted between Old Shakopee Road in Bloomington and County Road 46 (162nd Street West) in Lakeville. Traffic flow has a heavy directional split with northbound congestion occurring in the a.m. peak period. Data will only be collected in the northbound (a.m. period) along this route. The Minnesota River crossing creates a bottleneck in this corridor. The alternate route for this corridor is Trunk Highway (TH) 77 between Old Shakopee Road in Bloomington and County Road 38/140th Street in Apple Valley. This corridor is shown in Figure 5.4.

- **I-94 Corridor –** This corridor serves traffic demand between downtown Minneapolis and downtown St. Paul. The western end of the travel time runs will pass through the Lowry Hill Tunnel with a turn-around made via I-394 and Penn Avenue in Minneapolis. The eastern turn-around will be at Mounds Boulevard in St. Paul. Traffic flow is primarily bi-directional with congestion experienced in both directions during both the

Figure 5.3 I-494 Corridor

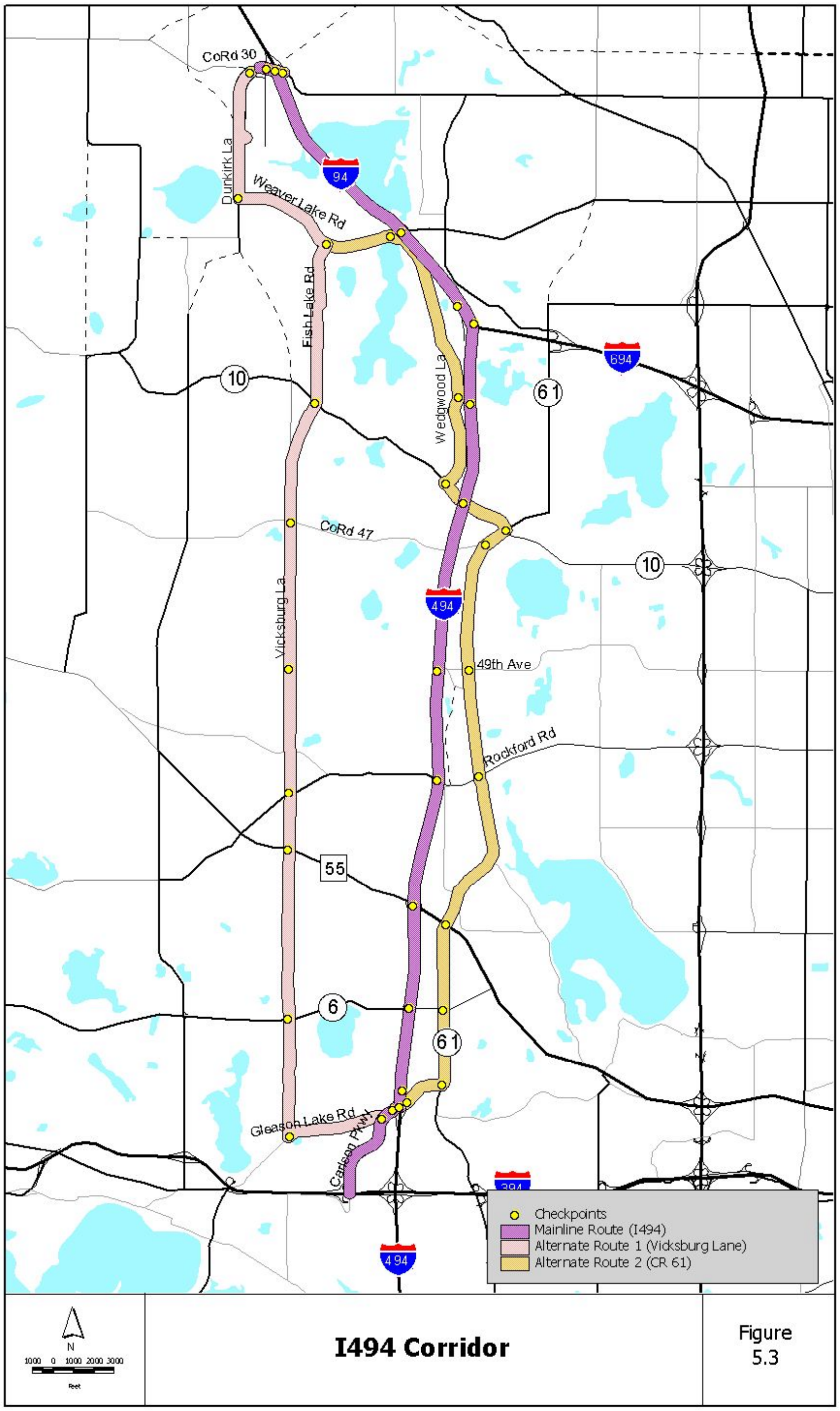
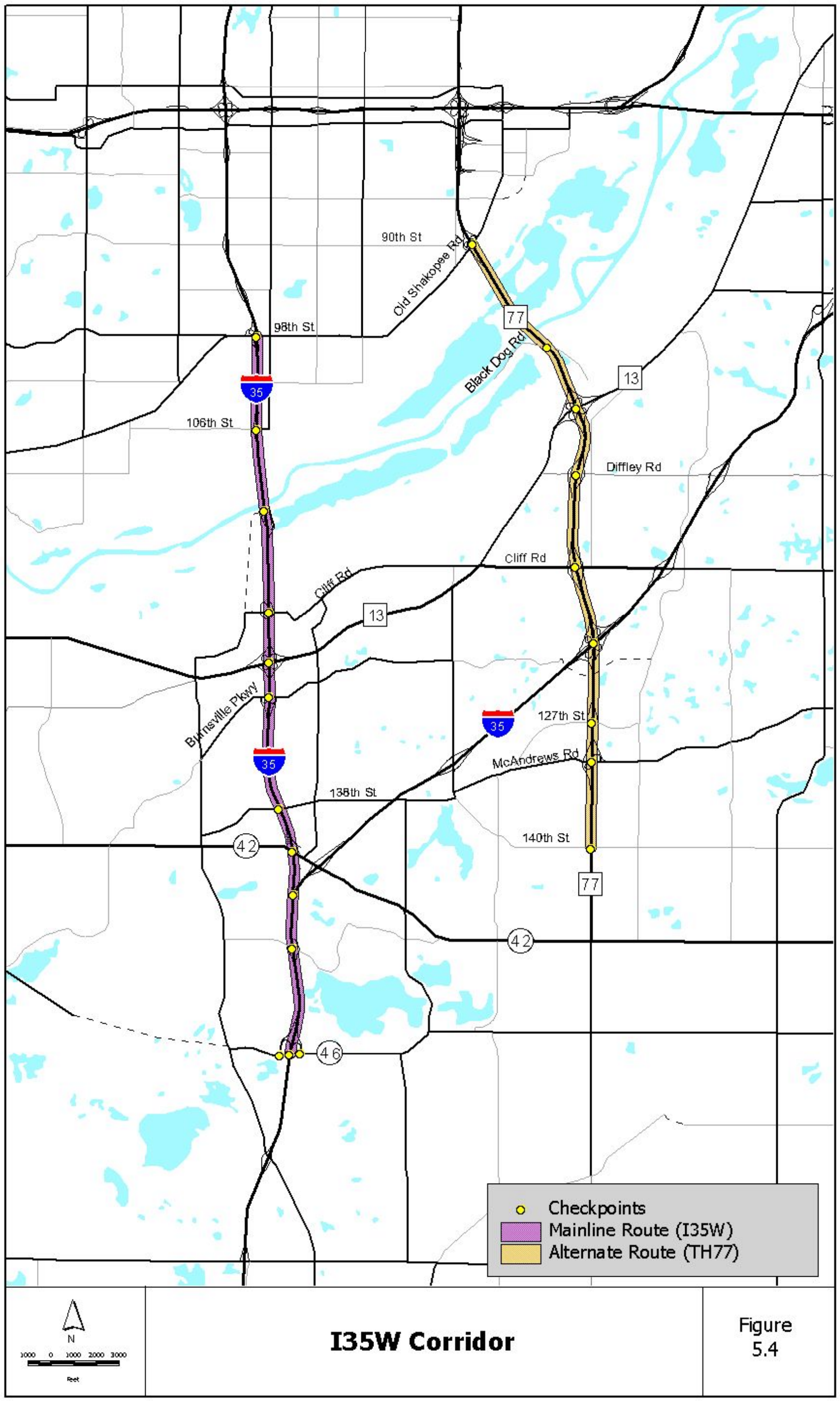


Figure 5.4 I-35W Corridor



morning and afternoon peak periods. There are two alternate routes for this corridor. To the north of I-94, University and Washington Avenue are used between Cedar Avenue in Minneapolis and Mounds Boulevard in St. Paul. To the south of I-94, Franklin, West River Parkway and Marshall Avenue are used between Cedar Avenue in Minneapolis and Rice Street/University Avenue in St. Paul. This corridor is shown in Figure 5.5.

- **I-35E Corridor –** This corridor serves commuter traffic between the northern residential communities and various employment destinations further south. Travel time runs will be conducted between County Road 96 in White Bear Lake and Wacouta Street in downtown St. Paul. Traffic flow has a directional split with southbound congestion occurring in the a.m. peak period and northbound congestion occurring in the p.m. peak period. There are two alternate routes for this corridor. To the west of I-35E, Rice Street (TH 49) is used between County Road 96 and University Avenue. Primarily to the east of I-35E, Edgerton Street and Centerville Road are used between County Road 96 and 7th Street West in downtown St. Paul. This corridor is shown on Figure 5.6.

Further detail on the travel time data collection approach is provided below.

1. Sample size:
   - The first step in determining the sample size is to identify the desired level of accuracy. The bounds of statistical error vary depending on the application; examples are listed below based on the Institute of Transportation Engineers (ITE) Traffic Engineering Manual – Page 95:
     - Transportation planning applications typically allow for speed data accuracy of +/-three mph to +/-five mph;
     - Traffic operations applications typically allow for speed data accuracy of +/-two mph to +/-four mph; and
     - Before and after evaluation studies typically allow for speed data accuracy of +/-one mph to +/-three mph.
   - A Confidence Interval of 95 percent is typically used for traffic studies (source ITE Traffic Engineering Manual – Page 96); and
   - Based on the information presented above and in the list of assumptions below, a sample size of 21 travel time runs in the a.m. period and 21 runs in the p.m. will be required in order to obtain a statistically significant sample size.
2. Assumptions:
   - Corridors range from approximately six to 12 miles in length;
   - Four-hour morning period is 5:00 to 9:00 a.m.;
   - Four-hour afternoon period is 3:00 to 7:00 p.m.;
   - Data will be collected Monday through Friday:
     - Monday and Friday (subset); and
     - Tuesday through Thursday (subset).

Figure 5.5 I-94 Corridor

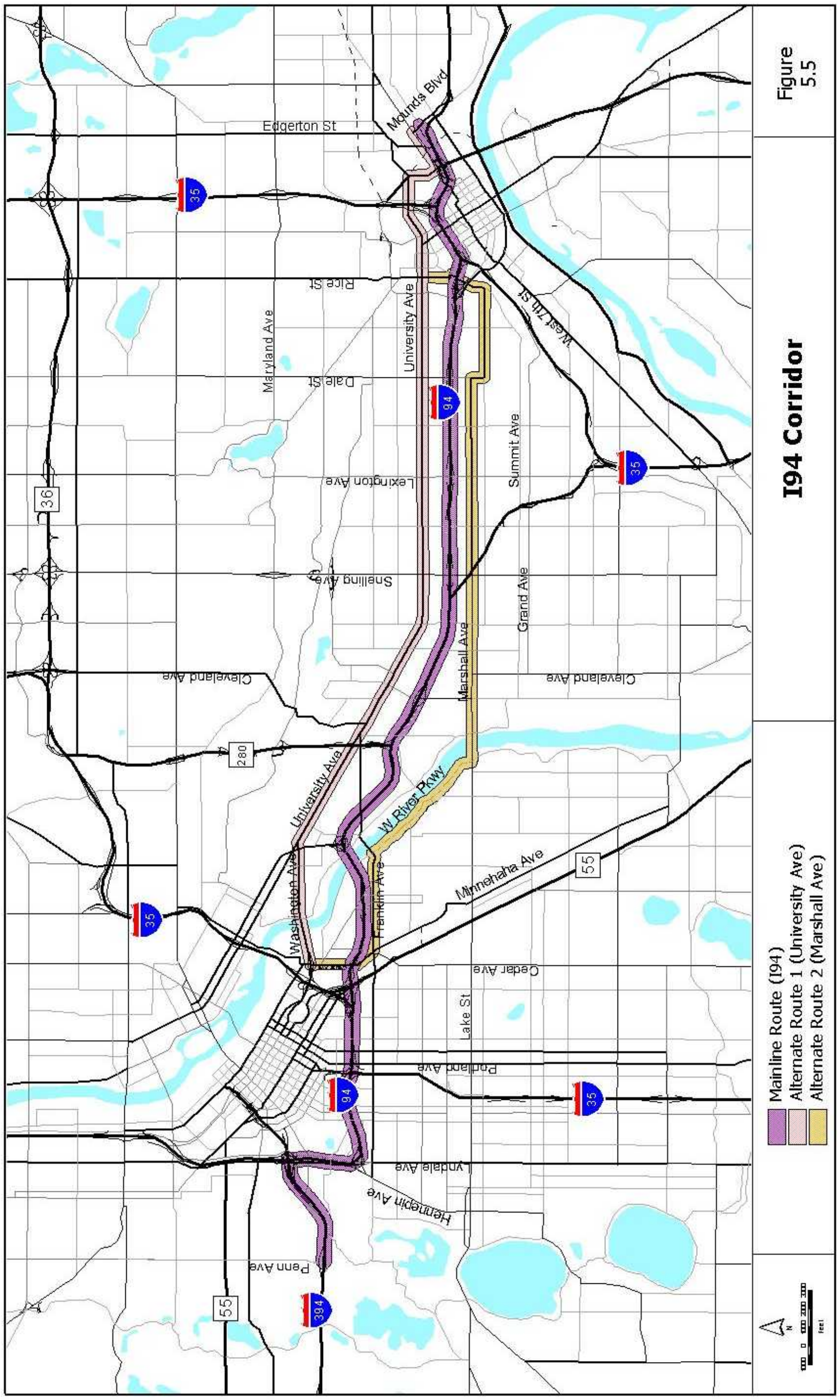
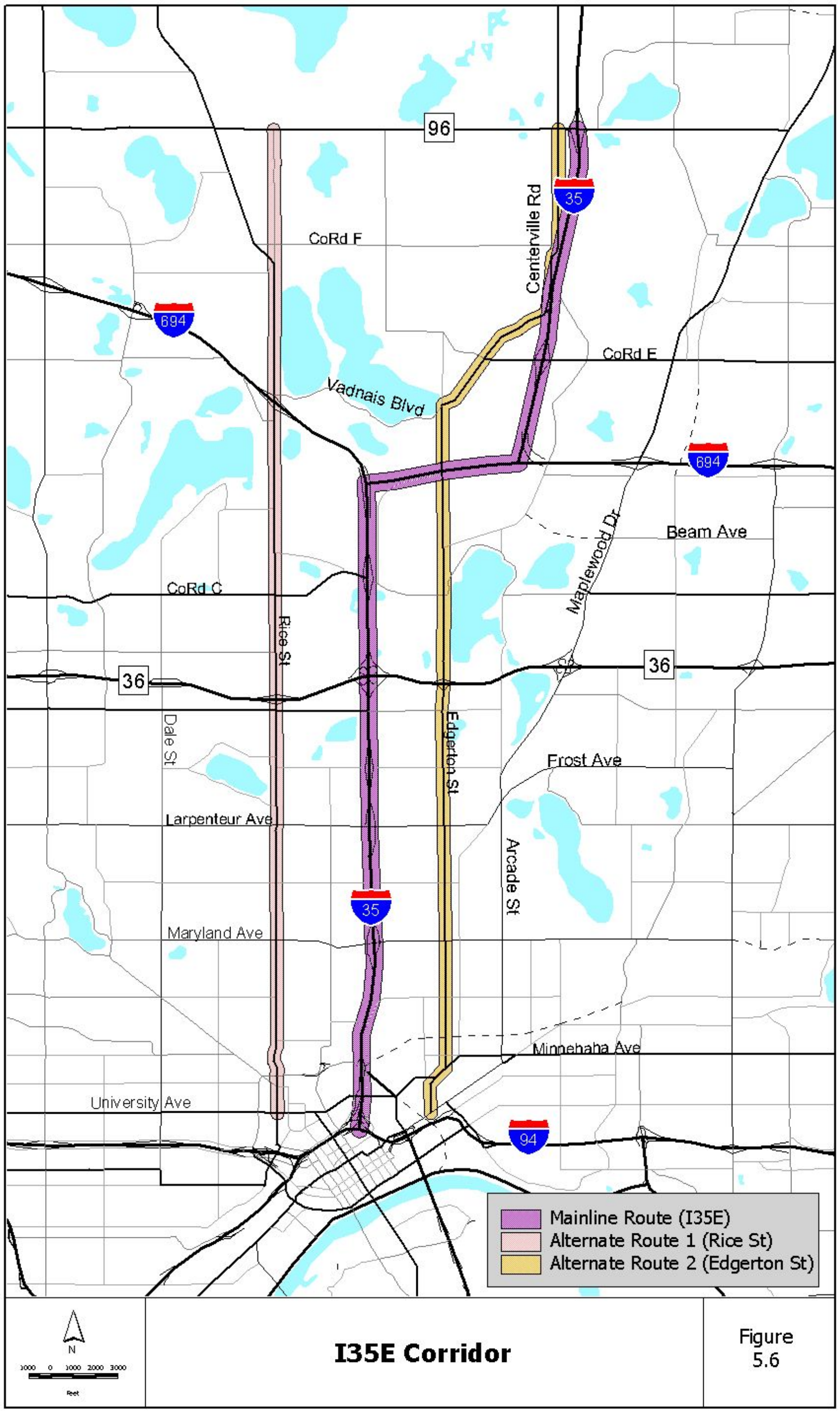


Figure 5.6 I-35E Corridor



- Four weeks with ramp metering and four weeks without;
- Average one run per hour;
- Average freeway speed will vary more than 20 mph between runs;
- Average alternate route speed will vary 10 mph between runs;
- Bound on error of +/-two mph for average freeway speed; and
- Bound on error of +/-one mph for average alternate route speed.

3. Data collection methods and tools:
   - Floating Car Method will be used to collect travel time data. With this method the probe vehicle driver estimates the median speed by passing and being passed by an equal number of vehicles.
   - GPS data collection will be used to collect travel time data in four of the probe vehicles
   - Jamar™ equipment data collection will be used to collect travel time data in three of the probe vehicles. Note that one of the vehicles will be equipped with both GPS and Jamar™ equipment in order to compare the two data collection methods. Therefore a total of six probe vehicles are available.
   - Travel time data will be collected in both the peak and non-peak direction.
   - Probe vehicle drivers will record weather, pavement conditions, light conditions, construction activity, and incidents; this will enable the isolation of anomalous data which might result from a day of severe weather, or the short-term effects of the start of standard time at the end of October which falls in the middle of the "without meters" evaluation period.

5.2.2.3 Objective 3: Assess Ramp Impacts

A variety of techniques will be used to assess the operational impact of ramp metering at freeway on-ramps. Ramp volume data (ramp merge detector data) and ramp meter turn-on times are readily available from the TMC system. Data will be collected from the ramps listed in Table 5.4.

1. Sample size:
   - Collect data for every ramp within the defined test corridors;
   - Five days of peak-period counts per site; and
   - All data will be collected in 15-minute intervals.
2. Assumptions:
   - Visual observation of ramp from persons in-field; and
   - Field observer will record ramp meter start-up/shut-off time.

Table 5.4. Ramps Selected for Manual Field Data Collection

Corridor	Ramp Description	A.M. Period	P.M. Period	Both Periods
I-494 Corridor	Weaver Lake Road to eastbound I-94	X		
	Bass Lake Road to northbound I-494		X	
	Bass Lake Road to southbound I-494	X		
	Rockford Road to northbound I-494		X	
	Rockford Road to southbound I-494	X		
	TH 55 to northbound I-494		X	
	TH 55 to southbound I-494	X		
	County Road 6 to northbound I-494		X	
	County Road 6 to southbound I-494	X		
	Carlson Parkway to northbound I-494		X	
I-35W Corridor	County Road 42 to northbound 35W	X		
	Burnsville Parkway to northbound 35W	X		
	Eastbound TH 13 to northbound 35W	X		
	Westbound TH 13 to northbound 35W	X		
	Cliff Road to northbound 35W	X		
	106th Street to northbound 35W	X		
I-94 Corridor	Hennepin Avenue to eastbound 94			X
	Lyndale Avenue to eastbound 94			X
	5th Avenue to eastbound 94		X	
	6th Street to eastbound 94		X	
	Cedar Avenue to eastbound 94		X	
	Riverside Avenue to eastbound 94		X	
	Huron Street to eastbound 94		X	
	Cretin Avenue to eastbound 94		X	
	Snelling Avenue to eastbound 94		X	
	Lexington Parkway to eastbound 94		X	
	Dale Street to eastbound 94		X	
	Marion Street to eastbound 94		X	
	Jackson Street to eastbound 94		X	
	Broadway Street to eastbound 94		X	
	Mounds Boulevard to westbound 94			X
	University Avenue to westbound 94			X
	12th Street/Wabasha to westbound 94			X
	Marion Street to westbound 94			X
	Dale Street to westbound 94			X
	Lexington Parkway to westbound 94			X
	Snelling Avenue to westbound 94			X
	Vandalia Street to westbound 94			X
	Highway 280 to westbound 94			X

Table 5.4. Ramps Selected for Manual Field Data Collection (continued)

Corridor	Ramp Description	A.M. Period	P.M. Period	Both Periods
	Huron Street to westbound 94			X
	25th Avenue to westbound 94			X
	Hiawatha Avenue to westbound 94			X
	35W to westbound 94			X
	4th Avenue to westbound 94			X
I-35E Corridor	Broadway Street to northbound 35E		X	
	Pennsylvania Avenue to northbound 35E		X	
	Maryland Avenue to northbound 35E		X	
	Larpenteur Avenue to northbound 35E		X	
	Roselawn Avenue to northbound 35E		X	
	Eastbound Highway 36 to northbound 35E		X	
	Westbound Highway 36 to northbound 35E		X	
	Little Canada Road to northbound 35E		X	
	Little Canada Road to southbound 35E	X		
	Westbound highway 36 to southbound 35E	X		
	Eastbound highway 36 to southbound 35E	X		
	Roselawn Avenue to southbound 35E	X		
	Wheelock Parkway to southbound 35E	X		
	Maryland Avenue to southbound 35E	X		

5.2.2.3.1 Ramp Queue Length and Delay

Manual field observations will be used to collect ramp queue length and delay data. The following information pertains to this data collection effort:

Data collection methods and tools:

- Jamar equipment to record when vehicles enter and when vehicles exit the ramp queue. Two observers will be required per ramp:
  - First observer will record vehicles entering ramp queue. (This observer will also note the time that the ramp queue backs into the intersection, see Section 5.2.2.3.4.)
  - Second observer will record vehicles exiting the ramp queue. (This observer will also record the number of ramp meter violators, see Section 5.2.2.3.2.)
- Jamar software will be used to calculate queue length and vehicle delay at the ramp.

5.2.2.3.2 HOV Lane Usage and Ramp Meter Violations

Manual field observations will be used to collect ramp meter violations. The same observer that is recording the number of vehicles exiting the ramp queue will count the number of violators.

TMC loop detector station data will be used to obtain the number of vehicles using the ramp's HOV bypass (it should be noted that even after the meters are shut off, there may still be some travel advantage in using the HOV bypasses at certain locations).

5.2.2.3.3 Frequency of the Ramp Queue Backing into Intersection

Manual field observations will be made to measure the length of time that a ramp queue backs into the adjacent intersection. The following information pertains to this data collection effort:

Data collection methods and tools:

- The same observer that is counting the number of vehicles entering the ramp queue will note the occurrences of ramp queues backing into the intersection.

5.2.2.3.4 Quality of Merge

Traffic volumes and average traffic speeds will be analyzed to determine the quality of traffic merging onto the freeway. Approximate traffic speeds will be calculated from the freeway occupancy data. As a reasonableness check, the occupancy-derived speeds will be compared to the speeds captured during the travel time runs. The volume and speed data will be used to assess the "quality of merge" at each of the on-ramps along the corridor. In addition, the freeway volumes can be analyzed on a lane-by-lane basis; an even distribution of volumes across all lanes suggests a higher quality of merge. The following information pertains to this data collection effort:

Data collection methods and tools:

- TMC entrance ramp volumes and occupancy (15-minute intervals);

- TMC mainline detector volumes and occupancy (upstream and downstream of ramp, lane-by-lane in 15-minute intervals)

- Collect data during same periods and locations as the ramp queue delay study.

5.2.2.4 Objective 4: Assess Safety Impacts

This evaluation objective will examine the safety impacts of the ramp metering system. The TMC incident logs will be reviewed to collect the number and duration of incidents on those freeway corridors selected for evaluation. In addition, the automated Mn/DOT crash log system will be reviewed to collect the number of crashes within the Twin Cities Metropolitan Area. This data will be used to directly measure the number of crashes in the "with ramp metering" and "without ramp metering" condition on a systemwide basis. In addition, historical crash data will be collected and analyzed as described below.

1. Sample size:
   - Collect TMC incident log data along corridors within study area;
   - TMC documents number and duration of incidents on freeways that are monitored by the traffic management system;
   - One-month lag time before incident logs are recorded in the database;
   - Collect metro-wide crash data from Mn/DOT's automated crash log system;
   - Four to six-week lag time before crash records are in the database;
   - "With ramp metering" four-week period data available early December;
   - "Without ramp metering" four-week period data available early January;
   - Collect crash data for entire freeway system;
   - Collect historical crash data;
   - Previous two years; and
   - Do not include data from ramps if metering was implemented within the two-year period.
2. Tools:
   - TMC incident log for four study corridors; and
   - Mn/DOT crash log system for full Twin Cities Metropolitan Area.
3. Analysis:
   - Separate data by freeway and parallel arterial segment;
   - Separate data for metered vs. unmetered freeways;
   - Identify crashes by type (rear-end, side-swipe, etc.);
   - Separate data by crash severity (PDO, injury, fatality);
   - Separate data by time of day: Crash data while meters are in operation versus data in the off-peak, while meters are off-line;
   - If possible separate data by speed range and level of congestion (allows correlation between congestion and number of crashes);
   - Ramps – examine data for ramp segments before and after meter; and
   - Arterials – examine data for cities that have freeway segments with ramp metering or diversion routes.

5.2.2.5 Objective 5: Assess Transit Impacts

This objective examines the impacts to transit caused by the ramp metering system. Numerous data sources will be used and performance measures will be collected. No transit data will be collected on the I-494 Corridor due to a lack of suburb-to-suburb transit service.

5.2.2.5.1 Transit Vehicle Travel Times

Transit vehicle travel times will be collected on a sample of transit routes running on the mainline and alternate travel routes on two to three of the four selected corridors. Travel time data collection has been confirmed for I-94 and I-35E. Discussions are underway with Metro Transit and Minnesota Valley Transit Authority as to their resource availability and willingness to provide travel times on I-35W.

Travel times on the following sample of routes will be collected over a one-week period.

I-94 Corridor	I-35E Corridor	I-35W Corridor
94BCD	35ABC	35MNRTV
16	270	37W
21	271	431
50	860	77PSV
	210	77AST
	212	442
	213	

Metro Transit will use AVL-equipped buses to collect this data on I-94. Metropolitan Council will use radio checks and field observations to collect this data on I-35E. Minnesota Valley Transit Authority will use radio checks to collect this data on I-35W.

1. Sample size:
   - A sampling of transit routes on the mainline and/or alternate travel routes within three of the four selected corridors;
   - Sample selection is dependent upon the availability of AVL-equipped transit vehicles or transit provider provided data collection personnel;
   - Selected routes are subject to change based upon data availability;
   - Transit vehicle travel times while within the corridor;
   - The a.m. and p.m. peak periods; and
   - Travel time data will be collected for one week within each of the three selected corridors.
2. Assumptions:
   - Request that Metro Transit use selected transit routes, to the extent possible, with AVL-equipped transit vehicles; and

- Request that Metro Transit and the Metropolitan Council provide personnel to conduct manual collection of travel time data on corridors lacking sufficient coverage of AVL-equipped transit vehicles.

3. Data collection methods and tools:
   - AVL-equipped transit vehicles;
   - Manual data collection; and
   - Extent of data collection to be determined by Metro Transit and other metro area transit providers.

5.2.2.5.2 Transit Ridership

Transit ridership data will be collected on a sample of transit routes running on the mainline and alternate travel routes on three of the four selected corridors. Ridership data collection has been confirmed for I-94, I-35E, and I-35W.

Ridership on the following sample of routes will be collected over a four-week period during the before period and a five-week period during the during period.

I-94 Corridor	I-35E Corridor	I-35W Corridor
94BCDJL	35ABC	35MNRTV
353	270	37W
355	271	431
95MU	860	77PSV
16	210	77AST
21	212	442
50	213	

Metro Transit, Metropolitan Council and Minnesota Valley Transit Authority will collect this data using both electronic farebox data and manual driver tally sheets.

1. Sample Size:
   - A sampling of transit routes on the mainline and/or alternate travel routes within the four selected corridors;
   - Sample selection is dependent on the availability of data;
   - Selected routes are subject to change based upon data availability;
   - The a.m. and p.m. peak periods; and
   - Entire study duration.

2. Assumptions:
   - Request that Metro Transit, the opt-out service providers and the contracted transit service providers provide ridership information on select routes with each corridor.
3. Data collection methods and tools:
   - Farebox data.

5.2.2.5.3 Park-and-Ride Facility Usage

Park-and-ride utilization data will be collected at a sample of facilities serving transit routes on three of the four selected corridors. Park-and-ride utilization data collection has been confirmed for I-94, I-35E, and I-35W. Discussions are still ongoing with Minnesota Valley Transit Authority on the possible expanding the I-35W sample to include additional facilities.

Utilization at the following facilities will be collected on three days over a one-week period during both the before and during periods.

I-94 Corridor	I-35E Corridor	I-35W Corridor
Woodbury Lutheran Church	Gustavus Adolphus Lutheran	Burnsville Transit Station
Christ Episcopal Church	Municipal Lot	Apple Valley Transit Station
Wooddale Recreation Center	TH61 & CRC	Palomino Hills
Faith United Methodist Church	Lake Owasso Beach	
West St. Paul Sports Complex	Rice & I-694	
	Maplewood Mall	
	Cub Foods	

The a.m. peak period auto travel time data collection personnel will manually collect this data through field observations directly after completion of the am peak travel runs.

1. Sample size and assumptions:
   - A sampling of facilities that serve transit routes traveling along three of the four selected corridors; and
   - Estimated number of facilities is 12.
2. Data collection methods and tools:
   - Park-and-ride lot occupancy count (after the a.m. peak period); and
   - Conducted by travel time personnel.

5.2.2.6 Summary of Performance Measures and Data Sources

Table 5.5 summarizes the performance measures and data sources used in the field data collection.

Table 5.5 Summary of Performance Measures and Data Sources

Objective	Performance Measures	Data Source
1 Assess traffic flow impacts	1.1 Freeway Volume	TMC Station Detectors
	1.2 Freeway Occupancy	TMC Station Detectors
	1.3 Alternate Route	Road Tubes
	Volume	Traffic Signal System Detectors
2 Assess travel time impacts	2.1 Freeway travel time	GPS- and Jamar-equipped vehicles
	2.2 Alternate route travel time	GPS- and Jamar-equipped vehicles
3 Assess ramp impacts	3.1 Ramp queue length	Jamar counter
	3.2 Ramp queue delay	Jamar counter
	3.3 HOV lane usage	Observation
	3.4 HOV lane violation	Observation
	3.5 Ramp meter violation	Observation
	3.6 Frequency of ramp queue backing into intersection	Observation
4 Assess crash impacts	4.1 Incidents on freeway corridors within study area	TMC Incident Logs
	4.2 Systemwide crashes	Mn/DOT Crash Database
5 Assess transit impacts	5.1 Mainline route travel time	AVL-equipped vehicles; field observations
	5.2 Alternate route travel time	AVL-equipped vehicles; field observations
	5.3 Ridership	Farebox
	5.4 Facility usage	Observation

5.3 Field Data Analysis Plan

During both the "with" and the "without" study periods all data collected on bad weather days (rain/snow), bad incident days, and dark vs. light conditions will be flagged. The data will then be grouped and analyzed in separate categories. If there is a statistically significant difference between groups, the data will be analyzed separately and comparisons will be made for data under similar weather/light/incident conditions. Also, the data will be analyzed across groups to identify differences in the effectiveness of ramp metering under the varying conditions. Finally, all data will be analyzed to measure the effects of peak-period spreading. The following subsets will be created with the data:

- Pavement Condition:
  - Dry,
  - Wet, and
  - Snow covered.
- Presence of Incidents along Corridor:
  - Yes, and
  - No.
- Light Condition:
  - Light (sunrise to sunset), and
  - Dark (sunset to sunrise).
- Day of Week:
  - Monday and Friday; and
  - Tuesday through Thursday.

5.4 Field Data Management Plan

5.4.1 Field Data Collection, Transfer, and Storage

The specific form of data collection, transfer, and storage will be finalized when detailed information regarding the data formats is available. An archive copy and one or more working copies of the data will be made. The original data will be stored at the SRF offices. A second archive copy will be given to Cambridge Systematics and/or Mn/DOT for storage at their offices.

The TMC detector station volume data will be electronically transmitted to SRF via the Internet File Transfer Protocol (FTP) method. Data from the previous 24-hours will be sent on a daily basis.

5.4.2 Field Data Security

There are no security issues related to the transfer of the field data that will be used in the evaluation process. The data will consist of traffic data, various log data entries, and public information. There will not be any data collected that will involve privacy considerations.

5.4.3 Configuration Control

Mn/DOT shall provide the detector station data in a binary format.

5.4.4 Documentation of External Influences

The main external influences on the system's performance will be weather, changes in the transportation system (lane closures, repairs, etc.), incidents causing traffic delays (crashes, stalled vehicles, etc.), and major events. Each of these will be continually monitored as a part of the project and will be used when possible to schedule the individual tests of the system.

5.4.5 Quality Control and Quality Assurance

A very large amount of data will be collected over the course of this evaluation. The following steps will be taken to ensure that the data is reliable and secure:

- Data collection personnel will be trained by data collection supervisors;
- Data collection supervisors will make periodic spot checks on personnel in the field;
- Data will be inspected on a daily basis to insure that the data is reasonable;
- In the event that equipment problems are encountered, backup data collection equipment will be available whenever possible;
- Make-up data collection activities will take place during week five of the before study in the event that additional data collection is required.

6.0 Test Plan for Focus Groups and Surveys

6.0 Test Plan for Focus Groups and Surveys

The primary research for this study consists of two market research tasks. As part of the qualitative market research, a set of two "with" and two "without" focus groups will be conducted to provide:

- Insights into ramp metering issues as viewed by individual travelers,
- Input to the "with" and "without" survey design process, and
- Measures of effectiveness and ways to reach non-technical audiences.

As part of the quantitative market research, a "with" and "without" set of surveys will be conducted of travelers in the Minneapolis/St. Paul metropolitan area. These surveys will include a random sample of travelers in the seven-county study area and surveys of travelers along the four area corridors for which traffic and travel time data will be collected. The survey data will be analyzed to identify:

- Changes in travel behavior and ramp usage "with" and "without" the ramp metering shutdown, and
- Changes in travelers' attitudes towards ramp meters "with" and "without" the ramp metering experiment.

6.1 Qualitative Research – Focus Groups

Travelers' perceptions of ramp meter shutdowns will be assessed though a series of focus group sessions among travelers in the Minneapolis/St. Paul metropolitan area. The objective of the qualitative research is to elicit travelers' overall reactions to the operation of ramp meters in the Twin City roadway system and the expected impact of shutting down the ramp meters on travelers' general travel patterns.

This will help to provide a better understanding of travelers' attitudes toward the operation of ramp meters in the region's freeway system including travelers' opinions about ramp meters in general, the types of benefits ramp meters may or may not provide, and how the existence of ramp meters affects route, mode, and departure time choices.

A screener questionnaire will be developed to select focus group participants. The criteria for recruiting participants in the focus groups include the following:

- Travelers who travel either during the morning peak period (6:00 to 9:00 a.m.) and/or during the afternoon peak periods (3:00 p.m. to 6:00 p.m.);

- Travelers who use one or more of the four study area corridors that will be analyzed in greater detail;

- Travelers are split into two groups depending on their freeway ramp usage patterns:
  - Heavy users: Six or more one-way trips per week, or
  - Light users: Less than six one-way trips per week.

Other criteria include the recruitment of respondents who are 18 years or older, travelers with and without a convenient alternate route, respondents living in urban and suburban communities, and a mix of male and female respondents across different age and income categories.

During each focus group session, the moderator will introduce topics, probe comments, and elicit reactions from all of the participants. The moderator will maintain a non-directive style of interviewing to avoid biasing any discussions. Participants will be encouraged to speak freely, interact, and offer disagreeing opinions whenever possible on each of the issues. The sessions will be conducted in a modern focus group facility with a one-way mirror to permit the observation of participants by members of the Technical and Advisory committees and Mn/DOT staff. An attempt will be made to over-recruit participants to ensure that eight to 10 individuals will actually arrive at each focus group.

The discussion topic guide that will be developed will include the following general topics for discussion during each focus group:

- Introduction by the moderator of the purpose of the discussion and the ground rules for participation in the discussion;

- General perceptions toward ramp meters;

- Evaluation of ramp meter performance and measures of effectiveness;

- Expectations for ramp meter shutdown; and

- Information needs for the ramp meter shutdown.

Tasks and deliverables in this effort include:

1. Development of a telephone screener questionnaire to select participants in the "with" focus groups.

2. Preparation of discussion topic guides to guide the discussion during the "with" and "without" focus group sessions.

3. Solicitation of input and approval from the Advisory and Technical committees and Mn/DOT for both the "with" and "without" focus groups.

4. Recruitment of a representative sample of travelers to participate in the "with" and "without" focus groups.

5. Moderation of two "with" and two "without" focus groups split among high-frequency ramp meter users (travel through ramp meters at least six times per week) and low-/ medium-frequency users.

6. A technical memorandum summarizing the results of the focus group sessions along with audio and video tapes of the group sessions will be produced following the completion of the focus groups.

6.2 Quantitative Research – Traveler Surveys

Travelers' perceptions of the ramp meter shutdown will be quantified though a set of "with" and "without" surveys among travelers in the Minneapolis/St. Paul metropolitan area. Travelers may perceive the effects of the ramp meter shutdown differently than the field data collected in other tasks would indicate. Therefore, an important element in the evaluation of the ramp meter shutdown experiment will be the measurement of travelers' attitudes both with operational ramp meters and with unrestricted ramp traffic.

The traveler surveys that are planned include a random sample of travelers in the seven-county study area and surveys of travelers along the four area corridors for which traffic and travel time data will be collected. The "with/without" analysis of traveler perceptions will help to interpret the findings of the traffic engineering measures and travel time data along each study corridor and for the study area population as a whole. The survey data will be analyzed to identify:

- Changes in travel behavior and ramp usage "with" and "without" the ramp metering shutdown, and

- Changes in travelers' attitudes towards ramp meters "with" and "without" the ramp metering experiment.

The total sample size planned for the "with ramp metering survey" is 750 observations. The "with" survey sample will be split by corridor and for the entire study area as follows:

- Random digit-dial sample for the seven-county metropolitan area (N = 250) and

- Random samples for each of the four corridors under study (N = 125 observations per corridor with N = 500 across the four corridors).

A sample size of 750 observations is also expected for the "without" survey. The distribution of the 750 observations across the random digit dial sample and the four corridor-specific random samples will be similar to the "with" survey.

During the month prior to the ramp meter shutdown, residents will be asked to provide information on travel behavior, freeway and ramp system usage, attitudes toward the effectiveness of the ramp meters, and demographic data. A similar wave of "without" surveys will be administered after the meters have been turned off for several weeks. The "without" survey design will be similar to the "with" survey, but will also include questions designed to evaluate the no-meter operational concept.

The random sample will be developed by means of random digit dialing and will include all travelers (potentially including transit riders) who travel during the peak periods. The corridor-specific samples will be based on license plate data collected at strategic locations along each of the test corridors. The sample will therefore be limited to automobile drivers and passengers in the designated corridors.

It is intended that a sufficient number of license plates will be collected once at the outset of the "with ramp metering" data collection effort to create a sample size sufficient to support both the "with ramp metering" and "without ramp metering" survey waves. If necessary, a second round of collection will occur during the "without ramp metering" phase. The target goal is to collect 72,000 license plates which, after discounting for duplicates, plates which cannot be converted into individual's telephone numbers (due to leased vehicles, etc.), and survey participation rates, should provide for a sufficient sample size. Mn/DOT will secure the assistance of the Department of Public Safety (DPS) to provide the support required to rapidly convert plates into contact information.

During discussions with the Technical and Advisory Committees, the issue of targeting some aspect of the primary research (either the qualitative or quantitative) to specific market subgroups such as commercial vehicle operators or transit riders was discussed. While it was recognized that such groups have unique concerns and issues, it was decided not to dilute the general random sample, or to disperse the overall level of effort, by specifically targeting such groups. The rationale for this decision was the fact that all vehicles and passengers will experience similar traffic conditions (since no vehicles operate on exclusive rights-of-way in the region with the exception of the HOV meter bypasses and highway diamond lanes), and therefore the conclusions which emerge from the general random samples can be applied to all travelers. In the case of the HOV lanes, traffic data will be collected on these facilities as part of the overall traffic data collection plan, and questions will be included in the random samples which address issues related to the operation of the HOV facilities. In addition, Metro Transit will be able to supplement the project's data collection plan with its own data regarding any operational impacts which its bus fleet may experience as a result of the meter shutdown.

The proposed structure for the "with" telephone survey includes the following groups of questions:

1. A set of screener questions will allocate peak-period users to each of the four corridors of interest. These questions include the identification of travel in corridor of interest; the direction of travel in the corridor; and the time of day that this trip is taking place. Respondents traveling in the peak direction between 6:00 and 9:00 a.m. and/or between 3:00 and 6:00 p.m. will be selected for the interview. Interviews with respondents working for Mn/DOT, planning agencies, media outlets, and city/county public works departments will be discontinued.

2. Characteristics of last peak-period trip on the freeway corridor. Information that will be collected includes:

   – Trip purpose and place of trip origin,
   – Date and time of trip,
   – Origin and destination (at town/suburb level and in detail),
   – Entry and exit points to the freeway of interest,
   – Total travel time,
   – Percentage of time traveled on freeway,
   – Rating of freeway congestion,
   – Vehicle occupancy and by-pass lane usage, and
   – Wait time at entrance meter and at other freeway-freeway meter(s).

3. Experience with "typical" freeway trip including the frequency of using the freeway, the percentage of time the respondents experience longer wait times at ramps and the corresponding longer total travel time.

4. A battery of attitudinal statements regarding the respondent's travel experiences in general and ramp meters in particular. Ramp-related questions will include travelers' attitudes toward ramp wait times, safety considerations, predictability of travel, and the usefulness of ramp by-pass lanes.

5. Demographic information to control for differences among respondents.

The analysis of the random sample survey and the four corridor-specific surveys will focus on "with/without" comparisons of travelers' attitudes toward travel in the Minneapolis/St. Paul metro area and their attitudes toward ramp meters in particular. The statistical analysis will aim to identify important differences by focusing on differences that are statistically significant at a 95 percent confidence level. To enhance the validity of these "with/without" comparisons the analysis will also take into account other factors that may have an impact on travelers' attitudes, such as:

- Frequency of travel during a typical week,
- Respondents' familiarity with different ramps in the area,
- The characteristics of the four freeway corridors under study,
- Differences in respondents' travel patterns, and
- Demographic characteristics of each respondent.

Tasks and deliverables in this effort include:

1. Design of the "with" and "without" survey instruments for a random sample traveler survey and for four surveys of respondents using each of the four study corridors.

2. Solicitation of input and approval from the Advisory and Technical committees and Mn/DOT for the "with" and "without" telephone survey design and the approach to survey sampling.

3. Collection of license plate numbers from automobiles along each of the four study corridors, translation to registration data, and development of user telephone number lists for each study corridor.

4. Revision of the survey content following each wave of focus groups.

5. Programming of the "with" and "without" random surveys and the four corridor-specific surveys into a computer aided telephone interview program.

6. Pre-testing of the "with" and "without" surveys.

7. Administration of the "with" and "without" telephone surveys for the random sample and the four random samples of corridor auto users.

8. Independent analyses of the "with" and the "without" surveys with two books of cross-tabulations (a total of 32 banner points) after the completion of the "with" and the "without" survey respectively.

9. A comparative statistical analysis of traveler perceptions and travel behavior between the "with" and "without" surveys and across various traveler market segments.

10. A technical memorandum summarizing each set of the survey findings and the comparative analysis highlighting changes in travelers' perceptions and travel behavior attributable to the ramp meter shutdown.

7.0 Test Plan for Benefit/Cost Analysis

7.0 Test Plan for Benefit/Cost Analysis

The benefit/cost analysis will extrapolate the focused findings from the analysis of the selected corridors and market research to produce estimates of regionwide impacts. A traditional spreadsheet benefit/cost model will be used to conduct the regional extrapolation of data and benefit/cost analysis.

This method involves the use of spreadsheet models to extrapolate data from the four selected corridors to the regional scale. All regional corridors will be classified similar to the selected corridors. Observed safety and traffic flow impacts from the selected corridors will then be applied to all ramp metered corridors according to their specific corridor type. Benefit values will be applied to the resulting impacts and will form the basis for the cost/benefit analysis. This method is advantageous in that the methodology is well accepted for conducting analysis of this type and can be applied in an expedient manner suitable to the schedule requirements. This method is limited in its ability to assess impacts on a location-by-location basis and would not completely capture some of the impacts on travel time reliability and other performance measures. This method is also limited in terms of presentation and data segmentation capabilities.

A second benefit-cost methodology may be used in the analysis of a broader set of ramp metering operating scenarios. After the "with/without" evaluation is completed, it is likely that there will be a need to investigate the role of ramp metering in optimizing system efficiency. Such an investigation is currently beyond the scope of the "with/without" evaluation which looks at an all-or-nothing comparison. An analysis of ramp metering operational strategies will require estimating the effect of these strategies onto multiple diversion routes for all Twin Cities corridors, queue lengths at freeways and ramps, and other details not analyzable in a spreadsheet format.

This further investigation would employ the ITS Deployment Analysis System (IDAS) software tool. IDAS was developed for the FHWA to provide planners with the ability to evaluate various traffic management strategies, including ramp metering. The IDAS software would use outputs from the Twin Cities' regional travel demand model as inputs to the software. Field data, as well as traveler survey data, will be used to calibrate the IDAS model so that it replicates traffic conditions observed in the field. The IDAS model would then be used to investigate and analyze a broader set of ramp metering operating strategies. The IDAS methodology has the advantage of analyzing the ramp meter impacts specific to each deployment location and could also be used for analyzing additional operational scenarios following the completion of this study.

The result of this task will be a technical memorandum providing an evaluation of the regional benefits of ramp metering compared with the associated costs and negative impacts. This memorandum will be supported by clear and useful graphical materials appropriate to a varying range of stakeholders and the public.

8.0 Test Plan for Secondary Research

8.0 Test Plan for Secondary Research

The purpose of this task is to review and summarize other relevant research regarding the benefits and costs of ramp metering and to identify ramp metering strategies employed in other comparable metropolitan areas.

In this task, the CS team will review, verify, and validate a currently unpublished Texas Transportation Institute (TTI) ramp meter comparison study. The CS team will identify any gaps in the TTI study, and make whatever adjustments are required to reflect the most current information regarding:

- A comparison of Minnesota's ramp metering system to other deployments in metropolitan areas across the country, including the total number of ramp meters, the type of deployment (pre-set, traffic actuated, centrally controlled), hours of operation, ramp configuration strategies (with or without HOV lanes, etc.), benefit-cost, environmental and safety studies undertaken, outreach and educational efforts, user feedback, and plans for expansions or new ramp metering deployments;
- A summary of the trends of ramp metering strategies and use; and
- A summary of the benefits, impacts, and costs of ramp metering from studies done across the country.

The CS team will also identify and search ITS and other transportation agency web sites and relevant domestic and international transportation trade press to find ramp metering information that is current and relevant. Trade press and databases anticipated to be searched include:

- Traffic Technology International;
- Roads and Bridges;
- The Journals of the Association of Metropolitan Planning Organizations; the Institute of Transportation Engineers (ITE) and American Public Works Association;
- U.S. DOT's electronic data library;
- U.S. DOT's ITS costs and benefits database; and
- State and other transportation agency DOT web sites.

The CS team will also interview and/or survey individuals from three sites to fill in any missing gaps in the TTI study. Alternative interview sites will be recommended by the contractor and approved by the State's project manager.

A technical memorandum will be produced summarizing the results of the secondary research.

9.0 Schedule, Meetings, and Deliverables

9.0 Schedule, Meetings, and Deliverables

The objective of this task is to ensure that a broad cross-section of stakeholders with both technical and non-technical levels of expertise participates in and guides the study to ensure that the results have credibility throughout the community.

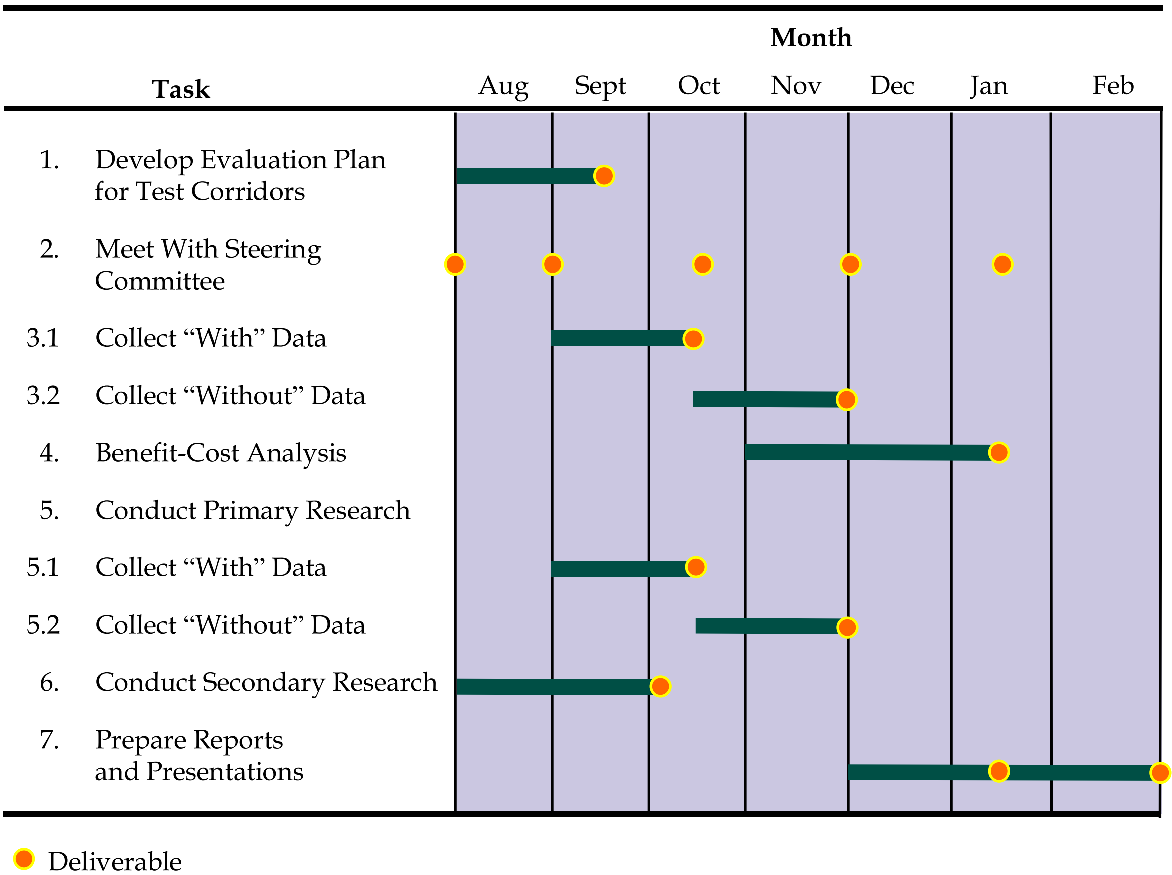
9.1 Project Schedule

The project schedule and key task deliverables are shown in Figure 9.1. As shown in the schedule, CS is committed to meeting Mn/DOT's legislatively mandated deadline of reporting the results of the study to the legislature by February 1, 2001.

The schedule proposed in Figure 9.1 is extremely aggressive and requires that Mn/DOT be an active partner with the CS team in facilitating the review and approval of project milestone submittals.

We are developing the Evaluation Plan (Task 1) during the months of August and September. The secondary research (Task 6) also may begin immediately and will be completed by early October. We have allocated September and the first half of October for the preparation and conduct of "with ramp metering" data collection, including both traffic field data (Task 3) and survey data (Task 5). It is desirable to have these two distinct data sources temporally linked. After meter shutdown, data collection will be prepared for and conducted in the second half of October and November (Tasks 3 and 5). Preparations for the cost/benefit analysis (Task 4) will begin in November and be completed by January. The draft report and legislative presentation (Task 7) will be completed by mid-January, in time for Mn/DOT and committee review and comment such that the documents will be ready for delivery to the legislature by February 1. The final report will be completed by March 1 following receipt of comments from the legislature.

Figure 9.1 Project Schedule



■ 9.2 Meetings

The CS team will meet with the committees at eight critical milestones in the project, including:

- Kickoff meeting;
- Evaluation strategy: Recommendation for the study period, corridor selection, corridor criteria and metering shut down;
- Completion of evaluation plan;
- Completion of "With ramp metering" data collection;
- Completion of "Without ramp metering" data collection;

- Completion of "top-down" overview of draft study report;
- Completion of cost/benefit analysis and draft report; and
- Completion of the secondary research.

Upon request of Mn/DOT's project manager, the CS team will participate in as many as four additional meetings, including:

- One additional set of advisory and technical committee meetings; and
- Two media briefings: The CS team will serve principally as an information resource to State/Advisory/Technical committee designated spokespeople, and be expected to provide hard copy hand-outs detailing their involvement in the study, the study design/process, and/or its results.

The CS team will supply the following materials for the meetings and presentations. An electronic and hardcopy version of all materials will be provided to the project manager.

- Presentation materials;
- Hard copy hand-outs to all attendees;
- Drafts of technical memoranda in advance of the meetings; and
- Meeting minutes.

9.3 Reports and Presentations

The objective of this task is to produce a set of clear and concise reports and presentation materials that will successfully communicate the key findings of the study to both technical and non-technical audiences.

The CS team will prepare a draft report for review by the committees at the completion of all other task activities. The report will:

1. Be highly graphical, readable, and understandable to a wide variety of audiences;
2. Include all appropriate supporting statistical data in technical appendices, resulting in a complete accounting of the study and analysis techniques;
3. Be produced in Microsoft (MS) Office;
4. Include an Executive Summary for non-technical audiences, a detailed technical analysis, and supporting appendices; and
5. Incorporate comments received on the task-specific technical memoranda.

The CS team will present a top-down summary of the evaluation results to the committees which accurately present the conclusion and supportive finding to the ramp metering study. CS will produce a final report, based on review and input received from the committees. This report will be delivered in a format suitable for posting on the Internet. CS will also prepare a PowerPoint presentation for use by the State and/or members of both committees. The presentation, and any accompanying graphics must be suitable for on-line media. The CS team will work closely with the State to explore particularly useful presentation formats and materials suitable to the intended audiences.

Deliverables include:

1. 75 copies of the Draft Final Ramp Metering Evaluation Report including an Executive Summary and supporting appendices along with an electronic copy to the Mn/DOT project manager. Due date is January 5, 2001.

2. 75 copies of the Final Ramp Metering Evaluation Report, plus one unbound camera-ready original and an electronic file in a format that is consistent with current State standards. Due date is January 24, 2001.

3. PowerPoint presentation suitable for legislative presentation. Due date is January 24, 2001. An electronic and hardcopy version of all materials will be provided to the project manager. An electronic and hardcopy version of all materials will be provided to the project manager.

Appendix H

Comparison Between "With" and "Without" Ratings for the Random Samples

Table H.1 Comparison Between "With" and "Without" Ratings for the Random Samples

	"With"		"Without"			
	Average Rating	Standard Error	Average Rating	Standard Error	Difference	t-Statistic
Feel safe from crashes on freeways	5.64	0.16	6.10	0.17	0.46	1.97
Special lane for buses/carpools	4.64	0.20	5.23	0.23	0.59	1.94
Good freeway network	5.43	0.16	5.16	0.16	-0.27	-1.19
Travel time predictable during peak	5.86	0.19	6.09	0.18	0.23	0.88
Overall satisfied with ramp meters	4.99	0.20	4.72	0.2	-0.27	-0.95
Wait time at meters is too long	**6.28**	**0.19**	**6.98**	**0.18**	**0.70**	**2.67**
Never know how long wait time will be	6.89	0.17	6.91	0.18	0.02	0.08
Safe when leaving ramp meter to merge	5.81	0.19	6.15	0.19	0.34	1.27
Ramp meters improve overall traffic	5.41	0.18	5.32	0.19	-0.09	-0.34
Cost of ramp meters is good value	4.63	0.19	4.14	0.19	-0.49	-1.82
Ramp meters shorten travel time	4.37	0.18	4.37	0.19	0.00	0.00
Ramp meters reduce car crashes	5.38	0.18	5.27	0.2	-0.11	-0.41
Ramp by-pass lanes benefit to me	4.33	0.21	4.26	0.21	-0.07	-0.24
Some meters may not be necessary	**6.38**	**0.20**	**7.88**	**0.17**	**1.50**	**5.71**
Buses/carpools should have ramp by-pass lanes	7.52	0.17	7.39	0.18	-0.13	-0.53
Sometimes need to wait even with smooth traffic	**6.72**	**0.18**	**7.52**	**0.17**	**0.80**	**3.23**
More alternative routes to avoid ramp meters	6.49	0.19	6.22	0.19	-0.27	-1.00
Ramp meters cause congestion on local streets	7.16	0.18	7.13	0.18	-0.03	-0.12
Electronic sign stating wait time	**5.85**	**0.21**	**5.13**	**0.22**	**-0.72**	**-2.37**
Tolerance for congestion	**5.27**	**0.16**	**4.54**	**0.18**	**-0.73**	**-3.03**
Amount of traffic congestion	5.82	0.20	5.45	0.19	-0.37	-1.34

Table H.2 Comparison Between "With" and "Without" Ratings for the I-494 Corridor Users

	"With"		"Without"			
	Average Rating	**Standard Error**	**Average Rating**	**Standard Error**	**Difference**	**t-Statistic**
Feel safe from crashes on freeways	5.63	0.23	5.4	0.23	-0.23	-0.71
Special lane for buses/carpools	5.54	0.30	5.64	0.32	0.1	0.23
Good freeway network	4.53	0.22	4.02	0.24	-0.51	-1.57
Travel time predictable during peak	4.83	0.24	4.94	0.24	0.11	0.32
Overall satisfied with ramp meters	**3.75**	**0.26**	**5.16**	**0.27**	**1.41**	**3.76**
Wait time at meters is too long	7.29	0.27	7.20	0.26	-0.09	-0.24
Never know how long wait time will be	7.20	0.27	6.97	0.28	-0.23	-0.59
Safe when leaving ramp meter to merge	**5.98**	**0.26**	**6.80**	**0.25**	**0.82**	**2.27**
Ramp meters improve overall traffic	**4.52**	**0.25**	**6.06**	**0.28**	**1.54**	**4.10**
Cost of ramp meters is good value	4.07	0.26	4.35	0.27	0.28	0.75
Ramp meters shorten travel time	**3.10**	**0.23**	**5.06**	**0.31**	**1.96**	**5.08**
Ramp meters reduce car crashes	4.56	0.26	5.26	0.27	*0.7*	*1.87*
Ramp by-pass lanes benefit to me	3.93	0.29	3.91	0.30	-0.02	-0.05
Some meters may not be necessary	6.26	0.29	6.89	0.28	0.63	1.56
Buses/carpools should have ramp by-pass lanes	**7.76**	**0.26**	**6.82**	**0.30**	**-0.94**	**-2.37**
Sometimes need to wait even with smooth traffic	7.50	0.24	7.79	0.25	0.29	0.84
More alternative routes to avoid ramp meters	6.88	0.27	6.90	0.25	0.02	0.05
Ramp meters cause congestion on local streets	7.31	0.26	7.14	0.27	-0.17	-0.45
Electronic sign stating wait time	**5.87**	**0.31**	**4.94**	**0.30**	**-0.93**	**-2.16**
Tolerance for congestion	6.06	0.20	5.80	0.28	-0.26	-0.76
Amount of traffic congestion on I-494	7.06	0.17	7.29	0.20	0.23	0.88

Table H.3 Comparison Between "With" and "Without" Ratings for the I-35E Corridor Users

	"With"		"Without"			
	Average Rating	**Standard Error**	**Average Rating**	**Standard Error**	**Difference**	**t-Statistic**
Feel safe from crashes on freeways	5.27	0.25	5.90	0.21	0.63	1.92
Special lane for buses/carpools	5.04	0.30	5.57	0.31	0.53	1.23
Good freeway network	4.87	0.22	5.17	0.24	0.30	0.92
Travel time predictable during peak	**4.94**	**0.24**	**6.05**	**0.26**	**1.11**	**3.13**
Overall satisfied with ramp meters	4.24	0.25	4.02	0.25	-0.22	-0.62
Wait time at meters is too long	**6.61**	**0.27**	**7.60**	**0.26**	**0.99**	**2.63**
Never know how long wait time will be	6.97	0.27	6.91	0.27	-0.06	-0.15
Safe when leaving ramp meter to merge	5.31	0.28	5.70	0.27	0.39	1.01
Ramp meters improve overall traffic	4.83	0.27	4.99	0.25	0.16	0.43
Cost of ramp meters is good value	4.09	0.27	3.82	0.25	-0.27	-0.73
Ramp meters shorten travel time	3.55	0.24	3.95	0.27	0.40	1.12
Ramp meters reduce car crashes	4.53	0.27	4.97	0.27	0.44	1.17
Ramp by-pass lanes benefit to me	3.58	0.27	3.51	0.28	-0.07	-0.17
Some meters may not be necessary	**6.26**	**0.27**	**7.88**	**0.26**	**1.62**	**4.32**
Buses/carpools should have ramp by-pass lanes	6.74	0.26	6.96	0.28	0.22	0.57
Sometimes need to wait even with smooth traffic	**7.34**	**0.26**	**8.26**	**0.23**	**0.92**	**2.66**
More alternative routes to avoid ramp meters	6.84	0.27	7.11	0.27	0.27	0.71
Ramp meters cause congestion on local streets	7.23	0.25	7.52	0.26	0.29	0.81
Electronic sign stating wait time	5.36	0.30	5.48	0.33	0.12	0.27
Tolerance for congestion	**6.98**	**0.17**	**4.85**	**0.25**	**-2.13**	**-7.06**
Amount of traffic congestion on I-35E	5.79	0.20	6.29	0.21	0.50	1.72

Table H.4 Comparison Between "With" and "Without" Ratings for the I-35W Corridor Users

	"With"		"Without"			
	Average Rating	**Standard Error**	**Average Rating**	**Standard Error**	**Difference**	**t-Statistic**
Feel safe from crashes on freeways	5.39	0.21	5.53	0.23	0.14	0.45
Special lane for buses/carpools	6.36	0.31	6.35	0.33	-0.01	-0.02
Good freeway network	4.52	0.22	4.71	0.22	0.19	0.61
Travel time predictable during peak	5.21	0.27	5.83	0.27	0.62	1.62
Overall satisfied with ramp meters	4.06	0.25	3.99	0.25	-0.07	-0.20
Wait time at meters is too long	**7.15**	**0.25**	**7.87**	**0.23**	**0.72**	**2.12**
Never know how long wait time will be	6.99	0.27	6.96	0.24	-0.03	-0.08
Safe when leaving ramp meter to merge	**5.14**	**0.26**	**6.54**	**0.23**	**1.4**	**4.03**
Ramp meters improve overall traffic	4.75	0.27	5.16	0.27	0.41	1.07
Cost of ramp meters is good value	4.08	0.28	4.28	0.27	0.2	0.51
Ramp meters shorten travel time	3.72	0.27	3.69	0.29	-0.03	-0.08
Ramp meters reduce car crashes	**4.19**	**0.27**	**4.93**	**0.27**	**0.74**	**1.94**
Ramp by-pass lanes benefit to me	**3.98**	**0.31**	**3.14**	**0.27**	**-0.84**	**-2.04**
Some meters may not be necessary	**5.62**	**0.29**	**7.44**	**0.26**	**1.82**	**4.67**
Buses/carpools should have ramp by-pass lanes	6.74	0.30	7.09	0.29	0.35	0.84
Sometimes need to wait even with smooth traffic	**7.29**	**0.27**	**8.61**	**0.19**	**1.32**	**4.00**
More alternative routes to avoid ramp meters	7.46	0.28	6.94	0.27	-0.52	-1.34
Ramp meters cause congestion on local streets	7.97	0.25	8.19	0.21	0.22	0.67
Electronic sign stating wait time	5.22	0.32	5.25	0.30	0.03	0.07
Tolerance for congestion	**5.40**	**0.19**	**4.43**	**0.25**	**-0.97**	**-3.09**
Amount of traffic congestion on I-35E	**6.98**	**0.19**	**6.34**	**0.20**	**-0.64**	**-2.32**

Table H.5 Comparison Between "With" and "Without" Ratings for the I-94 Corridor Users

	"With"		"Without"			
	Average Rating	**Standard Error**	**Average Rating**	**Standard Error**	**Difference**	**t-Statistic**
Feel safe from crashes on freeways	5.42	0.22	5.28	0.24	-0.14	-0.43
Special lane for buses/carpools	4.41	0.30	4.58	0.33	0.17	0.38
Good freeway network	4.92	0.20	4.63	0.23	-0.29	-0.95
Travel time predictable during peak	5.25	0.24	4.96	0.26	-0.29	-0.82
Overall satisfied with ramp meters	5.46	0.28	4.72	0.27	-0.74	-1.90
Wait time at meters is too long	**5.88**	**0.26**	**7.26**	**0.26**	**1.38**	**3.75**
Never know how long wait time will be	6.66	0.26	6.53	0.27	-0.13	-0.35
Safe when leaving ramp meter to merge	6.53	0.23	6.43	0.26	-0.1	-0.29
Ramp meters improve overall traffic	6.01	0.28	5.44	0.27	-0.57	-1.47
Cost of ramp meters is good value	**5.33**	**0.27**	**4.36**	**0.27**	**-0.97**	**-2.54**
Ramp meters shorten travel time	4.33	0.26	4.46	0.28	0.13	0.34
Ramp meters reduce car crashes	5.92	0.27	5.16	0.29	-0.76	-1.92
Ramp by-pass lanes benefit to me	4.72	0.31	3.95	0.29	-0.77	-1.81
Some meters may not be necessary	**5.58**	**0.28**	**7.18**	**0.27**	**1.6**	**4.11**
Buses/carpools should have ramp by-pass lanes	7.92	0.23	7.97	0.25	0.05	0.15
Sometimes need to wait even with smooth traffic	**6.60**	**0.26**	**8.06**	**0.22**	**1.46**	**4.29**
More alternative routes to avoid ramp meters	6.18	0.27	6.74	0.25	0.56	1.52
Ramp meters cause congestion on local streets	6.66	0.28	7.37	0.26	0.71	1.86
Electronic sign stating wait time	6.02	0.30	5.43	0.30	-0.59	-1.39
Tolerance for congestion	5.48	0.21	5.45	0.24	-0.03	-0.09
Amount of traffic congestion on I-94	**5.95**	**0.19**	**6.71**	**0.21**	**0.76**	**2.68**

Appendix I

Twin Cities Ramp Metering Effectiveness Study – "Before" and "After" Qualitative Research with Travelers

Qualitative Research with Travelers

technical report

prepared for

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December 2000

technical report

Qualitative Research with Travelers

prepared for

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Overview

The following conclusions represent a synthesis of the results emanating from qualitative research conducted among freeway travelers within the Twin Cities region. These results should only be used for gaining an initial understanding of travelers' attitudes toward the recent ramp meter shutdowns due to the limited nature of the qualitative research.

The main purpose of this qualitative research was to gather information from freeway travelers both "before" and then several weeks "after" ramp meters were shutdown. Additionally, the research was conducted to address a number of specific issues for each to the two evaluation periods:

"Before" Shutdown Evaluation

- *What are travelers' general attitudes and perceptions toward the use of ramp meters; and,*
- *Which ramp meter performance measures and issues should be included in a more quantifiable and representative survey to capture travelers' perceptions?*

"After" Shutdown Evaluation

- *What are travelers' general attitudes and perceptions toward the ramp meter shutdown experiment; and,*
- *What changes, if any, would travelers like to see done to the way ramp meters are operated as a consequence of the shutdown?*

On September 12 ("before") and November 14, 2000 ("after"), two focus group sessions were held in Bloomington, MN for each of the two evaluation periods. These sessions were held among individuals who traveled on one or more of the following routes: I-94 east- or westbound in Minneapolis or St. Paul, I-494 between I-94 and I-394, and I-35E north- or southbound in St. Paul and areas north of the city. These routes constituted the experimental corridors for the ramp meter shutdown. In order to qualify for participation, individuals had to travel these routes during weekday hours from either 6AM – 9AM or 3PM – 6PM. Additionally, separate groups were conducted based on the frequency of travel as follows:

1. **Light Ramp Users** – make a total of 1-5 trips per week on average; and,
2. **Heavy Ramp Users** – make a total of 6 or more trips per week on average.

Also, an effort was made to insure that about a third of the participants in the Heavy Ramp Users group traveled these routes for commercial/work reasons. Further, each of the two groups (Heavy and Light Ramp Users) contained an equal mixture of participants who resided in either an urban or suburban area, and who used roadways that had a "convenient" or "non-convenient" alternate route as defined by travelers. Finally, there was an equal mixture of both male and female travelers between 18 and 65 years of age in each session. Despite efforts to recruit participants who traveled on the designated test routes from throughout the region, the location of the focus group facility in Bloomington introduced a slight bias toward participants with urban and inner suburban work locations and residences. These areas, relative to outer suburbs, were more likely to benefit from the ramp meter shutdown. This experience is reflected in the comments of the participants.

The findings discussed below reflect the combined results of both types of freeway travelers (Light and Heavy Ramp Users) unless otherwise noted.

Chapter 1: "With Meters"

Key Findings

General Ramp Meter Perceptions

For the most part, the mention of ramp metering in the Twin Cities region was initially met with considerable negative reaction. However, participants were quick to point out that a distinction should be made between their experiences waiting at ramp meters and traveling on the region's freeway systems. Specifically, while many of the participants in both groups expressed the opinion that traveling on freeways has gotten worse over the years, it was never as bad as what they typically experienced waiting in line at ramp meters. This general feeling about traffic getting worse over the past 3 to 5 years was considered a result of population growth in suburban areas around the Twin Cities, while most of the jobs were still concentrated in urban areas. Thus, population sprawl in the suburbs contributed greatly to the increase in traffic congestion in the region's freeway systems, as well as causing problems and back-ups at ramp meter entrances.

It was also interesting to note that whenever ramp meters were mentioned, albeit in a mostly negative tone, participants appeared resigned to the fact that metering has become a way of life for travel in the region. As such, they have become so accustomed to waiting in lines at meters that they did not even think about the impact that ramp meters may have on their quality of life. In an effort to rationalize their existence, a few participants went on to say that compared to other major cities or regions in the US, traffic on freeways flowed much better in the Twin Cities area as a result of ramp metering. This feeling was especially true for several participants in the Heavy Ramp User group compared to those in the Light Ramp User group. Also on the positive side, ramp metering was perceived as making travel more predictable in terms of the time it took to get to their destination once on a freeway. This was not true for the wait times and amount of back-up occurring on the ramps themselves which was considered to be the most unpredictable portion of any given trip.

As a consequence of their becoming accustomed to ramp metering, travelers were very adept in terms of planning which specific routes to take during peak morning and afternoon travel periods. Pre-trip planning information was often used in making a decision to use one roadway versus another, where travelers were quite knowledgeable about the region's freeways and the use of local roads to get to their destinations. Advanced traveler information was readily available through commonly used sources such as the radio and in some cases the TV while at home in the morning. This information covered problems and major delays occurring in all major corridors as a result of normal rush hour congestion, accidents and bad weather driving conditions.

In addition to being very knowledgeable about specific roadways, participants were very familiar with the areas "best" and ""worst" ramp meters during peak travel periods. A number of participants were so knowledgeable that they were able to cite the best and worse times of day to use a particular meter. This translated into a very common practice of knowing which alternative ramp meters to use based on time of day and destination.

In fact, a number of participants mentioned that they "shop around" for the best ramp meter to use if their primary meter entrance is backed-up for any length of time. This practice could be quite time consuming in and of itself, but participants were willing to spend time looking for an alternative meter just to avoid sitting around waiting in line. Thus, factors pertaining to the actual location of a ramp meter, and time of day used, had a specific impact on the decision to use one roadway or another.

Awareness of Ramp Meter Benefits

Overall, most participants in both groups were unable to remember when ramp meters were first installed and the rationale behind their installation. Except for one or two older participants in the Light Ramp User group, they had never known what it was like driving in the region without them. In fact, when asked when ramp meters were first installed, only one person was able to correctly identify the date to the mid-to-late 1960's. However, participants were generally aware of the growth in ramp meter installations that typically followed construction of new freeways and other roadways connecting other points to the Twin Cities. But again, they could not remember when such growth actually occurred.

As such, there was a significant lack of justification for ramp metering since it occurred long ago and was not perceived as helping to increase the "quality of commuting life". Further, since ramp metering was mostly viewed in the negative, specific benefits were not at the top of peoples' minds. When participants in the two groups were able to cite specific benefits associated with ramp metering, the majority of comments given pertained to "reducing congestion" and "safety" issues. Specifically, it was mentioned that metering served to help traffic flow on the freeways, which in turn, allowed motorists to maintain adequate speeds and distances between vehicles. Also, meters decrease the potential for accidents since they provide a means to ease the merging of ramp traffic entering the freeway.

However, when specific benefits were provided on an aided basis (i.e., provided by the moderator), most participants agreed that the meters were indeed very beneficial to travelers. The benefits that resulted in the most positive reactions related to:

- Aids in merging traffic onto a freeway in a safe and orderly manner;
- Serves to increase speeds and the flow of traffic once on the freeway;
- Helps to conserve gas and expenses;
- Improves air quality and the environment; and,
- Reduces roadway stress and anxiety once on the freeway.

Interestingly enough, there was considerable debate over the merits of the last three benefits cited above. When it came to helping to conserve gas and thereby reduce air pollution, participants mentioned that travelers' driving habits had as much an impact on actual consumption as ramp metering did on these same benefits. Also, road rage was mentioned as not being restricted to Los Angeles or other highly congested cities since it has found its way most recently to the Twin Cities. However, participants again made a clear distinction between the potential for reducing road rage on the freeways but not always on the ramps since wait times could be very frustrating for most travelers.

Finally, after discussing these specific benefits, many participants wondered why they were never told of them before. In fact, one participant stated that up to this point most of the group had only negative comments to say about metering and now, it appeared that metering had some positive benefits associated with it. As a result of this information, they felt a little better and perhaps less negative about ramp metering in general.

Ramp Meter Performance Measures

In the aggregate, none of the participants in either group mentioned having problems with the actual operation of ramp meters since they were perceived as being well-maintained and fully operational most of the time. The few problems that were mentioned pertained to a light being out for a brief period of time, which caused some confusion for travelers.

However, when it came to their experiences with wait times at certain ramp meters, participants thought the time spent waiting had no association with the amount of traffic on the freeway itself. For most part, there appeared to be no degree of consistency between the wait times experienced from one meter to the next, where several participants claimed that wait times were even inconsistent between adjacent ramps that were in proximity to one another. Also, it appeared to not even matter how heavy the traffic on the roadway was flowing since the wait time at one specific meter was always 30 seconds regardless of traffic. Furthermore, very few participants believed that there was “someone” who was responsible for controlling the wait time at a meter, and that it was simply turned off and on for set intervals much like a timer on a lamp in their homes. A few participants, however, mentioned that they thought they saw “cameras” in the proximity of ramp meters; but again, the idea of a “control center” was completely foreign to most of them.

When asked how they went about keeping track of waiting times at ramp meters, besides looking at their watch, travelers had some very interesting ways of measuring time. These included: counting cars ahead in line and noting the wait time interval, and the number of songs played on the radio, to name a few. For others, they simply waited in line for their turn to move with no need to keep track of the time. Additionally, in an attempt to ascertain the tolerance levels of travelers in terms of the amount of time they were willing to spend waiting in line before making a decision to use another ramp meter, participants were in agreement on this time interval. Overall, waiting times of 2-5 minutes were very acceptable to most participants. Whereas, wait times of 5-8 minutes were still tolerable and anything over 10 minutes was considered to be quite frustrating. Of course, the notion of waiting 10-20 minutes at some ramp meters was cause for seeking an alternate ramp to use if available on a particular route.

In addition to problems with wait times, back-ups on many of the more heavily traveled ramps meters was also cause for concern and was viewed as yet another source of frustration. Under such conditions, travelers had to be very clever in the strategies used to circumvent such problems. It was often difficult for travelers to get out of line or even attempt to take another route since there were very few alternatives available to them in most instances. As such, most travelers would like to have either longer ramps or some advanced notification of wait times before entering a ramp. This latter idea was very appealing to participants since it provided them with information that could be used to make a decision about using a particular ramp meter just as long as an electronic message sign was located in a sufficient distance before the entrance. (It should be noted that the Mn/DOT Orion program experimented with just such signs and that this program was also evaluated by Cambridge Systematics. The study found wide receptivity to the signs. Unfortunately, technical problems in estimating average wait times have prevented advancement of this concept.)

Lastly, the use of by-pass lanes (or commonly referred to as "sane lanes") as a means to avoid ramp meters altogether was not considered to be very useful by the majority of participants. This perception speaks to the fact that most commuters prefer the convenience of traveling alone for most of their trips, even though they are well aware of the many benefits associated with ridesharing. As such, participants often perceive the by-pass lanes to be underutilized for certain ramps, and would rather see them opened to all travelers instead of using them for their intended purpose.

Attitudes toward Ramp Meter Shutdowns

Even though several reports were written in the local media about the impending ramp meter experiment, only a few individuals in each group claimed to have heard anything about a temporary shutdown of the region's ramp meters. Most of what was heard about this event came from articles in the newspaper or by word-of-mouth. However, there were several conflicting recollections about the exact nature of the event suggesting that the media was either somewhat vague in its reporting (which was not the case after reviewing a couple of these articles) or most likely, it just didn't stick in the minds of most of them for a variety of reasons. These recollections ranged from shutting down ramp meters in specific corridors for a day or two to shutting down all meters for a few weeks. Among those participants who remembered hearing or reading something about the shutdown, the media's description of it was felt to be more factual in content rather than opinioned and biased.

Participants were also asked what concerns, if any, they would have about such a shutdown of the region's ramp meters. The most common reaction was that it would wreak havoc on travel in the region. The greatest cause for concern centered on those agencies or vehicles that needed to travel for emergency or safety purposes, such as ambulances and fire trucks. Surprisingly, however, most participants stated that except for leaving a little earlier in the morning, they would not change their travel routes or stay at home during the first few days of the experiment should it actually occur. They were convinced that to make an accurate judgement about the value of ramp meters, they should not do anything differently even if it meant taking on the extra burden of increased travel times for their normal commute during this period. Instead, most participants indicated that they would continue with their usual routines and wait to see what happens before making plans to use alternate routes. Also, when asked whether they would be more likely to rideshare or take public transportation, stated that they would be highly unlikely to do so. Perhaps not surprisingly, participants mentioned that public transit was not an option under this circumstance since it is not available to most travelers across the region.

Information Needs for Ramp Meter Shutdowns

In an effort to understand how information about the impending shutdown should be conveyed to the general public, participants were asked what they would like to know about it and the best way to inform them. For the most part, participants did not feel the need to have any specific types of information other than knowing when it would occur, what routes would be affected, and the duration of the experiment. This reaction to such a major event was rather surprising to say the least, but perhaps not out of character given their previous comments indicating that they wanted to treat this event as a real "experiment" where they should not do anything different. In fact, a couple of participants in each group suggested that they should be given as little information and advance notice as possible. However, once they began to realize the possible implications that this "experiment" could have on their own travel, participants generally agreed that they would like to be notified anywhere from 10 to 14 days in advance of the event in order to make adjustments to their schedules (e.g., don't make any early morning meetings the first few days). Also, all media (newspaper, radio, and TV) should be used to convey information about the shutdown.

With regard to what information they would like to have available from Mn/DOT to be able to judge the impact of such a shutdown, participants were very clear about their needs. Interestingly, information pertaining to traditional traffic performance measures would be viewed as carrying more weight than either direct feedback from the general public or statements made by politicians and Mn/DOT officials. As such, they would like to have traffic performance data such as:

- Travel time between O-D pairs by time of day; and,
- Accident occurrences before and during the experiment.

Also, participants did feel the need to have input to the evaluation process where they would like to be surveyed and asked about their actual travel experiences during this experimental period. Participants were quite savvy about accepted research practices since a couple of them suggested that could be conducted by mail or over the telephone to be as representative as possible. Similarly, they recommended that the survey be conducted by a third-party source that had no stake in the outcome. This way, they would be assured that the evaluation would be completely unbiased and at the same time carry more credibility compared to what they might receive from a survey conducted by Mn/DOT or another government agency.

Implications

Based on the summary of findings from this initial qualitative exploratory research among travelers in the Twin Cities region, there are several overall implications that can be deduced from the "before" group sessions. These implications, however, do not focus on what needs to be asked during the "after" focus group sessions that will be conducted. Rather, they address the need to improve existing ramp meters should the decision be made to continue their operation in the region. Specifically, these include:

- Develop programs (media and outreach) that can be used to educate the general public on the benefits and rationale of ramp metering;
- Post average waiting times on an electronic display located well before the entrance to a ramp to allow travelers to make decisions about using alternate routes; and,
- Provide a degree of consistency between waiting times for adjacent ramp meters where wait times are adjusted for the amount of actual congestion on a roadway.

Chapter 2: "Without Meters"

Key Findings

General Reactions toward Ramp Meter Shutdowns

Based on the negative attitudes of travelers towards ramp meters when they were fully operational, it was not surprising that reactions were quite positive about the recent shutdown experiment. Overall, participants' experiences traveling on freeways in the Twin Cities region were favorable since most felt that their commutes were now faster end-to-end compared to when meters were operational. Also, very few travelers noticed the occurrence of substantially more accidents as a result of the shutdown, meaning that travel on the region's freeways did not appear to be any less safe than before. Further, once on the freeways, they did not experience any more back-ups than was typically the case before the shutdown. For the most part, the same bottlenecks existed as before with perhaps a little more wait time to go through them, but no new ones were created. Meanwhile, a few participants in the Light User group mentioned that they had experienced more congestion on certain sections of the freeway compared to travel on the same freeways when the ramp meters were operational. Overall, this situation was very surprising to some of the travelers who believed that there would be severe problems traveling in the region after the shutdown occurred.

In terms of their experiences on the ramps themselves, travelers' levels of frustration had completely vanished. Wait times at even moderately congested ramps disappeared and became a non-issue. Several travelers went on to mention that instead of using alternate routes and back roads just to avoid the meters, they were now more likely to use a direct route which meant using a once congested ramp to get onto the freeway. Thus, short trips, which were previously diverted away from freeways by ramp meters, were now re-attracted to the freeways. When asked whether they would feel better about having to wait at a congested ramp meter to get on a freeway, or not having to wait at a meter but experiencing more congestion on the freeway, most of them chose the latter condition. Similar to what was heard in the "before" groups, travelers would rather be moving, albeit even at slower speeds, than enduring long waits at meters. Also, some travelers appeared not to mind the perceived increase in congestion since being in "control" and having the "freedom" to make decisions about which routes to use made the situation tolerable. Thus, travel on the freeways was viewed as being even more predictable since they did not have to anticipate the length of the wait at meters. This belief was perhaps based on perceptions of the immense variability in wait times that occurred at some meters when they were operational. Further, since they now believed that travel times to their destinations were slightly faster, this perception along with not having to wait at meters made them think that travel times had become more predictable.

As an interesting aside to this discussion, heavy travelers were first to mention that an unsuspected phenomenon was taking place concerning travel behavior in the region. Specifically, there was now a need for travelers to relearn how to merge into ongoing freeway traffic. Some travelers were still coming to a complete stop at the end of the ramp instead of trying to cautiously merge into traffic by adjusting their speeds and distances.

According to many participants in both groups, travelers had become so used to stopping at the end of the ramp that this habit was difficult to break, especially for older motorists in the region. In fact, radio and news broadcasters were constantly telling their audiences to "merge", merge, merge" whenever possible since this would be the best way to get onto a freeway now that the meters were closed. As such, travelers would need to learn a whole new set of freeway travel behaviors if the decision was made to permanently shut down the ramp meters at the conclusion of the experiment. For these frequent travelers, they perceived that many drivers in the region were not inherently too timid about merging onto freeways.

Impact of Ramp Meter Shutdowns on Travel Behaviors

Consistent with travelers' statements about what they would do during the first few days of the shutdown experiment, very few of them mentioned that they had actually modified their travel behaviors or routes taken to get to a particular destination. Except for a few travelers who were now more willing to use the freeways instead of taking alternate routes, they continued to use the same ramp entrances and routes as before. This was the case during the first few days of the experiment and continued up to the point when the group sessions were conducted. Interestingly enough, however, these consistencies in travel behaviors were not so much a result of a conscious decision to try to give the experiment a fair evaluation, rather, old habits were mentioned as being hard to break. In other words, unlike the altruistic sentiments expressed in the "before" groups, travelers did not feel a need to do anything different unless absolutely needed, which did not end up being the case as a result of the shutdown.

Again, similar to what was heard in the earlier portions of the discussions, travelers were quite pleased about the fact that there was essentially no more congestion on the freeways than they had experienced before the shutdowns. Also, no new bottlenecks were created aside from the ones that existed before the experiment, which everyone in both traveler groups already knew about. Therefore, it appeared that their tolerance levels for such congestion even at bottlenecks had risen dramatically since the single most common source of their frustrations (ramp meters) had been removed. Now, travelers wanted to see Mn/DOT spend public funds on improving the freeway system in the Twin Cities region rather than on maintaining ramp meters which they believed was just a "band aide" to a more pervasive and growing infrastructure capacity problem.

Finally, it should also be noted that since wait times and congestion on most ramp meters had actually disappeared, there was no need to discuss whether back-ups into intersections were still a problem after the shutdowns. And as such, it became a non-issue for the rest of the topic areas addressed in both traveler groups. However, even though wait times and back-ups were substantially reduced or non-existent, there was still a feeling that it would be necessary for some specific ramp meters to remain operational. This sentiment was based on the awareness that certain areas of the freeway system are still heavily congested and in need of metering to help alleviate such congestion. Therefore, in these cases metering made a lot of sense.

Media Coverage of Ramp Meter Shutdowns

As previously discussed, travelers' prior expectations for what would happen after ramp meters were shutdown, did not materialize after it actually occurred. Prior to the shutdown, the expectation was that travel in the area would be difficult during the initial period of the experiment and then taper off gradually to where it would become tolerable again. Instead, the exact opposite occurred where even on Day 2 of the experiment travel in the region appeared to improve. Perhaps participants' reactions in the "before" groups were mainly a fear of the unknown since metering has been a way of life in the Twin Cities for a long time. Also, the media's portrayal of what would happen leading up to the experiment was more alarmist-based rather than reality-based. In spite of this, most travelers adopted a "wait and see" attitude before deciding to make substantial changes in their travel behaviors.

Consistent with this observation, travelers were very vocal about the way various media sources depicted the shutdown experiment both before and during its occurrence. In their view, the media made a big deal over nothing and tended to exaggerate the situation making it more newsworthy than what it should have been. There were accounts of accidents occurring all over the roadways and incidents taking place on ramps that most travelers did not experience. Therefore, travelers tended to discount these stories and placed more importance on what they saw rather than what they heard.

In terms of the specific information disseminated by Mn/DOT and the media to inform travelers about the shutdown experiment prior to it happening, all travelers mentioned that they were given sufficient information and in a timely manner. When asked about the lead-time given for when the shutdown actually would occur, travelers indicated that they knew about it anywhere from 3-4 weeks in advance. Also, they recollected receiving information about the actual shutdown date about one week in advance which was more than ample time for them to make alternate plans if warranted. Thus, it appeared that Mn/DOT did a more than acceptable job of informing the public about the experiment since participants in both groups mentioned that they did not require anything else about the shutdown other than what they had been told. Also, the various dissemination sources (TV, radio and newspapers) used were more than adequate in making sure the general public knew of the specific details of the shutdown.

Evaluation of Ramp Meter Shutdown Experiment

Similar to what was heard in the "before" group sessions, participants in the "after" groups were very clear about the types of information they would like to have available from Mn/DOT to be able to judge the impact of the shutdown experiment. Again, information pertaining to traditional traffic performance measures would be viewed as carrying more weight than either direct feedback from the general public or statements made by politicians and Mn/DOT officials. As such, they would like to have traffic performance data such as:

- Travel time between O-D pairs by time of day; and,
- Accident occurrences before and during the experiment.

However, unlike the previous sessions, they had very mixed feeling about what sources should be used to make these evaluations and who should be responsible for sharing the outcome. In the "before" sessions, it was felt that a third-party source would more unbiased and carry more credibility with the general public than would be the case if the evaluation was done solely by Mn/DOT. Whereas, in the "after" groups, this belief was not as clear-cut. This may have been in part due to several participants in the Light Ramp User group mentioning that they had read something about MN/DOT spending a large sum of money to have an external consult (sic, Cambridge Systematics) perform the evaluation. As such, these participants thought that the funds could be better spend improving the freeway system in the region. However, many others were not as skeptical as these participants and realized that an unbiased source should perform the evaluation.

Also, when it came to informing the public about the outcome of the shutdown experiment, participants in the "before groups" were unanimous in their feelings that the information should come directly from Mn/DOT officials. Specifically, they mentioned that the best way to inform the public about the outcome and the future status of the experiment would be through a series of short announcements conducted with the media (primarily TV and newspapers). They wanted to be able to hear the criteria that MN/DOT would be using to make their decisions about the status of metering so that they could form their own opinions about the reliability and credibility of such performance measures.

Preferences for Alternative Ramp Meter Solutions

Prior to asking travelers what they would like to see done to improve ramp metering in the Twin Cities region, a vote was taken where they had to choose between three different outcomes based on their experiences with the recent shutdowns. The options included:

A) Re-open the ramp meters the way they were before;

B) Keep the ramp meters permanently closed; or,

C) Keep ramp meters but change the way they operate.

Interestingly, no one in either of the two groups chose Option A, which meant re-opening the meters the way they were before. However, travelers were equally split between Options B and C based on the general feeling that although they would like to have a source of frustration disappear, they believed that ramp metering does help to alleviate traffic congestion for certain areas of the region's freeway system. Also, travelers were asked whether Mn/DOT should turn the meters back on while deciding to proceed in one direction or another, or whether they would like to have the experiment continue for an indefinite period where new ways of operating meters could be tried. Perhaps not unexpectedly, travelers were again unanimous in their feeling that they would not like to see the meters re-opened as before and that it is important for Mn/DOT to try as many solutions as possible to improve traffic flow on the freeways.

In keeping with this attitude, travelers were given a series of potential ramp meter solutions to evaluate, which included:

- *Keeping some meters open and others closed based on the degree of congestion;*
- *Adjusting wait times at meters so that queues are shorter;*
- *Installing "smart" meters that adjust wait times to actual traffic congestion and queue lengths;*
- *Providing signage/displays at ramp meter entrances that post average wait times; and,*
- *Shortening the hours of ramp metering during peak morning/afternoon travel.*

Across both groups, travelers were very much in favor of either keeping some meters open and closing others, or, installing "smart" meters to adjust waiting times to reflect a variety of traffic conditions. These two solutions were cited most often, followed by two others that included displaying wait times at ramp meter entrances and shortening the hours of ramp meter operations (especially turning them off earlier at night rather than turning them off later in the morning). Again, these solutions were in keeping with many of the opinions discussed during the sessions and provided acceptable courses of actions for Mn/DOT to take if the decision is made to continue the experiment.

Implications

Based on the summary of findings from this qualitative exploratory research among travelers in the Twin Cities region, there are several overall implications that can be deduced from the "after" group sessions. These implications center on the publics' wish to have Mn/DOT continue to evaluate acceptable ramp metering solutions rather than merely turning them back on or keeping them permanently off. Specifically, these recommendations reflect the need to make changes in both travelers' driving behaviors and habits and the actual operations of the ramp meters themselves as follows:

- Develop driver education programs that can be used to "train" travelers about appropriate ramp merging behaviors and freeway etiquette;

- Monitor ramp meters one at a time to evaluate whether it should be opened or permanently closed based on traffic conditions and the alleviation of congestion; and,

- Install "smart" meters on those ramps that have been found to require metering so that wait times reflect actual traffic conditions on the ramp at the time.

Appendix A: "Before" & "After" Topic Guides

MINNESOTA DEPARTMENT OF TRANSPORTATION
RAMP METER STUDY – QUALITATIVE RESEARCH
"BEFORE" GROUP SESSION TOPIC GUIDE

I. INTRODUCTION (10 Minutes)

1. Moderator Introduction: State name, title and company.

   - Explain what discussion groups are all about.
   - Inform Participants: A study is being conducted in the Twin Cities area among people like yourselves who travel freeway routes with ramp meters. The information you provide tonight will be used by the Minnesota Department of Transportation and other government agencies to gain a better understanding of travelers' attitudes towards the installation of ramp meters in the region's freeway system.

2. Specific Purpose of Discussion: To learn what you think about ramp meters in general, the types of benefits ramp meters may or may not provide, and how the existence of ramp meters effect your decision to use specific routes, modes of transportation, and times of travel.

3. Explain To Participants:

   - Ground rules (no right or wrong answers and informal open discussion)
   - Observers (one-way mirror)
   - Audio and video taping
   - Two-way confidentiality

4. Participant's Introduction: State name, occupation, residence/community (urban or suburban location), and describe a typical trip on and the freeway during peak travel periods in terms of:

   - sections of freeway routes traveled on (I-94/-394/-494/-694/-35E/-35W/TH 77);
   - amount of time (percentage of travel) spent on such routes during peak weekday periods (6–9 AM and 3-6 PM); and,
   - primary reasons for traveling on these routes.

5. Stress to Participants: We are not here to talk about future expansions of the freeway system, or any roadway construction problems that you encounter.

II GENERAL PERCEPTIONS OF RAMP METERS (25 Minutes)

1. With this said, overall, what can you say about traveling on roadways with ramp meters in the Twin Cities region (I-94/-394/-494/-694/-35E/-35W/TH 77)? (*Probe for*: general impressions and experiences)

   - Has traveling on these roadways gotten better or worse over the last few years? (*Probe for:* reasons why or why not and specific examples)
   - What do you think is primarily responsible for making this experience better/worse? (*Probe for*: specific conditions and demographic changes)
   - Have you become accustomed to ramp meters as a way of traveling in the region, and how so?

2. Also, I'd like to know your feelings about the installation and operations of ramp meters in the region's roadways? (*Probe for*: positive or negative reactions)

   - To the best of your knowledge, what were some of the reasons for installing ramp meters in the first place – and, were these good reasons for doing so?
   - Do you think they make travel more predictable and reliable? (*Probe for*: reasons why or why not)

3. Based on your own experiences, what are some of the primary benefits to travelers in having ramp meters installed on certain roadways? And, what are some of their primary drawbacks? (*Probe for*: general benefits obtained)

4. In addition to these benefits and drawbacks, do you think ramp meters have an effect on … ?

   -- Travel times and speeds
   -- Safety and accident reduction
   -- Gas consumption & expenses
   -- Air quality & environment
   -- Roadway stress and anxiety
   -- Person- and vehicle-trips made/mileage

   For safety and accident reduction mentions, probe for: ramp itself, ramp traffic merging onto freeways, and freeway traffic itself.

5. What do you think about when making plans to travel on roadways that have ramp meters? (*Probe for*: pre-trip planning decisions)

   - Is the presence of ramp meters a factor in your decision to use one roadway versus another, one time of day versus another, or another mode if both could get you to the same destination?
   - Does it make a difference whether your travel is for commuting or work-related reasons versus pleasure reasons in terms of your choice of roadway types to use (*Probe for*: freeway vs. arterial)?

6. Is information available to you from any source about existing ramp meter back-ups or problems prior to your departure? And, is this information provided well in advance to allow you to make a decision about using a specific roadway? (*Probe for:* impact on departure and arrival times)

III. Evaluation of Ramp Meter Performance – MOE's (25 Minutes)

1. Now, I'd like to focus our discussion on the overall operations of ramp meters in particular?

   - Have any of you encountered problems or incidents with ramp meters operating properly, and what were they?
   - Do you think they are adequately maintained most of the time?
   - What happens to traffic on the ramp and the next few miles of freeways/ roadway when a meter has broken down or doesn't function properly?
   - Are these problems serious enough to make you want to try an alternate route? (*Probe for:* reasons why or why not)

2. Next, I'd like to know about your experiences with actual ramp meter <u>wait times</u> on routes such as (<u>I-94/-394/-494/-694/-35E/-35W/TH 77</u>)?

   - In general, what can you say about the average wait times on these ramps?
   - Are most of the ramps properly metered in terms of the amount of time you are required to wait?
   - Do you ever think about how long you have been waiting – do you keep track of the time and how do you measure it if you do?

3. Also, thinking about getting onto a specific ramp meter entrance, are most of the ramps long enough to accommodate all of the vehicles waiting in line? (*Probe for*: general experiences and adequacy of ramp itself)

   - Does traffic ever back up onto streets and intersections – and, how frequently does this occur in your estimation?
   - What do you do when ramps are backed up – do you get out of line or avoid it entirely and take an alternate route or another ramp?
   - How convenient is it for you to avoid back-ups and take an alternate route or another ramp?
   - Do you wish there could be some sort of notification at the ramp when problems occur – and, what would you like to know?

4. Are "by-pass lanes" (HOV's) an adequate solution to ramp meter back-up? (*Probe for*: reasons why or why not)

   - Do you think there are enough of them, and are they located where they are needed most?
   - Do you think they are used appropriately and serve a purpose?

5. In your opinion, what would you like to see done to improve waiting times and lines on some of the busiest ramp meters? (*Probe for*: specific recommendations and why it would improve time/lines)

6. And, is there anything that you would like to see done to improve ramp meters in general? Give me <u>three things</u> that you would like to see done.

IV. Expectations for Ramp Meter Shutdowns (20 Minutes)

1. Up this point, we have been talking a great deal about your experiences with ramp meters and travel in the Twin Cities region, so I'm wondering whether any of you have heard about possible ramp meter shutdowns by MnDOT.

   - First, how many of you have ever heard or read anything about this shutdown? (*Probe for*: show of hands)
   - And, where did you hear or read about this shutdown?

2. In your opinion, has the information been generally positive or negative? (*Probe for*: general media reactions)

   - Has this information been presented in a fair and unbiased manner?
   - Have you been given sufficient information by MnDOT and the media to let you know what to expect once the shutdown happens?

3. What do think about shutting down the ramp meters on a temporary basis as an experiment to see would happen to freeway travel in the Twin Cities Region? (*Probe for*: overall public reactions to such news)

4. Overall, what concerns or problems do you foresee with shutting down ramp meters? And, how do you think most travelers will react? (*Probe for*: specific expectations)

5. How do you think such a shutdown will affect your own travel habits on such routes as (<u>I-94/-394/-494/-694/-35E/-35W/TH 77</u>)?

- Would any of you avoid leaving home to go to work or another destination when the ramp meters are shutdown?
- Would you make fewer trips during the period that the meters are shut down? How convenient would that be for you?
- Would you plan on taking alternate routes, and how convenient would these routes be in such a situation?
- Would you plan on leaving earlier or later, and how convenient would that be for you?
- Would you consider car pooling during this period and do you think this strategy would be effective?
- And, how many of you would consider taking public transportation to your destination?
- What other travel strategies would you consider, if any?

V. Information Needs for Ramp Meter Shutdowns (10 Minutes)

1. If an announcement were made that all ramp meters were being temporarily shut down a week from today, what would you want to know about the shutdown? (*Probe for*: specific information needed)

   - How far in advance would you want to know about the shutdowns to allow you to make appropriate travel decisions? (*Probe for*: 2 days, 4 days, a week, or more)
   - Would you like to know about possible alternate routes to take or other travel options, if available in your area?
   - From what sources would you like to be able to obtain this type of information? (*Probe for*: specific sources/media and why useful)
   - And, what else would you like to know about it?

2. Assuming that the ramp meters are going to be shut down for a limited period of time, what information would you like to have from MnDOT to be able to judge the impact of such a shutdown for yourself?

   If <u>not</u> mentioned, probe for:

   -- Travel times and speeds
   -- Safety and accident reduction
   -- Gas consumption & expenses
   -- Air quality & environment
   -- Person- and vehicle-trips made
   -- Person- and vehicle-trips mileage

   For <u>safety and accident reduction mentions</u>, probe for: ramp itself, ramp traffic merging onto freeways, and freeway traffic itself.

3. Do you think you would be in a position to judge the impact of such a shutdown based on your own travel experiences during this period? And, why so?

4. Finally, what would be the best way to inform the general public about the outcome of a temporary ramp meter shutdown prior to MnDOT making any permanent decisions about it? (*Probe for*: specific sources/media and why useful)

VI. CONCLUSION (5 MINUTES)

1. Ask participants: is there anything else that you would like to discuss before we conclude?
2. Thank participants for their valuable input and attendance at the session.

MINNESOTA DEPARTMENT OF TRANSPORTATION
RAMP METER STUDY – QUALITATIVE RESEARCH
"AFTER" GROUP SESSION TOPIC GUIDE

I. INTRODUCTION (10 Minutes)

1. Moderator Introduction: State name, title and company.

   - Explain what discussion groups are all about.
   - Inform Participants: A study is being conducted in the Twin Cities area among people like yourselves who travel freeway routes with ramp meters. The information you provide tonight will be used by the Minnesota Department of Transportation and other government agencies to help decide whether ramp meters should be kept closed, reopened or somehow modified going forward in the future.

2. Specific Purpose of Discussion: To gauge your overall reactions toward the recent closing of ramp meters, the specific advantages or disadvantages that are gained by keeping ramp meters either opened or closed, how the closure of ramp meters has effected your decision to use specific routes and different modes of travel, and finally, what impacts have ramp meter closures had on both travel times and your "quality of life".

3. Explain To Participants:

   - Ground rules (no right or wrong answers and informal open discussion)
   - Observers (one-way mirror)
   - Audio <u>and</u> video taping
   - Two-way confidentiality

4. Participant's Introduction: State name, occupation, residence/community (urban or suburban location), and describe a typical trip on the freeway during peak travel periods both <u>before and after the shutdown</u> in terms of:

   - sections of freeway routes traveled on (I-94/-394/-494/-694/-35E/-35W/TH 77 – "before" and "after");
   - use of specific ramp meter entrances ("before" and "after")
   - changes in percentage of travel time spent on such routes during peak weekday periods from "before" to "after"(6–9 AM and 3-6 PM); and,
   - primary reasons for traveling on these routes.

II GENERAL PERCEPTIONS OF RAMP METER CLOSURES (20 Minutes)

1. To begin, what can you say about traveling on roadways in the Twin Cities region now that ramp meters have been shutdown (I-94/-394/-494/-694/-35E/-35W/TH 77)? (*Probe for*: general impressions and experiences)

   - Has the shutdown been a favorable or unfavorable experience overall? (*Probe for*: reasons why for each experience)
   - Has traveling on roadways gotten better or worse compared to when they were open? (*Probe for:* reasons why or why not and specific examples)
   - What do you think is primarily responsible for making this experience better/worse? (*Probe for*: specific conditions)

2. Do you think the recent closure of ramp meters has made travel on these roadways more predictable or less predictable than before? (*Probe for*: reasons why or why not)

   - Thinking only about the time you now spend <u>entering a ramp and merging into traffic</u>, is your travel time more or less predictable than before? (*Probe for*: reasons why or why not)
   - And, how about once you are on the roadway itself, is your travel time more or less predictable than before? (*Probe for*: reasons why or why not)

3. Based on your own experiences, what are some of the primary benefits to travelers in having ramp meters closed? And, what are some of their primary drawbacks? (*Probe for*: general benefits and drawbacks)

4. In addition to these benefits and drawbacks, how do you think ramp meter shutdowns have affected … ?

   -- Travel times and speeds
   -- Safety and accident reduction
   -- Gas consumption & expenses
   -- Air quality & environment
   -- Roadway stress and anxiety
   -- Person- and vehicle-trips made/mileage

   For <u>safety and accident rates or occurrences mentions</u>, probe for: ramp itself, ramp traffic merging onto freeways, and freeway traffic itself.

III. Impact of Ramp Meter Closures on Travel Behaviors (30 Minutes)

1. Now, I'd like to focus our discussion on how the recent shutdown of ramp meters in the Twin Cities region has affected the way you now travel to your particular destinations. Thinking only about the first day or two of this event, how many of you …?

   -- Stayed at home or worked from your home rather than go to your normal destination? (*Probe for*: take show of hands)
   -- Made plans to do something different, like leaving earlier or later in the day? (*Probe for*: take show of hands)
   -- Tried a different route, maybe one that you would liked to have taken before the shutdown or one than you now thought would be faster or easier? (*Probe for*: take show of hands)
   -- Decided to rideshare or car pool without someone else? (*Probe for*: take show of hands)
   -- Took a bus/express bus or some form of public/private transit? (*Probe for*: take show of hands)

2. For those of you who did nothing different, why didn't you change your plans? (*Probe for*: general reasons for their inertia)

3. Did any of you feel that by doing something different, you would not be giving the "experiment" a fair chance to be evaluated? (*Probe for*: how many felt this way and reasons why)

4. Next, is traffic on the freeways you use more or less congested than it was before the shutdown? (*Probe for*: general impressions)

   - Are there bottlenecks along certain routes that were not there before, and where along these routes does this now occur?
   - Where do you see the most problems occurring, if any, now that the ramps have been closed?

5. Also, I'd like to know about your experiences with actually getting onto ramps at routes such as (I-94/-394/-494/-694/-35E/-35W/TH 77) at this time?

   - In general, what can you say now about entering a ramp and merging onto traffic – is it much easier, more difficult or about the same?
   - Is traffic at certain ramps still backed up onto streets and intersections – and, how frequently does this now occur of at all?

6. Thinking about the use of alternate routes to get to your particular destination, I'd like to know whether your decision to use such routes has been affected as a result of the ramp meter shutdown? (*Probe for*: general impressions)

   - Are you now more likely or less likely to use to use such routes compared to before the meters were shutdown?
   - How convenient is it for you to use an alternative route now, and are you using certain routes that you would never used before the shutdown?
   - If you used a particular alternate route prior to the shutdown, how would you compare your experiences on such routes after the shutdown?

IV. Expectations and Media Coverage of Ramp Meter Shutdowns (20 Minutes)

1. Up this point, we have been talking a great deal about your experiences with ramp meter shutdowns and their impact on travel in the Twin Cities region.

   - First, prior to the shutdown, did your expectations for what would happen to travel in the region come true in terms of what actually occurred? (*Probe for*: degree of consistency between expectations and reality)
   - And, were any of you surprised by what actually occurred – and if so, how and why were you surprised?

2. In terms of the information you were provided prior to the shutdown, how much of an advanced notice were you given by Mn/DOT and the media about the shutdown "experiment"? (*Probe for*: perceptions of time)

   - Was the time from when you were first officially notified about the shutdown to when it actually took place acceptable to you? (*Probe for*: why or why not, and how long of a time should a notice have been given)
   - Were you given sufficient details about the shutdown to allow you to make alternative travel plans, if desired?
   - What other information about the shutdown would you have liked to known now that you have actually experienced it? (*Probe for*: specific types of information needed)
   - What other media sources, if any, should have been used to provide such information to you? (*Probe for*: adequacy of availability and access to media sources)

3. Has the media coverage of the shutdown "experiment" affected your opinion about ramp meters in general, and if yes, how so? (*Probe for*: general feelings)

4. In your opinion, has the media's depiction of the shutdown "experiment" been generally positive or negative? (*Probe for*: general media reactions)

   - What has been the general consensus of the media overall?
   - Has their reporting of the shutdowns been presented in a fair and unbiased manner?

5. And, have your own attitudes toward the installation of ramp meters in the Twin Cities region changes as a result of the "experiment" and how so if yes? (*Probe for*: general reactions)

   - Do you think most people's opinions have changed as a result of the "experiment", and are they more positive, negative or neutral than before?
   - Do you think you have been given adequate time to be able to evaluate the outcome of this "experiment"?

6. Also, what information would you like to have from Mn/DOT to be able to judge the impact of such a shutdown for yourself?

   If <u>not</u> mentioned, probe for:

   -- Travel times and speeds
   -- Safety and accident reduction
   -- Gas consumption & expenses
   -- Air quality & environment
   -- Person- and vehicle-trips made
   -- Person- and vehicle-trips mileage

   For <u>safety and accident rates or occurrences mentions</u>, probe for: ramp itself, ramp traffic merging onto freeways, and freeway traffic itself.

7. Finally, what would be the best way to inform the general public about the outcome of the temporary ramp meter shutdown prior to Mn/DOT making any permanent decisions about it? (*Probe for*: specific sources/media and why useful)

V. Travelers Preferences for Alternative Ramp Meter Solutions (15 Minutes)

1. Thinking about all of the issues we have talked about tonight, and your own experiences with the shutdown of ramp meters, it is now time to take a vote.

   This time, you have three choices and they are (take show of hands for each):

   A.) Re-open the ramp meters the way they were before;
   B.) Keep the ramp meters permanently closed; or,
   C.) Keep ramp meters but change the way it is done (operate).

2. For those of you who would like to do something different, what would you like to see Mn/DOT do with them. Please give me three things that you would like to see done?

   If not mentioned probe for:

   -- Keep some meters open and close others based on the degree of congestion.
   -- Adjust waiting times on the meters so that you don't have to wait more than some specific length of time, say 5 or 10 minutes.
   -- Install "smart" meters that adjust waiting times to reflect actual freeway congestion and the length of the queue on the ramp.
   -- Provide signage/LCD displays at certain meters to let travelers know what the average waiting time will be.
   -- Other recommendations.

3. And finally, if you had the chance to say something to Mn/DOT about this entire ramp meter shutdown "experiment", what would you now like to say to them?

VI. CONCLUSION (5 MINUTES)

1. Ask participants: is there anything else that you would like to discuss before we conclude?
2. Thank participants for their valuable input and attendance at the session.

Appendix B: Recruitment Screener

MINNESOTA DEPARTMENT OF TRANSPORTATION
- RAMP METER STUDY -

FOCUS GROUP SCREENER

Interview Date ____/____/00

Interviewer Name: ____________________________

Respondent Name: ____________________________

Address: ____________________________

City, State, Zip: ____________________________

Respondent Phone # (   ) ____________________________

Agree to Invitation: (   )

Not Agree to Invitation: (   )

Term: (   )   at Q.____

Status

Heavy Ramp Users -1 (   )
Light Ramp Users -2

Market

Twin Cities, MN -1 (   )

Group Assignment

Minneapolis, MN – 9/12/00 (Tuesday)

Group 1: Heavy Ramp Users - 6:00 p.m.
Group 2: Light Ramp Users - 8:00 p.m.

INTRODUCTION

Hello, my name is __________. I'm calling for Cambridge Systematics, an independent consulting and marketing research company. We're conducting a study about travel habits in the Twin Cities region on behalf of the Minnesota Department of Transportation and would like to ask you a few questions.

***Interviewer:* Make sure that an even mixture of travelers with different ages and sexes are recruited for each group. If necessary, alternate between asking for either a female or male over 18 years of age during the initial HH introduction below.**

Household Introduction

May I speak to someone in this household over 18 years of age that travels outside the home and uses one or more of the following routes: : **(a) I-94 East or West bound in Minneapolis or St. Paul, (b) I-494 between I-94 and I-394, and (c) 35E North or South bound in St. Paul and areas north of the city** during weekday hours between 6 – 9 AM or 3 – 6 PM.

Business Introduction

May I speak to someone at this location that regularly uses one or more of the following routes: **(a) I-94 East or West bound in Minneapolis or St. Paul, (b) I-494 between I-94 and I-394, and (c) 35E North or South bound in St. Paul and areas north of the city** during weekday hours between 6 – 9 AM or 3 – 6 PM for commercial driving purposes such as hauling freight, making deliveries or transporting passengers.

Q1 Would this person be you or someone else (in your household/at this location)?

(Continue) -- Person -1 ( )
(Ask to speak to person or arrange callback) ------------------------------- Someone Else -2
(Discontinue, and record as "none HH") ----- No Person in HH/Business Location -3

Q2 And, which of these specific routes do you regularly use? ***(Read list if necessary. Record all that apply below.)***

I-94 East or West bound in Minneapolis or St. Paul -1 ( )
I-494 between I-94 and I-394 -2
35E North or South in St. Paul and areas north of the city -3
(Discontinue, and record as "no routes") ----------------- Don't Know/Not Sure -4
(Discontinue, and record as "no routes") ---- Don't Use Any of These Routes -5

Q3 Do you mostly travel this/these route(s) … ? ***(Read list. Record one response)***

Weekdays from 6:00 AM to 9:00 AM -1 ( )
Weekdays from 3:00 PM to 6:00 PM -2
(Discontinue, and record as "wrong hours") ------ Weekdays after 6:00 PM -3
(Discontinue, and record as "wrong hours") --- Or, weekends and holidays -4
(Do not read. Discontinue, and record as "wrong hours") ------------ Don't know/Not sure -5

Q4 In an **average week**, about how many times do you use this/these route(s) **during weekday hours** for any travel reasons? Please assume that if you travel round trip, each leg counts as a single trip in your estimate. ***(Record number of trips below.)***

Number of Trips per Week: ______ ( )

If the total trips is "6 or more", then qualifies for Group 1 – Heavy Ramp Users (check quotas).

If the total trips is "1-5", then qualifies for Group 2 – Light Ramp Users (check quotas).

If respondent does <u>not</u> qualify for either group (0 trips), discontinue and record as "no trips".

Q5A And, what is your primary reason for using this/these route(s)? ***(Record all that apply below.)***

Commute to work/business -1 ( )
Hauling freight/goods/materials -2
Making deliveries -3
Transporting passengers -4
Traveling to airport -5
Visiting clients/other businesses -6
Visiting friends/relatives/others -7
School/education -8
Shopping -9
Entertainment (restaurants/movies/music/clubs/special events) -10
Sporting events -11
Appointments (medical/dental/business) -12
Other purpose ***(Specify)***:_________________________________ -13

Q5B Are you aware of alternate routes that you could use if this/these route(s) became congested or was closed for any reason?

(Continue) --------------------------- Yes -1 ( )
(Skip to Q6) ------------------------------ No -2
(Skip to 6) ------- Don't know/Not sure -3

Q5C How convenient is it for you to take this/these alternate route(s)?

Extremely convenient -1 ( )
Very convenient -2
Somewhat convenient -3
Not very convenient -4
Not at all convenient -5

Q6 And, what is your age, please? ***(Read list if necessary.)***

(Discontinue, and record as "wrong age") ---------- Under 18 -1 ( )
18-29 -2
30-39 -3
40-49 -4
50-65 -5
66 and over -6
(Discontinue, and record as "wrong age") → Refused -7

Q7 Do you, or any member of your household and friends work for ...? ***(Read list. Check all that apply.)***

	Yes	No	Not Sure
• An Advertising Agency or Public Relations Firm	-1	-2	-3 ( )
• A Newspaper, Radio or Television Broadcasting Company	-1	-2	-3 ( )
• A Marketing or Opinion Research Company or Department	-1	-2	-3 ( )
• A Local, State or Federal Government Agency	-1	-2	-3 ( )

If "Yes/Not Sure" (codes "1" or "3") to any of the above in Q7, then discontinue and record as "competitive industry".

Q8 Within the **past 6 months** have you participated in a marketing research study where you were asked to attend a round table discussion?

(Discontinue, and record as "past participant") ----- Yes -1 ( )
(Continue) ------- No -2

Q9 ***(Do <u>not</u> read)*** Record respondent sex:

Female -1 ( )
Male -2

******STOP AND ASSIGN RESPONDENT TO GROUP BEFORE CONTINUING ******
****** IF QUOTAS FILLED THEN THANK AND DISCONTINUE INTERVIEW. ******

GROUP ASSIGNMENT GRID

Heavy Ramp User: Travel on designated routes (Q2 – codes 1-6) during weekday peak hours (Q3 – codes 1-3) at least 6 or more trips per week (Q4)

Light Ramp User: Travel on designated routes (Q2 – codes 1-6) during weekday peak hours (Q3 – codes 1-3) at 1-5 trips per week (Q4)

<u>Interviewer</u>: ***If respondent does <u>not</u> qualify for either "Heavy or Light Ramp Meter User" groups, then thank and discontinue interview.***

<u>Important</u>: **Please make sure that group sessions contain:**

- **<u>Heavy Ramp Meter Users Only</u> - at least 3-4 participants who travel the designated routes during peak hours for business/commercial-related purposes (Q5 – codes 2-6)**
- **An equal mixture of participants who reside/located either inside (urban) or outside (suburban) the Twin Cities area – 50/50% split.**
- **A mixture of participants who use roadways with "convenient alternate routes" or "non-convenient alternate routes" – 40/60%. Where,**
    - **A "convenient route" is: "Yes" to Q5B <u>and</u> Q5C codes 1-2;**
    - **A "non-convenient route" is: "No" to Q5B, or, Q5B is "yes" <u>and</u> Q5C codes 3-5**
- **An equal mixture of females/males representing each of the six different age categories.**

INVITATION

We are contacting people like yourself to ask you to participate in an informal, round table discussion. The discussion will focus on your opinions about traveling within the greater Twin Cities region. As a token of our appreciation, you will be given **($____)** for your participation. Refreshments will be served during the discussion and no attempt will be made to sell you anything. This discussion is being conducted for research purposes only.

Q10 The discussion will last approximately 1 1/2 hours, and will be held on (date) and (time) at our facility. Will you be able to attend?

(Continue) ----- Yes -1 ( )
(Discontinue, and record as "not agree") ------- No -2

Prior to attending the discussion, I'd like to ask you a few more brief questions.

Q11 Do you use your own vehicle or a company vehicle for **most of your weekday** trips on the route(s) you previously mentioned?

Use Own Vehicle -1 ( )
Use Company Vehicle -2
Don't Know/Refused -3

Q12 What is your primary occupation? ***(Record exact verbatim below.)***

Primary Occupation: ________________________________ ( )

Q13 Also, what is your total annual household income before taxes? Would it be ... ***(Read ranges below.)***

Under $15,000 -1 ( )
$15,000 to under $25,000 -2
$25,000 to under $40,000 -3
$40,000 to under $75,000 -4
$75,000 to under 100,000 -5
$100,000 to under $150,000 -6
$150,000 and over -7
(Do not read) ---------- DK/Ref. -8

Give verbal directions to focus group facility and continue with:

Thank you very much for your cooperation. We will look forward to seeing you on (date) at (time). We have invited only a limited number of people, and we are counting on your attendance. We will call you a day or two prior to the group discussion to confirm your attendance. We will also be sending you a letter containing directions to our facility. Finally, may I please verify your:

Name: ____

Street Address: ____

City: ____________________ State: _______________ Zip: ___________

Telephone Number:____

If you have any questions, please call us at (phone number).

Appendix J

Summary of Benefit Cost/Calculations

Twin Cities Ramp Meter Study

Benefit Estimation

	Daily Change		Value		Daily Benefit	Annual Change		Annual Benefit
Travel Time								
Change in Freeway Travel Time (person hours)	30,550	$	9.85	$	300,922	7,545,965	$	74,327,759
Change in Ramp Travel Time (person hours)	(30,449)	$	9.85	$	(299,920)	(7,520,844)	$	(74,080,315)
Subtotal	*101.7*			*$*	*1,002*	*25,121.2*	*$*	*247,443*
Travel Time Reliability								
Change in Freeway Travel Time Reliability (person hours)	33,089	$	9.85	$	325,923	8,172,895	$	80,503,016
Change in Ramp Travel Time Reliability (person hours)	(22,628)	$	9.85	$	(222,889)	(5,589,201)	$	(55,053,626)
Subtotal	*10,460.3*			*$*	*103,034*	*2,583,694.5*	*$*	*25,449,390*
Safety								
Fatality Crashes	0.0228	$	1,176,584.23	$	26,834	5.6333	$	6,628,064
Injury Crashes								
Severe	0.1210	$	57,287.50	$	6,930	29.8777	$	1,711,617
Moderate	0.4888	$	21,711.76	$	10,612	120.7214	$	2,621,075
Minor	0.7423	$	13,471.42	$	10,000	183.3433	$	2,469,895
Property Damage Crashes	2.8424	$	6,789.87	$	19,300	702.0742	$	4,766,992
Subtotal	*4.2172*			*$*	*73,675*	*1041.6499*	*$*	*18,197,643*
Emissions								
Hydrocarbon (tons)	0.43	$	1,774.00	$	754	104.99	$	186,247
Carbon Monoxide (tons)	4.91	$	3,731.00	$	18,329	1213.41	$	4,527,229
Nitrous Oxide (tons)	(0.64)	$	3,889.00	$	(2,480)	(157.48)	$	(612,442)
Subtotal	*4.70*			*$*	*16,603*	*1160.92*	*$*	*4,101,034*
Energy								
Fuel Use (gallons)	(22,246.3)	$	1.45	$	(32,257)	(5,494,829)	$	(7,967,502)
Subtotal				*$*	*(32,257)*	*(5,494,829)*	*$*	*(7,967,502)*
DAILY TOTAL				$	162,057			
Number of Metering Days Per Year					247			
TOTAL ANNUAL BENEFIT								**40,028,008**

Mn/DOT Ramp Metering Study

Cost Estimation

Capital Costs

Congestion Management Subsystems	# of System Components	System Capital Cost	Annual Captial Cost	% Attributable to Metering	Annual Metering Cost
Ramp Meters	431	$ 4,183,019	$ 356,597	100%	**$ 356,597**
System Detection	3500	$ 13,072,500	$ 1,762,417	15%	**$ 264,363**
CCTV Surveillance	229	$ 21,073,015	$ 1,669,764	0%	**$ -**
Traffic Management Center	1	$ 24,943,438	$ 1,247,172	10%	**$ 124,717**
Subtotal		*$ 63,271,972*	*$ 5,035,950*		***$ 745,677***
HOV Bypass Ramps*	73	$ 21,900,000	$ 730,000	100%	**$ 730,000**
TOTAL			**$ 5,765,950**		**$ 1,475,677**

* HOV bypass ramps are a transit initiative and are not generally considered part of the congestion management system.

Total Costs

Cost Item	All Congestion Management Capabilities	Amount Related to Ramp Metering
CMS Operation Costs	$ 893,836	$ 431,879
CMS Maintenance Costs	$ 967,489	$ 464,395
Additional Research	$ 250,000	$ 250,000
Subtotal	***$ 2,111,325***	***$ 1,146,274***
+ Annual Capital Costs	$ 5,765,950	$ 1,475,677
TOTAL	**$ 7,877,275**	**$ 2,621,950**

Twin Cities Ramp Meter Study

Benefit/Cost Comparison

Benefit/Cost Comparison

	All Congestion Management Costs	Ramp Metering Only Costs
Cost Item		
Annual Capital Cost	$ 5,765,950	$ 1,475,677
Annual O&M Costs	$ 2,111,325	$ 1,146,274
TOTAL ANNUAL COST	*$ 7,877,275*	*$ 2,621,950*
TOTAL ANNUAL BENEFIT	*$ 40,028,008*	*$ 40,028,008*
Comparison		
Net Annual Benefit	**$ 32,150,734**	**$ 37,406,058**
Benefit/Cost Ratio	**5.1**	**15.3**

Appendix K

Technical Memorandum: Secondary Research

Appendix K Technical Memorandum – Secondary Research

The purpose of this technical memorandum is to summarize the results of the secondary research task of the Twin Cities Ramp Meter Evaluation. This task involved reviewing and summarizing relevant research regarding the benefits and costs of ramp metering strategies employed in other comparable metropolitan areas. Included in this review and summary was the Texas Transportation Institute (TTI) ramp meter study titled "Ramp Metering in Minnesota" by Lomax and Schrank (1). In addition, two cities (Seattle, Washington and Phoenix, Arizona) were interviewed to obtain more detailed insight into the objectives, strategies, successes, and issues with their ramp metering systems.

Each section of this document contains the most recent information and trends regarding ramp metering and includes:

- Section 1.0 – Basics of Ramp Metering,
- Section 2.0 – Extent, Type, and Usage of Ramp Meters,
- Section 3.0 – Metering Goals and Strategies,
- Section 4.0 – Ramp Configurations,
- Section 5.0 – Measures of Effectiveness,
- Section 6.0 – Public Relations Efforts and Public Feedback,
- Section 7.0 – Enforcement Issues,
- Section 8.0 – Future Plans by Implementing Agencies,
- Section 9.0 – Keys to a Successful Ramp Metering Program,
- Section 10.0 – Keys to a Good Ramp Metering Study/Evaluation,
- Section 11.0 – Suggested Interviewees,
- Section 12.0 – Peer City Interviews, and
- Section 13.0 – References.

■ 1.0 Basics of Ramp Metering

Ramp meters, sometimes called "merge lights," are traffic lights installed at freeway on-ramps metering each vehicle that enters the freeways by a certain amount of time. Without metering, vehicles usually enter the freeways in platoons, thus, creating turbulence at the freeway mainline. When the mainline traffic is already at or near its capacity, such turbulence causes even more adverse impacts. This turbulence causes stop-and-go traffic, which often leads to rear-end or sideswipe accidents. Simply put, ramp metering is "one proven method of maximizing existing roadway capacity" (1).

Depending on the type of the hardware, strategies used by the implementing agencies, and physical ramp/freeway/ alternative arterial configurations, the general benefits of ramp meters may include (1-8):

- Increases in freeway productivity, up to 2,700 vehicles per hour per lane (vphpl);
- Reductions in stop-and-go traffic;
- Reductions in sideswipe or rear-end accidents and fatalities;
- Reductions on impacts of recurring congestion due to heavy traffic demand;
- Reductions in fuel consumption from stop-and-go travel;
- Improvements in air quality and other societal goals;
- Delaying or preventing the occurrence of freeway slow speed operations;
- Breaking up of vehicle platoons;
- Promoting easier and safer merging from ramps;
- Reducing emergency or vehicle breakdown response time;
- Encouraging motorists on shorter trips to use arterials; and
- Encouraging motorists to shift travel times or change travel modes.

On the other hand, disadvantages of ramp metering include (1,2,4,7):

- Delays and increased emissions at the ramps – Although the overall travel time is improved and overall emissions are reduced, ramps experience increases in delay time and emissions. Furthermore, time spent waiting at the ramps is normally perceived to be longer, lowering its perceived benefits by the motorists (detailed in Section 5.0).

- Queues extending to the arterials – City agencies have worked hard to prevent such occurrences, because consistent interruption of local traffic will reduce the benefits of the ramp metering program. Depending on the geometric configuration of ramps and metering strategies used, this problem can be easily avoided (detailed in Sections 3.0 and 4.0).

- Higher volumes on the local arterials – Similar to the previous disbenefit, city officials often fear that the ramp delays encourage motorists to use the arterials, which is actually a desired effect for shorter trips. In fact, ramp metering is proven more effective when alternative arterials exist. Nevertheless, to gain support, standard agreements are often made between the highway agencies and local citizens/officials, limiting the traffic volume increases on the alternative arterials. The Oregon Department of Transportation (ODOT), for example, agreed that it would abandon the ramp metering program in Portland (OR) if the arterial volumes increased by 25 percent or more. Fortunately, this did not happen. In fact, studies in Portland and several other cities show that ramp metering did not create any significant traffic increases on the alternative arterials.

- Inequity issues – This is one of the main causes for public opposition to ramp metering. Ramp meters are believed be a disadvantage to citizens that are: 1) traveling on short trips without any alternative routes, and 2) living near the city centers, because freeway systems near the city centers are more likely to be congested, triggering the traffic-responsive ramp meters to impose higher delays. To gain public support, good educational efforts, along with certain compromises must be made (detailed in Section 6.0).

- Expensive – Costs of installation, maintenance, enforcement, and public relations of a ramp metering program can be high. The costs largely depend on the existing ramp geometry, selected controllers, and the extent of the ramp metering system.

- Accidents on the ramps – In Phoenix (AZ), installation of ramp meters caused a substantial increase in rear-end accidents (from two to 82 within six years) at the ramps, while the ramp meters were in operation. When not operating, the mere presence of the meters caused a significant increase in accidents at the ramps (from 34 to 76). However, mainline accidents decreased by 10 percent. Further study is recommended, since this phenomenon has not been well documented in other cities.

- Potential increase in single occupancy vehicle (SOV) use – A good, successful ramp metering campaign that dramatically improves freeway operations may encourage motorists to travel in SOV. But contrary to this opinion, Seattle experienced a 10 to 15 percent increase in HOV lane usage. While further study should be performed to gain conclusive evidence, implementation of ramp metering along with good corridor travel demand management (TDM) strategies may be able to discourage SOV.

- Encouraging longer trips – Along the line of the previous disbenefit, not only is the overall travel demand higher, motorists are also encouraged to travel longer trips.

2.0 Extent, Type, and Usage of Ramp Metering

Extent

By 1995, ramp meters had been installed and operated in 23 metropolitan areas in the U.S. Of these, 11 cities have a system of more than 50 ramp meters, including Minneapolis-St. Paul (Twin Cities) in Minnesota. Los Angeles (CA) has the most ramp meters, with over 1,000 meters in operation. Due to the overall positive benefits and publicized success stories, the number of participating cities is expected to only get larger.

System Warrant

Generally, there are no specific warrants for ramp metering, because of the many local factors involved. The Texas Department of Transportation (TxDOT) compares the peak sum of the ramp and all freeway mainline volumes to a preset table and determines if ramp metering is warranted at such location. Similarly, the Arizona Department of Transportation (ADOT) determines that the peak sum of the ramp volume and the right-most mainline lane volume must be equal or greater than 1,800 vehicles per hour (vph) to warrant ramp metering. If the rightmost mainline lane volumes are not available, ADOT uses the standard developed by TxDOT (7).

Historically, freeway sections that warrant ramp metering usually have the following characteristics (2,4):

- Peak-period speeds less than 48 kph (or less than 30 mph);
- Vehicle flows between 1,200 to 1,500 vphpl;
- High accident rates; and
- Significant merging problems.

Locations for Ramp Metering

There are three types of ramp meter locations (2):

1. **Arterial-to-Freeway Metering –** The most common ramp metering location to date, where ramp meters are installed on the on-ramps between city streets and the freeway.

2. **Freeway-to-Freeway Metering –** Ramp meters are placed on the ramp connectors between two freeways. This type of metering is less common and should only be adopted if there is ample storage room for the queuing vehicles, since freeways carry considerably more traffic than city arterials. Minneapolis-St. Paul and Los Angeles are the only two U.S. cities with extensive use of freeway-to-freeway ramp meters.

3. **Mainline Metering –** Technically, this should not be classified as ramp metering, since it meters the freeway mainline. This metering type should only be used upstream of severe geometric bottlenecks, such as bridges or tunnels, where infrastructure expansion is virtually impossible. More than just the travel time benefits, mainline meters help trucks avoid up-ramp stop-and-go movements on bridges and help improve emergency response times. Two tunnels in Virginia and Baltimore (MD) had mainline meters installed and resulted in positive benefits, but were removed due to public and political pressure. The Bay Bridge in Oakland (CA) has the only operating mainline meters in the U.S.

Controllers

Controllers are the software or logic that meters use in controlling the ramps. The oldest and simplest form of ramp meter controller is fixed-time, where equal delay is imposed on each vehicle no matter how good or bad the mainline condition is operating. On the other hand, new controller technology allows for more sophisticated metering, where metering can adapt to the changes in mainline and ramp traffic conditions.

There are five different types of ramp meter controllers (3,4,8):

1. **Fixed-Time Controller –** This most basic type of controller uses a fixed, pre-set metering rate, which usually ranges between four to five seconds. During the early years, police officers were stationed on the ramps to control the traffic. Relatively easy and cheap to install and operate, this control strategy is not flexible to significant changes in demands, or changes due to accidents/incidents.

2. **Local Traffic Responsive Controller –** This control strategy is directly influenced by the mainline and ramp traffic volumes. When the upstream and downstream freeway volumes are high, metering rates are automatically decreased (higher delays). Conversely, when ramp volumes are to the point where queues reach the city arterials, meter timings can be modified or eliminated. These rate adjustments usually occur about one minute after the data is collected. Generally, traffic responsive controllers result in five to 10 percent greater benefits than fixed-time controllers.

3. **Central Controller –** By centrally controlling the ramp meters within a network, traffic bottlenecks or accidents/incidents that occur several miles ahead can be detected, optimizing further the benefits of ramp metering. Furthermore, metering rates can be balanced among the ramps within the network, promoting equity. Many cities prefer centrally controlled ramp metering as it allows for more extensive monitoring, easier system override, and it improves performance of the transportation system. However, central controllers are very expensive and are more beneficial where recurring congestion exists.

4. **Integrated Controller –** In addition to detecting traffic conditions on the freeway network, the integrated controllers monitor traffic conditions on the alternative arterials. If traffic volumes on the city streets are too high, the meter delays may be reduced to encourage motorists to use the freeway instead.

5. **Fuzzy Logic Controller –** Traffic responsive controllers normally react to, rather than prevent congestion. As mentioned, traffic responsive controllers usually apply metering rates based on traffic data from the previous minute, which may be too late in the case of an accident/incident. Furthermore, traffic responsive controllers are not capable of interpreting erroneous or imprecise traffic data, which often occurs with freeway loop detectors. Fuzzy logic controllers manage to solve these problems by having short-range predictive capabilities, and can be utilized to smooth out and process imprecise or erroneous information.

Several cities, such as the Twin Cities, Seattle (WA), Denver (CO), and Detroit (MI), have adopted the centrally controlled ramp metering strategy. The remaining cities have installed the traffic responsive controllers. Of these, several still operate the ramp meters at fixed-time, due to public and political pressure (1).

During the Twin Cities evaluation effort, the University of Minnesota, with assistance from the Minnesota DOT, conducted a performance analysis of three selected algorithms (rules for operation of the meters) using a macroscopic simulation model with real freeway data. The study was called "Comparative Analysis of Operational Algorithms for Coordinated Ramp Metering" by Eil Kwon and Sreeman Nanduri at the University of Minnesota and Rich Lau and James Aswegan from the Minnesota Department of Transportation. Three algorithms were included in the study: 1) incremental group coordination (Denver, CO); 2) explicit section-wide coordination (Twin Cities); and 3) implicit coordination with fuzzy-logic approach (Seattle, WA).

The performance for each algorithm was analyzed using a simulation model developed at the University of Minnesota. Each of the algorithms were applied to the same freeway segment, a 16-mile section of TH 169 (northbound) which contains 28 entrance and 28 exit ramps. The travel data used for the analysis was collected during the ramp meter shutdown, October 17 and 24, 2000 from 2:00 pm to 8:00 pm.

The results of the algorithm analysis are summarized below:

- Incremental group coordination – Simple algorithm which does not require capacity estimates, resulted in more total congested vehicle hours than the other algorithms, and it is sensitive to detector malfunction.

- Explicit section-wide coordination – Consistently produced less total congested vehicle hours than other algorithms, resulted in more evenly distributed traffic over space and time, requires pre-determined bottleneck location and capacity estimates, and it needs accurate and reliable detection at key locations.

- Implicit coordination with fuzzy-logic approach – Algorithm does not require capacity estimation or pre-determined bottlenecks, less dependent on individual detector malfunctions, performance very sensitive to parameter changes, easy to adjust performance in real time by manipulating rules, and results in less congestion with compatible mainline vehicle miles.

Hours of Operation

In general, most ramp meters across the country operate during the a.m. and p.m. peak periods, which range between 6:30 a.m. to 9:30 a.m. for the a.m. peak, and 2:30 p.m. to 6:30 p.m. for the p.m. peak. Ramp meters with controllers other than fixed-time may turn on or off depending on the traffic volumes or occurrence of accidents/incidents. However, most agencies use standard hours to turn on/off their ramp meters, except in emergencies, for reasons of stability and reliability in the public eye. In San Diego (CA), for example, no manual intervention or ramp overrides are ever allowed.

However, several anomalies exist. In a busy, freeway-dependent city like Los Angeles, 32 ramp meters are operating at all times. As a result of a compromise between the Washington State Department of Transportation (WSDOT) and local neighborhood groups, a ramp meter in Seattle (WA) is only turned on during the p.m. peak (because fewer local commuters use the ramp during the afternoon hours). Due to equity issues, Detroit ramps that are close to the city centers are only metered in the off-peak direction. Another ramp meter in Seattle operates on weekends as well as weekdays.

3.0 Ramp Metering Goals and Strategies

Depending on the goals and objectives of the implementing agency, several types of ramp meter strategies can be pursued. Several factors influence how agencies choose the best strategy for their cities, but the decision is mainly driven by the public, local politicians, and geometric conditions of the ramps (detailed in Section 4.0). The types of ramp metering strategies include (1,5):

1. **Emphasis on Safety –** Under this scenario, safety is the main objective, and metering rates are typically very restrictive (imposing high metering delays). This reduces the traffic flow turbulence, and therefore the number of accidents at the merge areas. Often viewed as too restrictive and controversial, currently there are no agencies adopting this strategy.

2. **Optimize Travel Safety and Efficiency –** Metering rates are less restrictive, since some than Strategy 1 since some emphasis is placed on maximizing the capacity of the freeway. Minneapolis-St. Paul and San Diego are the primary cities implementing this strategy.

3. **Minimize Local Street Impacts –** When queue storage is limited on the ramps, as in the case of Houston (TX) and Arlington (TX), more provisions need to be made to ensure no queues develop on the arterials. However, such compromises decrease the effectiveness of ramp metering. Nevertheless, studies show that some positive benefits are obtained.

4. **Combination of Strategies 2 and 3: Basic Freeway Management –** Due to public and/or political pressure, most cities adopt this strategy as a compromise. Since the public is wary of queues and delay at the ramps, metering rates are adjusted at some cost to the freeway and overall transportation efficiency.

■ 4.0 Ramp Configuration

Geometric Configuration

As mentioned in the previous section, the geometric configuration of the ramps is a key factor in deciding the ramp metering strategy. Since vehicles queue up at the ramps, ample storage room must be available. Increasing ramp storage capacity can be addressed using one of the following approaches:

- **Increasing the Length of the Ramps –** One simple way to provide more vehicle capacity is by increasing the length of the ramps. However, long ramps are expensive and space-consumptive. In urban areas, there is typically not enough room to build long ramps. Furthermore, long ramps may increase violation rates, especially if queues are constantly backed up to the ramp entrance.

- **Two-Lane Ramps –** Another simple way to increase ramp storage capacity is by adding another lane to the ramp. Similar to longer ramps, constructing a two-lane ramp can be an expensive and difficult effort, especially in urban areas.

- **High-Occupancy Vehicle (HOV) Bypass Lane –** When the on-ramp has two lanes, certain agencies prefer to dedicate one of the lanes as an HOV bypass lane, instead of metering both lanes. HOV bypass lanes are sometimes more attractive over two-lane ramp meters because they also promote carpooling and improve transit operations (4). The disadvantage of HOV bypass lanes is the possible increase in violation rates (6).

Experiences in Several Cities

The Minneapolis-St. Paul area has long, two-lane ramps that can store large numbers of vehicles. However, delays at the ramps have been known to be long, as high as 20 minutes. Interestingly, violation rates at these ramps remain low. Nevertheless, the Minnesota Department of Transportation (MnDOT) was able to implement Strategy #2 (Optimize Freeway Safety and Efficiency), largely because of the favorable ramp geometrics.

Conversely, most Texas freeways have frontage roads or arterials that parallel the freeways. Due to the close proximity between the frontage roads and the freeways, Texas on- and off-ramps are extremely short. Because of these unfavorable ramp geometrics, queues build up quickly at the ramps, jeopardizing traffic conditions on the arterials, which led the TxDOT to implement Strategy 3 (Minimize Street Impacts).

Other implementing cities tend to adopt a strategy that falls between Strategy 2 and 3, in part because of their ramp geometric configurations. Since modifying existing ramp configurations for ramp metering is not feasible in most areas, most cities work with the geometrics they already have. If an existing ramp is wide enough to safely accommodate an addition lane, most cities opt to install an HOV bypass lane.

Queue Detectors

If no further infrastructure improvements can be made and extensive queues consistently develop at the ramp, the implementing agency may: 1) increase the metering rates (lower meter delays) to quickly dissipate the queue, or 2) turn off the meters temporarily to flush all of the vehicles off the ramp. To accomplish this, queue detectors are necessary to detect traffic levels on the ramps. According to Havinoski (5), detectors are typically placed at the following locations:

- On the ramp, based on a fixed distance to the ramp meter stop line.
- On the ramp, based on a fixed distance downstream from the ramp entrance.
- Near the cross street, at the ramp entrance.
- On the frontage road, upstream of the ramp entrance – This configuration is more typical for ramps that are connected to the frontage roads, where the length of the ramp is short.
- Multiple queue detector configuration – In Seattle, ramp detectors are placed both in the middle of the ramp, as well as at the ramp entrance. The first set of detectors is used to increase the metering rates. If the queue still builds up and finally reaches the advance detectors, the meters can temporarily turn off to flush the queue off the ramp.

5.0 Measures of Effectiveness

Numerous evaluation studies have been performed on ramp metering systems throughout the world. Depending on the goals and objectives of each program, the measures of effectiveness (MOEs) used for each study are different. Table K.1 lists the MOEs that have been used, along with the trends caused by ramp metering.

Table K.1 List of MOEs

MOE	Trend
Freeway mainline speed	Increases
Accident rate/frequency	Decreases
Freeway mainline occupancy	Decreases
Overall travel time/delay time	Decreases
Freeway mainline volume/flow/stability of flow	Increases and stabilizes
Fuel savings	Increase
Benefit/cost (B/C) ratio	>1.0
Ramp delays	Increase
Arterial vehicle volume	Increases, but insignificant
Overall travel demand	Increases
Public/motorist survey results (qualitative)	Mixed

Source: 1-2.

Table K.2 provides a summary comparison of the Twin Cities evaluation effort to other ramp metering studies that have been conducted dating back to 1975. Where data was available, the table identifies the number of meters, type of control, metering strategy, hours of operation, and the various measures of effectiveness. The following conclusions have been observed from the studies:

- This study's finding of 22 percent savings in freeway travel time is well within the seven percent to 91 percent range observed in other areas (average of 25 percent travel time savings for 13 observations). The 22 percent travel time savings is also within the range of prior studies conducted on ramp metering within the Twin Cities (14 to 26 percent).

- Systemwide crashes for the Twin Cities increased by 26 percent without ramp metering. The average across eight other ramp meter evaluation studies reviewed by the evaluation team is 32 percent reduction in crashes. The range of values for reductions in crashes due to ramp metering is from five percent to 50 percent. In areas with more than 50 meters, the average crash reduction is 29 percent.

Table K.2 Comparison of Twin Cities Evaluation Findings to Other Ramp Meter Evaluation Studies

Location	Twin Cities	Abilene	Arlington	Atlanta	Austin	Denver
State/Country	**MN**	**TX**	**TX**	**GA**	**TX**	**CO**
Study Date	**2000**		1999	1996	1997	1982
Number of Ramp Meters in Study	**431**		5	5	3	28
Total Number of Ramp Meters	**431**		26	>50		
Type	**Mostly central control, few fixed**		Fixed, 4 sec cycle	Fixed		Central control
Strategy[1]	**2**		3	2-3		
Hours of Operation	**Varies, peak period**		6:15-8:30 a.m.	3:45-6:30 p.m.	a.m. peak	
Freeway Travel Time Impacts	**-22%**	-13%	-10%	-10%	-37.5%	-26.7% to -37%
Freeway Speed Impacts	**+7 mph**	+22%			+60%	+35.5 to +58%
Impact on Crashes	**-26%**					-5% to -50%
Traffic Volume and Throughput	**+9% to +14%**				+7.9%	+19%
Emissions Impacts	**1,161 tons annually**					+24%
Fuel Impacts	**+22,000 gallons/day**	-6%				
Benefit/Cost Ratio	**5:1 to 15:1**	62:1		4:1 to 20:1		
Average Ramp Delays	**+2.3 min/veh**					
Arterial Volume Impacts	**Insignificant**					+300 vph

Table K.2 Comparison of Twin Cities Evaluation Findings to Other Ramp Meter Evaluation Studies (continued)

Location	Detroit	Houston	Long Island	Los Angeles	Milwaukee	Minn-St. Paul
State/Country	**MI**	**TX**	**NY**	**CA**	**WI**	**MN**
Study Date		1997	1987 to 1990, 1991	1975	1995	Several, 1975 to 1996
Number of Ramp Meters in Study	28		60	259	6	Varied
Total Number of Ramp Meters	49	<50	75	808	43	431
Type	Central control	Fixed	Traffic responsive and central control	Traffic responsive	Traffic responsive and central control	Mostly central control, few fixed
Strategy[1]		3		2-3	2-3	2
Hours of Operation		6:30-9:30 am, 3:30-6:00 p.m.		Varies, 32 all day	Varies, 6-9 am, 3:00-6:30 PM	
Freeway Travel Time Impacts	-7.4%	-22%	-13% to -20%	-13%		-13.8% to -26.5%
Freeway Speed Impacts	+8%	+29%	+9% to +21%	+15 mph	+3% to +35%	+14% to +60%
Impact on Crashes	-50%		-15%	-20%		-24% to -29%
Traffic Volume and Throughput	+14%		0% to +7%	900 vpd	+22%	+8% to +40%
Emissions Impacts	124,600 tons annually		+17.4% CO, +13.1% HC, -2.4% NOx			2.2 million kg annually
Fuel Impacts			-6.7%	-13%		
Benefit/Cost Ratio						7.3:1
Average Ramp Delays			1.2 to 3.4 vehicles			0.1 to 2.5 minutes
Arterial Volume Impacts	Insignificant			Insignificant		

Table K.2 Comparison of Twin Cities Evaluation Findings to Other Ramp Meter Evaluation Studies (continued)

Location	Phoenix	Portland	Sacramento	Seattle	Zoetemeer	M6 Motorway
State/Country	**AZ**	**OR**	**CA**	**WA**	**Netherlands**	**England**
Study Date	1989 to 1995	1982	1984	1981 to 87	1995	1986
Number of Ramp Meters in Study	9	16	9	22	9	1
Total Number of Ramp Meters	121	58	19	105		
Type	Fixed	Fixed	Traffic responsive	Central Control, fuzzy logic		Fixed
Strategy[1]	2-3	2-3	2-3	2-3		
Hours of Operation	5:30-9:00 a.m., 2:30-6:30 p. m.	6:30-9:30 a.m., 3:00-6:30 p.m.	7:00-9:00 a.m.	6:30-9:00 am, 3:00-6:30 p.m.		
Freeway Travel Time Impacts		-7.4% to -39%		-47.7% to -91%	-13%	
Freeway Speed Impacts	+5 to +10%	+7.5% to +155%		+20-25%	+15%	
Impact on Crashes		-43%	-50%	-38%		
Traffic Volume and Throughput	+15%	+25%	+3% to +5%	+62% to +86%	+3%	+3.2%
Emissions Impacts						
Fuel Impacts		540 to 700 gal/day				
Benefit/Cost Ratio	5:1 to 10:1			10:1 or more		
Average Ramp Delays				< 3 min	+20 sec	+1.5 min
Arterial Volume Impacts				Insignificant		<5% diverted from fwy

[1]Metering Strategies: 1 = Emphasis on safety; 2 = Optimize Travel Safety and Efficiency; and 3 = Minimize Local Street Impacts.

Abbreviations: sec = seconds, min = minutes, hrs = hours, mph = miles per hour, vph = vehicles per hour, HOV = high-occupancy vehicle, VMT = vehicle miles traveled, fwy = freeway, veh = vehicle, kg = kilograms.

- This evaluation shows that there is a 14 percent increase in freeway throughput due to ramp metering. The average for the 12 other studies reviewed by the evaluation team is 18 percent, with a range from zero percent to 86 percent. Long Island, Phoenix, Portland, and Seattle (cities with more than 50 meters) show an average of 38 percent increase in freeway throughput.

- Other evaluation studies have limited impact information related to emissions impacts of ramp metering. Three other metropolitan areas (Denver, Detroit, Long Island), which evaluated emissions as part of their ramp meter study, showed some improvement in overall emissions due to ramp metering. Long Island showed a 6.7 percent increase in NOx, and the improvements in CO and HC of 17.4 and 13.1 percent, respectively.

- Four areas which evaluated fuel consumption impacts of ramp metering showed savings due to ramp metering ranging from about six percent to 13 percent. However, as mentioned in Section 7.0 of this report, the fuel consumption analysis used in this evaluation used a simple straight-line estimation technique which does not address the tempering of flow typically due to ramp metering, by smoothing the travel speed variability (less acceleration and deceleration).

- There is limited information on benefit/cost ratios of ramp metering evaluations. This current study's benefit/cost ratio of 5:1 for the entire congestion management system and 15:1 for the ramp metering costs only are within the ranges seen for other areas. For five areas (Abilene, Atlanta, Phoenix, Seattle, and previous Minneapolis/St. Paul evaluation efforts), the range of benefit/cost ratios is from 4:1 to 62:1, with an average of 20:1.

6.0 Public Relations Efforts and Public Feedback

Most quantitative studies and evaluation results show that ramp metering has achieved numerous positive benefits, including reduced travel time and accident rates. However, these are benefits quantified and seen by the implementing agencies, but the results are often not communicated to the public. Like most other public works projects, the citizens are the customers, and to ensure the success and/or longevity of these projects, customer understanding and satisfaction are important.

In fact, city agencies believe that support from the public and local politicians are crucial to the success of ramp metering. Some of the public relations (PR) efforts that have been done in various implementing cities are listed below (1-3):

- Support from local politicians.
- Positive reviews from local media.
- Public meetings and input sessions.
- Publicity (media, ads, brochures, billboards, free keychains/pins, etc.).
- Educational efforts (free videotapes and classes).
- Compromises and agreements – As in the case of Portland (arterial volumes not to increase by 25 percent or more), Seattle (one ramp activated only in the p.m. peak, lower meter delays near downtown), Detroit (metering the downtown ramps only in the off-peak direction), and Milwaukee (equal metering rates within the network).
- Catchphrases – Coin slogans that are easy to understand and remember, and highlight certain benefits/solutions to problems that citizens would like to have. For example, New York City (NY) calls their ramp meters "Merge Lights," stressing the safety benefits of ramp meters in the merging areas. Houston launched a publicity campaign with the catchphrase "Go With the Flow," highlighting the travel time benefits of ramp metering.

The following highlights some of the typical customer feedback from users of ramp metering systems (1):

- In Portland (OR) and San Jose (CA), citizens saw positive results and tangible benefits from ramp metering. In both cases, the positive reviews came from highly publicized benefits of ramp meters and public surveys performed by the local media.
- In Houston (TX), the public was split between realizing the "positive benefits" and "no real change" of ramp metering. This was largely due to the short ramps, which forced TxDOT to adopt the least beneficial strategy (detailed in Section 4.0).

- In the Twin Cities (MN), the public generally had positive perceptions towards ramp metering, but it has been declining. Mainly, citizens realize benefits of ramp metering, but think that the ramp delays are too long. Interestingly, violation rates still remain low at these ramps. Again, because of the strategy chosen by MnDOT (#2 – Optimize Travel Safety and Efficiency), the ramps are set to be more restrictive, while realizing additional delays at the ramps.

7.0 Enforcement Issues

Newman et al. (6) indicate that a good ramp metering enforcement strategy can result in violation rates as low as five percent. Generally, it is imperative to keep violation rates below 10 to 20 percent, otherwise public trust may start to deteriorate. The following lists a few reasons why compliance rates may tend to drop (1,2,6):

- **Lack of police enforcement –** Since police officers are often needed to respond to emergency calls, consistent police enforcement is difficult and expensive.

- **Diminished returns –** Over time, the public may lose their perceptions on the benefits of ramp metering, as experienced in Minneapolis-St. Paul.

- **Presence of HOV bypass lanes –** Since freeway HOV violation rates tend to be high, motorists may be reluctant to comply with HOV bypass lane regulations.

- **Technical problems –** Public trust can deteriorate significantly if ramp meters experience technical breakdowns on a frequent basis. Also, since the ramp metering controllers are date- and time-sensitive, agencies must remember to adjust for daylight savings time changes.

- **Extensive ramp delays –** Although no studies have been performed to prove this hypothesis, long delays are expected to increase violation rates.

- **Light punishment –** Again, no studies have been done to support this suggestion, but light punishment may tempt motorists to violate more often. Newman et al. (6) believed that "an increased fine might help to offset some of the expense of police enforcement, while a more publicized penalty might reduce violations."

The following lists some ramp meter enforcement strategies that have been implemented by various agencies across the country (6):

- **Consistent police enforcement –** Though costly, police enforcement is the most effective enforcement strategy.

- **Video enforcement –** Video enforcement may not be a very accurate method of enforcement, due to high false-identification rates. However, the presence of video cameras may deter motorists from violating.

- **Reporting system –** In Seattle, WSDOT launched the "HERO" program, which allows motorists to report violators via a toll-free number. The violators will then receive warnings by mail. Initially, the program resulted in a significant reduction in the violation rate. Over time, however, as violators realized that no further action would be taken, the program lost its effectiveness.

8.0 Future Plans for Ramp Metering Systems by Implementing Agencies

Below are some of the future goals set by several transportation agencies, to continuously improve upon their existing ramp metering program (1):

- **Install more meters –** Cities with small to medium-sized ramp metering programs usually set this future goal, a clear indication that the existing program has achieved a certain level of success and acceptance in the eye of the public.

- **Install centrally controlled meters –** Cities with fixed or traffic responsive controllers plan to install centrally controlled systems to achieve greater benefits through this more efficient and extensive ramp metering program.

- **Upgrade computer systems –** Denver, which already has a centrally-controlled ramp metering system, hopes to upgrade its computer hardware and software systems. The upgrade is expected to make the program more effective and efficient.

■ 9.0 Keys to a Successful Ramp Metering Program

Based upon the secondary research, the following lists some of the strategies for a successful ramp meter program.

- **Select the right place –** In order to realize significant positive benefits of ramp metering, it is necessary to implement ramp metering in freeway sections that actually need it. As discussed in Section 2.0, appropriate locations typically have the following characteristics: peak-period speeds less than 30 mph, flow of 1,200 to 1,500 vphpl, high accident rates, and significant merging problems.

- **Secure funding –** Before embarking on a ramp metering program, make sure that the local politicians and city officials are committed to funding the program. In some cases, public-private partnerships can forge a more secure funding situation.

- **Start small and simple –** Cities trying to implement ramp metering for the first time should start with a few ramps, with a fixed-time control, adopting a more conservative strategy (Combination of Strategy 2 and 3 – Basic Freeway Management, or 3 – Minimize Street Impacts).

- **Excellent public support –** All implementing cities believe that public education and support are critical to the success of their ramp metering programs (detailed in Section 6.0).

- **Ample storage capacity –** Most cities would like to have longer and wider ramps, to prevent queues from extending beyond the ramps, onto the arterials. If long queues with backups onto the arterials occur on a consistent basis, good queue detection systems, and adopting a more conservative strategy (Strategy 3 – Minimize Street Impacts) may be necessary (detailed in Section 4.0).

- **Synergy –** Use other forms of Intelligent Transportation Systems (ITS) to eliminate disadvantages found in ramp metering alone (i.e., ramp delays or increases in arterial volumes). Agencies may couple ramp metering with ramp queue wait time signs or an Advanced Traveler Information System (ATIS) that can inform motorists of crowded ramps, or provide motorists with options of different travel modes, times, or routes.

- **Avoid conflicting solutions –** Mainline freeway HOV lanes and ramp meters are two freeway management solutions that may not work well together. In some cases, mainline HOV lanes are believed to dilute the benefits of ramp metering (3). Without HOV bypass lanes or direct HOV connectors, metering may impose unnecessary delay to buses and carpools.

- **Eliminate technical problems –** Make sure the system is free from technical breakdowns, to sustain high public trust and compliance rates (detailed in Section 7.0).

- **Consistent enforcement –** A study by Newman et al. (6) showed that consistent police enforcement, though costly, is the most effective enforcement strategy (detailed in Section 7.0).

- **Continuous improvement –** Upgrade the fixed or traffic responsive controllers to central or fuzzy logic controllers. Central control offers greater benefits because it can monitor an entire system, while fuzzy logic controllers eliminates the possibility of processing and applying imprecise or erroneous traffic data (Section 2.0).

■ 10.0 Keys to a Good Ramp Metering Study/Evaluation

Based upon the secondary research, the following summarizes some of the strategies agencies can use to obtain a successful ramp metering evaluation study.

- In an area where ramp meters have been in operation for a long period of time, a "without ramp metering" study may be necessary. If the area has experienced significant changes over the years ramp metering has been in place, using the "before ramp metering" data collected prior to deployment is unlikely to be relevant with today's conditions.
- Since fixed-time ramp metering is believed to be a disbenefit for freeway sections that are not congested (by unnecessarily delaying motorists at the ramps), these meters may be deactivated temporarily, to study the differences in benefits.
- When comparing evaluation results from other areas with ramp metering, consider that the differences in benefits can be attributed to:
  - Strategy adopted,
  - Ramp geometric configuration,
  - Population/population growth,
  - Freeway lane miles,
  - Travel rate index – measure of additional time required to complete a peak-period trip compared to the same off-peak trip,
  - Travel delay per person – measure of time wasted each year in hours by each person in the urban area due to heavy traffic, and
  - Roadway congestion index – traffic density measure showing relationship of vehi cle-miles of travel to lane-miles of roadway. When this index reaches 1.0, the roadways in the urban area are considered congested at an area-wide level.
- A good ramp metering study/evaluation effort should possess the following characteristics:
  - Short intervals for data collection (20 seconds to 15 minutes),
  - Long duration (at least several weeks),
  - Automated data collection effort as much as possible,
  - Studies of travel behavioral changes, especially the use of alternative arterials/ routes/modes/travel times,
  - Study of accident rates at the freeway mainline, as well as on the ramps,
  - Analysis of a larger study area (to determine systemwide benefits/costs),

- Analysis of travel time versus waiting time versus perceived waiting time, and
- Analysis of the benefits and costs using local data, instead of national data (i.e., local value of time, inflation, etc.).

■ 11.0 Suggested Interviewees

Case studies of a few implementing agencies were desired in order to obtain more detailed information regarding the strategies, objectives, successes, and issues related ramp metering systems in similar metropolitan areas. The following list contains some of the implementing agencies which were considered for the case studies as part of the Minnesota Ramp Metering Evaluation. Seattle, Washington and Phoenix, Arizona were included in the case studies and the results from these interviews are located in Section 12.0. Included within the following list are the potential lessons that can be learned from the agencies, as well as each agency's contact person(s).

1. **Location:** Seattle, Washington
   Agency: Washington Department of Transportation (WSDOT)
   Contact: Mr. Morgan Balogh
   15700 Dayton Avenue North
   P.O. Box 330310
   Seattle, Washington 98133
   (206) 440-4485
   baloghm@wsdot.wa.gov

Potential Lessons:

- Why Seattle's benefits are so substantial compared to Minneapolis-St. Paul's,
- New 'aggressive' model,
- Long history in politically-based decisions,
- Excellent publicity and educational campaigns (keychains to videotapes),
- Updates on the "HERO" program, and
- Effectiveness of the multiple queue detection configuration.

2. **Location:** San Diego, California
   Agency: California Department of Transportation (Caltrans)
   Contact: Ms. Carolyn Rumsey
   (858) 467-3029
   carolyn_rumsey@dot.ca.gov

Potential Lessons:

- Similarities/differences in the strategy adopted (Strategy 2 – Optimize Travel Safety and Efficiency),
- Elimination of HOV bypass lanes,

- Good system and management, and
- Benefits/costs data.

3. **Location:** Phoenix, Arizona
   Agency: Arizona Department of Transportation (ADOT)
   Contact: Mr. Tim Wolfe or Mr. Jim Shea
   2302 W. Durango Street
   Mail Drop PM02
   Phoenix, Arizona 85009
   twolfe@dot.state.az.us
   (602) 712-6622 (office)
   (602) 712-3394 (fax)
   (602) 370-6301 (cellular)
   (602) 662-4630 (pager)

Potential Lessons:

- Ramp metering strategies from a different perspective,
- More laid back management style,
- More 'static' system relative to Seattle or Minneapolis-St. Paul, and
- Why ramp accidents are so high.

4. **Location:** Atlanta, Georgia
   Agency: Georgia Department of Transportation
   Contact: Mr. Joe Stapleton
   #2 Capitol Square, S.W.
   Atlanta, Georgia 30334-1002
   (404) 656-5423

Potential Lessons:

- Ramp metering strategies from a different perspective,
- More laid back management style, and
- More 'static' system relative to Seattle or Minneapolis-St. Paul.

5. **Location:** San Francisco Bay Area, particularly San Jose, California
   Agency: California Department of Transportation (Caltrans) – District 4
   Contact: Ms. Laurie A. Guiness
   1120 N. Street
   Sacramento, California 95814
   (916) 654-6112

Potential Lessons:

- Similar institutional problems as Minneapolis-St. Paul,
- Common technical problems ('issues') with the ramp meters, and
- Benefits/costs data.

12.0 Peer City Interviews

Of the five cities listed in previous section, two cities were selected to be interviewed. The two cities include Seattle (WA) and Phoenix (AZ). They were selected based upon recommendations from the Technical Committee and the Expert Panel. The results of the interviews (9,10) are summarized below.

Seattle, Washington

Seattle started the implementation of ramp meters in 1981, and continues to expand today and into the future. Currently, the Seattle metropolitan area has 105 metered ramps, serving approximately 8,000 lane-miles of freeway. Approximately 85 ramps (80 percent) have HOV-bypass lanes and 20 ramps (20 percent) have dual metered lanes. The average length of the ramps is approximately 750 feet, ranging from 500 to 1,200 feet. The meters are centrally controlled, and normally activated during the weekday a.m. and p.m. peak periods (6:30 to 9:00 a.m. and 3:00 to 6:30 p.m.), but few exceptions exist.

Recently, Seattle implemented a new metering algorithm that "adjusts the meters … based on neural network programming." Washington Department of Transportation (WSDOT) claims it to be more responsive, an improvement over previously used algorithms.

According to WSDOT, the objective of Seattle's ramp metering program is to "improve safety and efficiency" (Strategy 2). This alludes to the conclusion that Seattle has the same strategy as Minneapolis-St. Paul. However, based on further comparative analysis between the two cities, Seattle is less stringent with its metering strategy, and probably should not be considered as adopting Strategy 2. In fact, Lomax and Schrank (2) believe that Seattle's strategy falls between Strategy 2 and 3 (Basic Freeway Management).

WSDOT considers its ramp meter program in Seattle to be very successful, largely due to coupling this program with a solid HOV program. Integration between metering, mainline HOV and HOV-bypass lanes is done as often possible. Furthermore, a substantial amount of time and effort is always invested into working with the communities near a metering system prior to activation. This way, public support has always been excellent, while violation rates remain very low (less than two percent).

Queue lengths are found to be the main constraints to the program. While the ramp metering strategies are area-wide, further refinements are performed at the corridor and community level, to address the constraints. Again, good local community relations are necessary to achieve mutual goals between the agency and the citizens.

When news of the Minnesota Ramp Meter Evaluation project reached Seattle's legislature and local media, skepticism regarding the usefulness of the metering program started to re-appear, something which has not occurred in recent years. WSDOT took this opportunity to re-educate the public about the benefits of ramp metering, and the questions "quickly ended."

Currently, Seattle undergoes collision avoidance studies at the freeway merging areas. Since accident reduction studies typically look at crashes that had occurred, collision avoidance studies analyze reductions in "near misses" or almost-accidents. Generally, ramp meters reduce the potential conflicts at the merging areas by about 30 to 60 percent.

Phoenix, Arizona

The Arizona Department of Transportation (ADOT) started to implement stand-alone ramp meters in Phoenix during the mid-1980s, but did not implement any ramp meter systems (series of meters along a given corridor) until 1995. Currently, the Phoenix metropolitan area operates 121 ramp meters, of which 22 ramps (18 percent) have HOV-bypass lanes and 21 ramps (18 percent) have dual lanes. Ramp lengths vary greatly between ramps, all ranging between 500 feet (older ramps) to 1,300 feet (newer ramps).

The majority of the ramp meters are centrally controlled and capable of adapting to traffic patterns, but operated under fixed-time control. The fixed-time delays range between 3.5 to 15 seconds, which is about the maximum threshold for ramp delay per vehicle. ADOT believes that delays beyond 15 seconds per vehicle would increase violation rates.

Most ramp meters in Phoenix are activated during the a.m. and p.m. peak periods (6:00 a.m. to 9:00 a.m. and 4:00 to 7:00 p.m.), except at ramps near freeway construction zones, where meters are turned on 24 hours per day.

ADOT's main objective for the ramp meter program in Phoenix is to improve the current Freeway Management System, and to "break up platoons." ADOT believes that its ramp meter program has been a tremendous success in Phoenix, especially because of the city's grid system (one square-mile grids throughout the metro area). Unlike Minneapolis-St. Paul, where often geographical constraints such as rivers and lakes force commuters to get on the freeway, Phoenix's grid system provides alternative routes for the short-trip commuters, especially during peak periods. Furthermore, since the grid system is in place in both the downtown and suburban areas, no multiple strategies need to be adopted in Phoenix.

Like Seattle, queue lengths are found to be the constraints of the program. In the past, queue detectors were placed to detect when and how far queues have extended at (or beyond) the ramps. However, continuous adjustments (week-to-week or month-to-month) and balancing between the city street and freeway volumes have proven to be more effective methods in preventing extended backups. Two full-time technicians have been allocated to manage and maintain all ramp meters in the Phoenix metropolitan area.

There has been little or no public involvement both prior to and after the implementation of ramp metering. Still, public and media perceptions are generally positive. According to ADOT, the number of complaints and praises received regarding ramp meters are almost equal one to another.

ADOT raised an interesting issue with respect to their metered ramps with HOV-bypass lanes. Since these ramps have dual lanes (one for all vehicles, the other for HOV or transit only), dual left-turn lanes are often placed on the arterials leading to the ramps. But during the heaviest periods, backups sometimes reach the end of the ramps, even extending towards the left-turn lanes and beyond. The HOV-bypass lanes carry less traffic than their counterparts, leading the regular lane to become very congested while the HOV-bypass lane remains empty. Out of frustration, motorists are found to switch over to the empty left-turn lane and use the HOV-bypass lane illegally. In Phoenix, this situation results in a violation rate of over 45 percent. Under normal circumstances, the ramp meter violation rate is approximately 10 percent. Because of this, ADOT is starting to favor operating dual lane ramp meters over a metered lane with an HOV-bypass lane.

Recently, ADOT passed the legislative effort in raising the amount of fines that can be levied against violators, up to $619. The large sum caused uproar among the citizens and in the local media, but early results show that violation rates have decreased substantially.

As much as possible, ADOT prefers to expand its ramp metering system in Phoenix in conjunction with other freeway management or construction projects. Every system addition requires strong relationships with local city agencies and governments. But so far, there are no political controversies caused by ramp meters.

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