4.0 Evaluation Methodologies

The evaluation goals, objectives, and performance measures presented in the previous section provided the framework for the evaluation. This section presents an overview of the methodologies that were employed to collect and analyze data for the study. The entire *Evaluation Plan* is included as Appendix L.

■ 4.1 Overview of Evaluation Methodologies

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

Data collected during a second period were used to evaluate the "without ramp meters" scenario. In this scenario, *all ramp meters were deactivated systemwide*. The deactivated ramp meters were set to "flashing yellow" mode – consistent with their normal operation during off-peak periods. It is important to note that, during the ramp meter deactivation period, all other congestion management systems were fully operational, including incident detection and camera surveillance.

Although all ramp meters throughout the system were deactivated during the test, the data collection effort was focused on four selected corridors. These corridors were selected as representative of other corridors throughout the metropolitan region. Other systemwide data were 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 were conducted. This effort included both focus groups and surveys conducted during both the "with" and "without" scenarios.

Data collection occurred over a five-week period during both the "with" and "without" scenarios. "With ramp meter" data collection occurred between September 11th (following the Labor Day holiday and the return of normal fall business and school activity) and October 15th, 2000. The public was informed on October 9th that the ramp meters were to be deactivated the following Monday, October 16th.

The goals of the data collection schedule were:

- To provide adequate time for the collection of the "with ramp meters deactivation" data;
- 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
- To not provide so much advance notice that the resulting induced behavioral change would in some way taint the data collection following the deactivation of ramp meters.

The ramp meters remained deactivated from October 16th through November 17th, thereby enabling data collection to conclude prior to the onset of the Holiday shopping season.[1] Following the conclusion of the "without" scenario test, data analysis was conducted to isolate the incremental impact observed between the two scenarios during this time. These incremental impacts were then extrapolated and combined with other data to support the regionwide analysis of ramp meter effectiveness.

To support the evaluation, several data collection and analysis efforts were conducted. Each effort focused on a specific aspect of the study. Yet, all the data collection and analysis efforts were carefully coordinated. The parallel data collection and analysis activities are summarized as follows.

- **Corridor Selection (Section 4.2) –** In this effort, the evaluation team defined corridor selection criteria and selected corridors for data collection.
- **Field Data Collection for Selected Corridors (Section 4.3) –** In this effort, the evaluation team collected field data at selected corridors.
- **Market Research (Section 4.4) –** This activity involved focus group and survey data collection.
- **Benefit/Cost Analysis (Section 4.5) –** In this activity, data collected for the selected corridors were extrapolated to develop estimates of regionwide impacts.
- **Secondary Research (Section 4.6) –** In this effort, the evaluation team conducted research to compare and contrast the ramp metering system in the Twin Cities with systems in other national and international locations.

Subsequent sections in this section provide detail on the methodology employed in each activity and provide specifics on the conduct of the various evaluation tasks.

[1] The meters remained deactivated until December 8th, during which time Mn/DOT conducted an interim policy review and then reactivated the meters in a modified operating mode.

■ 4.2 Corridor Selection

Collecting field data on the entire Twin Cities transportation system would have required an extraordinary amount of resources. In order to make better use of evaluation resources and meet the demanding schedule requirements of the project, the evaluation team instead focused the field data collection on several select corridors that are representative of other corridors throughout the entire system. These data were then extrapolated to the entire system.

The key to corridor selection was to select study corridors that are representative of most of the freeway corridors in the Twin Cities Metropolitan Area so that the results could be extrapolated to the entire freeway system. The first task in the corridor selection was 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 allowed 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:

1. **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 from suburb to suburb.

2. **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).

3. **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.

4. **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 was 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.

4.2.1 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 and balance within the Twin Cities Metropolitan Area;
- Construction activity on freeway and alternate routes;
- HOV lanes and bypass ramps;
- Transit service on corridor;
- Geometric constraints;
- Traveler market segments; and
- Representative corridor length.

4.2.2 Identification of Candidate Corridors

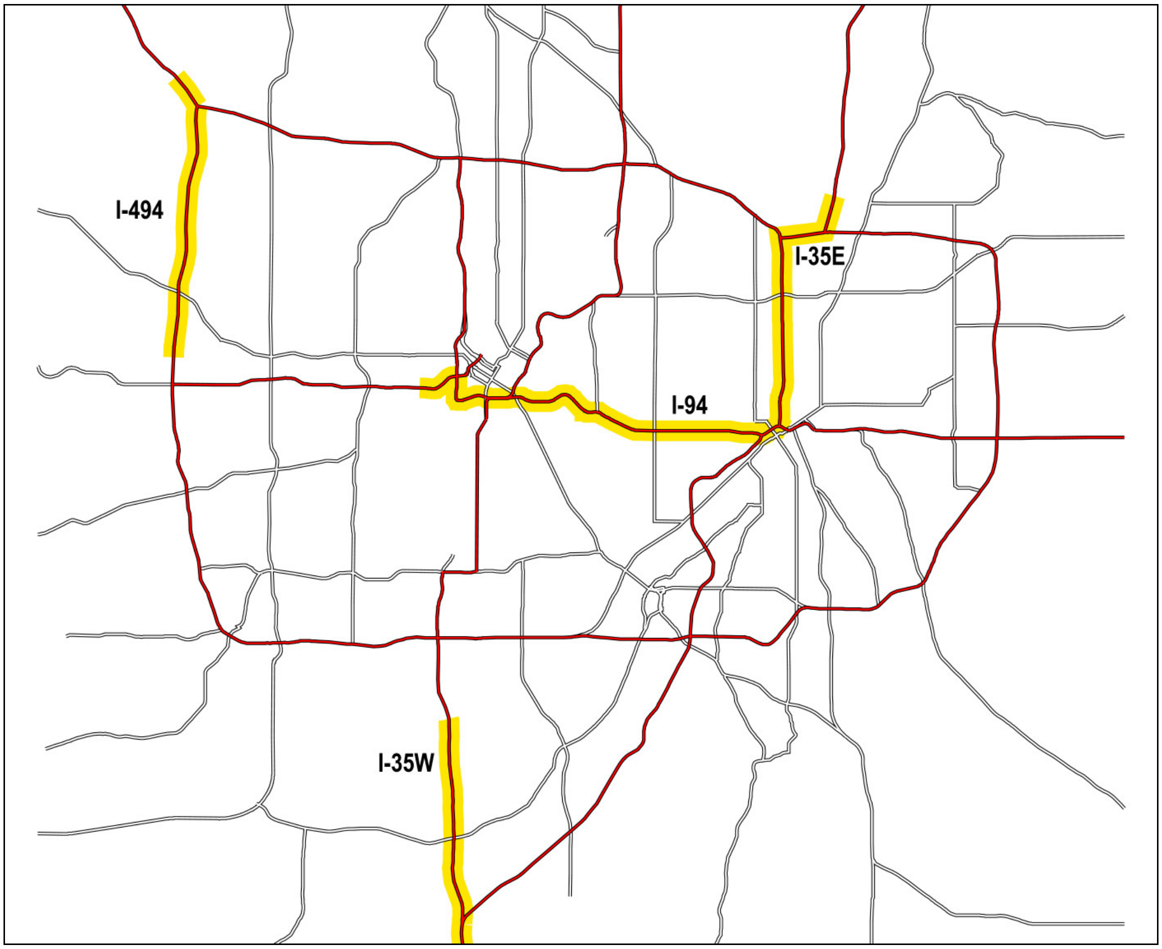
The CS team applied the corridor selection criteria to freeway sections throughout the Twin Cities Metropolitan Area and identified an initial list of 11 freeway corridors that adequately met the primary selection criteria. The entire study *Evaluation Plan* (September 20, 2000) is presented as Appendix G and provides details on the traffic and geometric characteristics of these candidate corridors. Next, the CS team gathered detailed information on the 11 candidate corridors and applied the selection criteria to these corridors, resulting in the selection and presentation of nine candidate freeway corridors for review by the Technical and Advisory Committees.

4.2.3 Selection of 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 within the Twin Cities Metropolitan Area. The four corridors selected for the study are shown in Figure 4.1 and described as follows:

1. **I-494 Corridor –** As shown in Figure 4.2, 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 –** As shown in Figure 4.3, 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.

Figure 4.1 Twin Cities Corridors Selected for Detailed Evaluation



3. **I-94 Corridor –** As shown in Figure 4.4, this corridor serves traffic demand between downtown Minneapolis and downtown St. Paul.

4. **I-35E Corridor –** As shown in Figure 4.5, this corridor serves commuter traffic between the northern residential communities and various employment destinations further south.

■ 4.3 Field Data Collection

The premise of the field data collection was to measure the transportation system impacts of the ramp metering system in the Twin Cities Metropolitan Area. This task involved an extensive "with ramp metering" and "without ramp metering" traffic data collection program to address the impacts on traffic operations and safety. Traffic data were collected at specific ramps and along selected corridors within the region over several weeks for both

Figure 4.2 I-494 Corridor

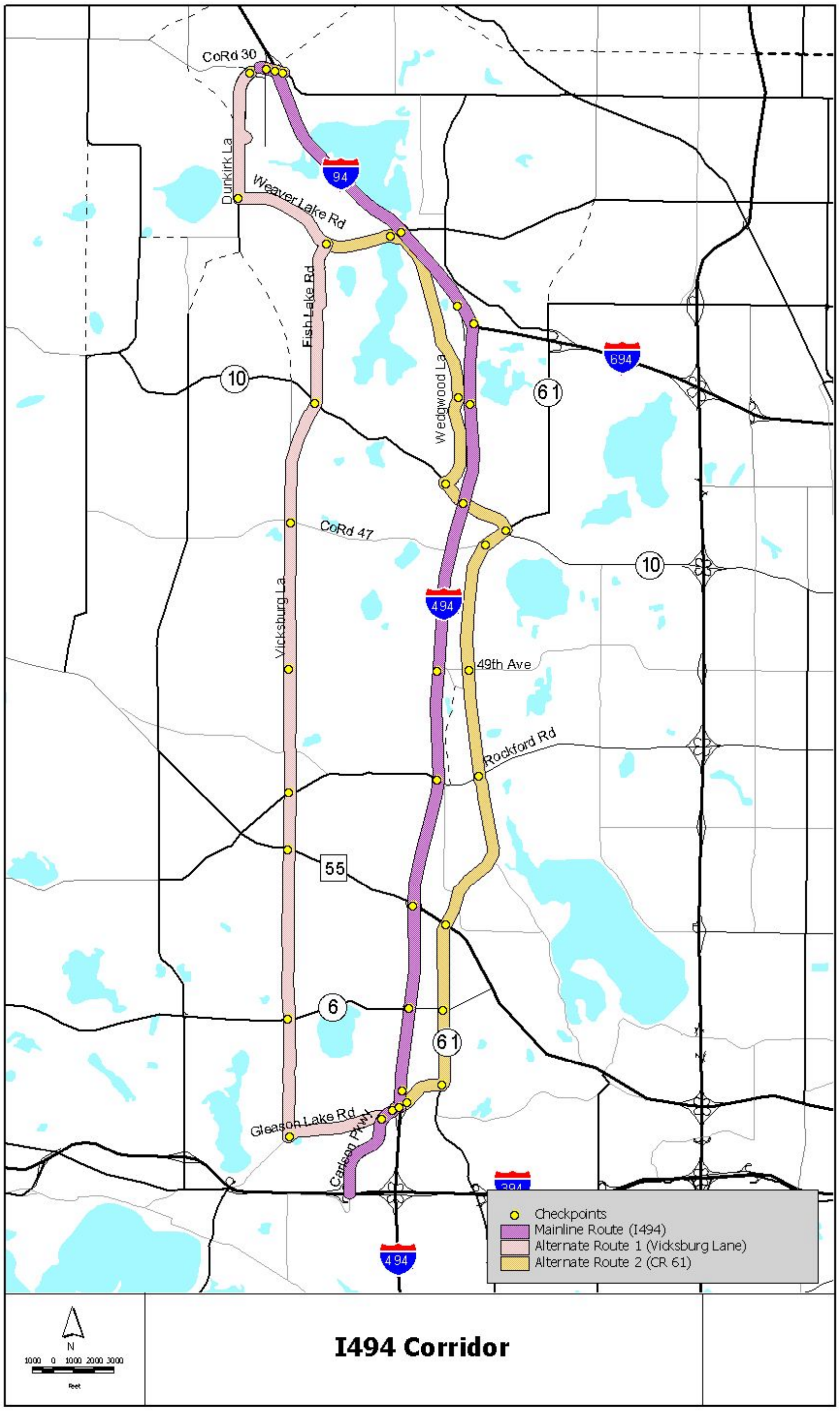


Figure 4.3 I-35W Corridor

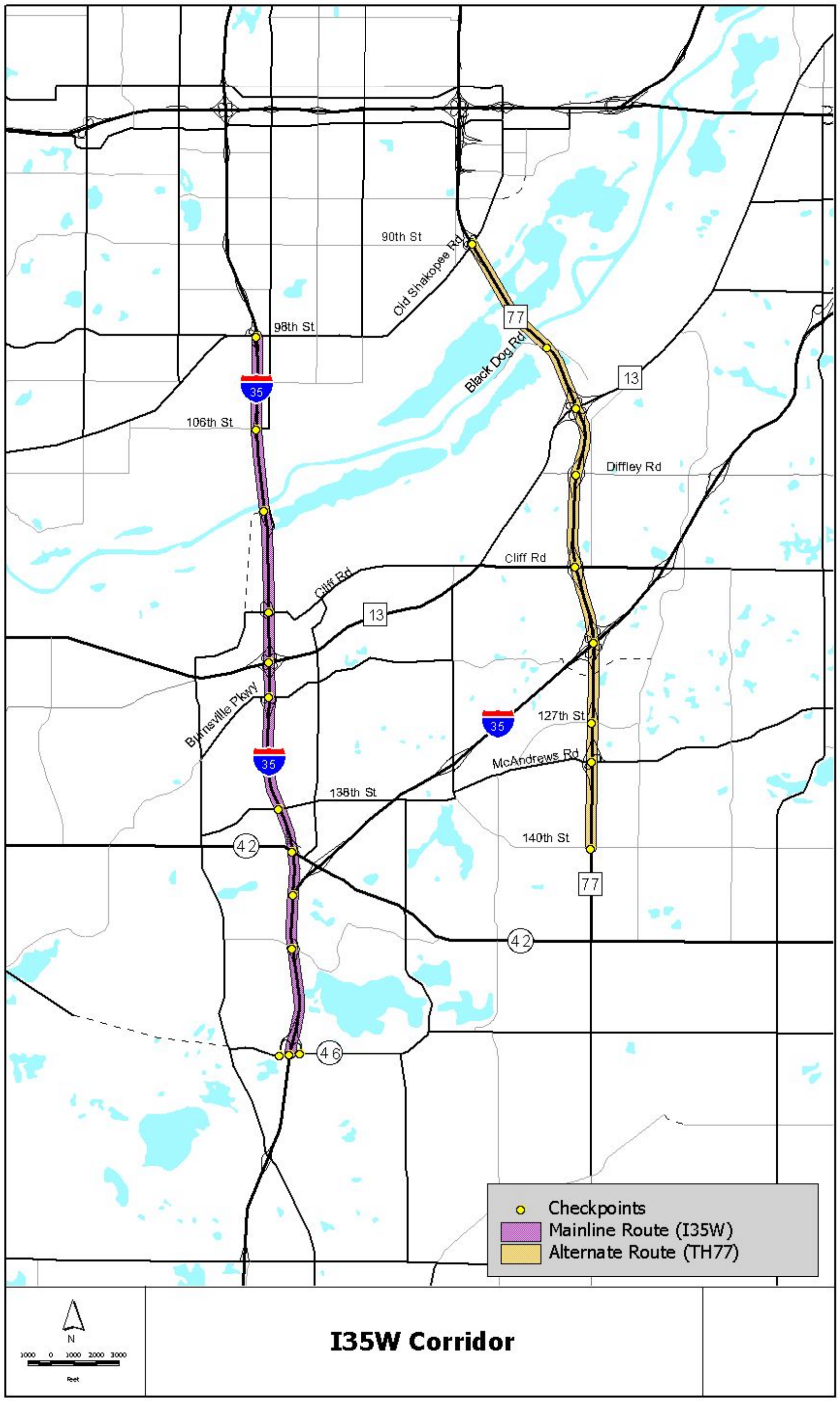


Figure 4.4 I-94 Corridor

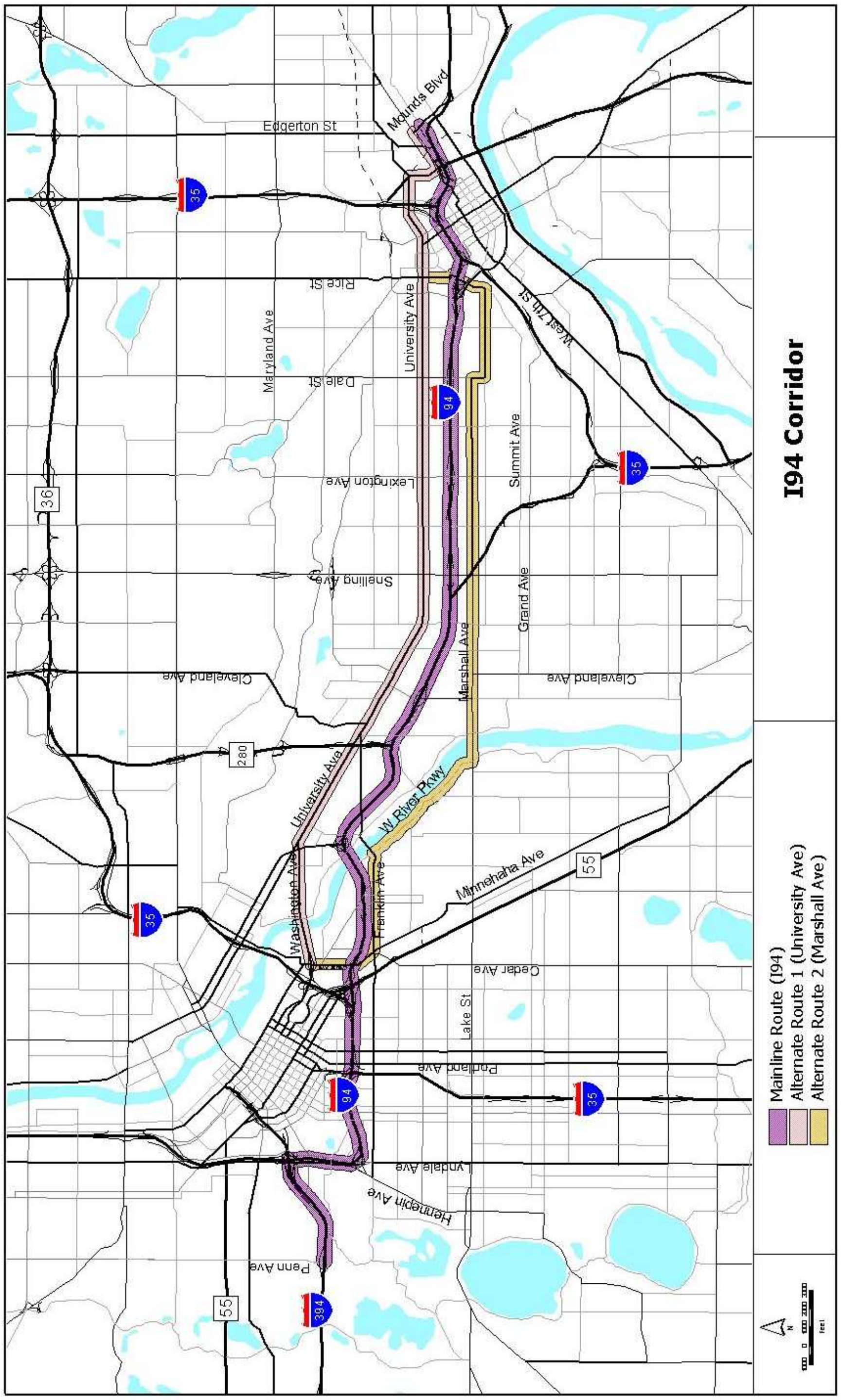
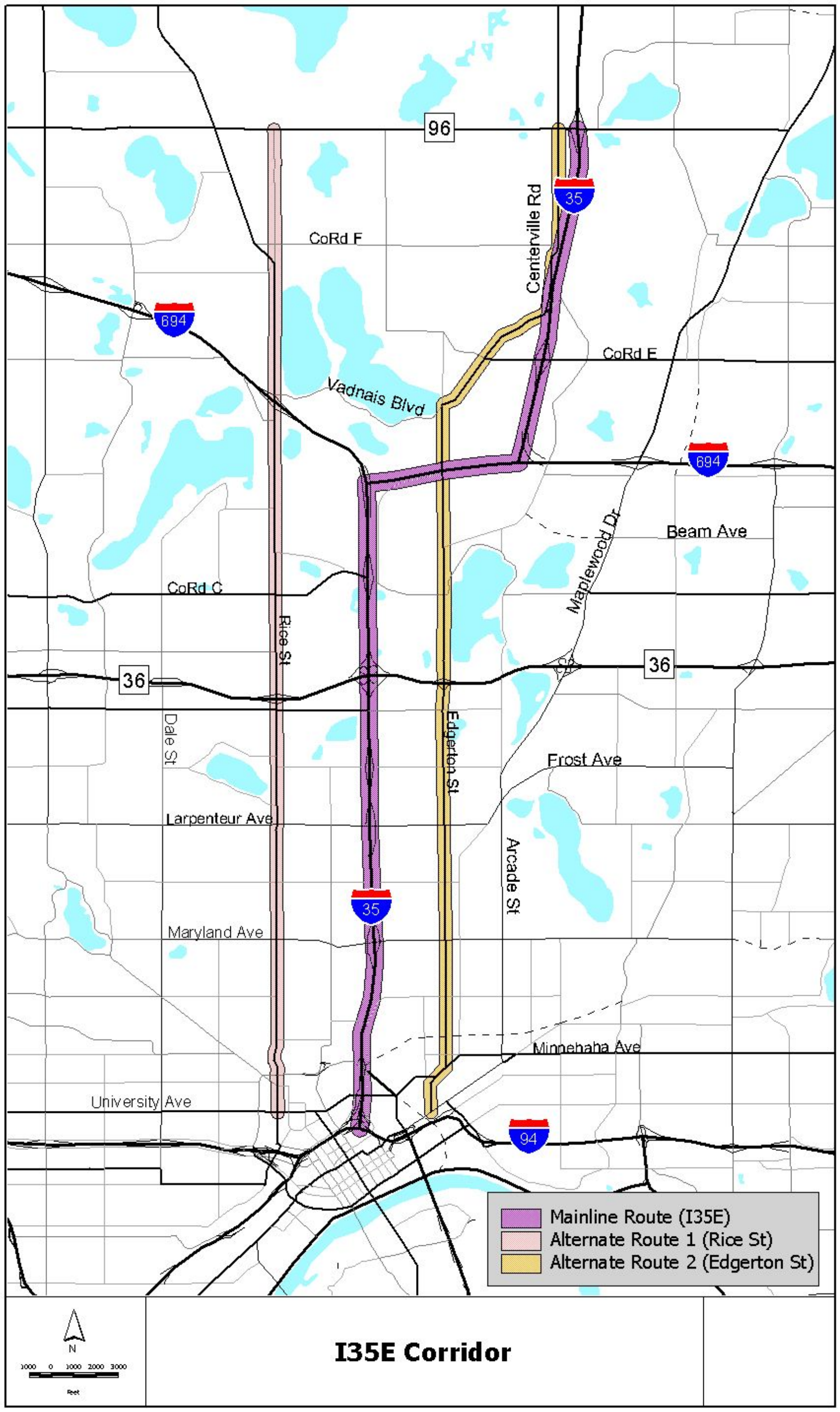


Figure 4.5 I-35E Corridor



the "with" and "without" ramp metering evaluation scenario. Data collection occurred during the morning and afternoon peak periods for approximately 3.5 hours per peak period from Monday through Friday within the evaluation timeframe. Ramp operational studies were conducted during hours the ramps are metered. Subsets were created for Monday and Friday data, and for Tuesday through Thursday data.

The following types of field data were collected to evaluate and quantify the transportation system impacts with and without the ramp metering system:

- Traffic flow data;
- Travel time data;
- Ramp impact data;
- Crash data; and
- Transit usage data.

The main external influences on the system's performance were weather, changes in the transportation system (lane closures, repairs, etc.), incidents causing traffic delays (crashes, stalled vehicles, etc.), and major events. During both the "with" and the "without" study periods all data collected on bad weather days (rain/snow), bad incident days, and dark versus light conditions were flagged. The data were then grouped and analyzed in separate categories. If a statistically significant difference was found between groups, the data were analyzed separately and comparisons were made for data under similar weather/light/incident conditions. Also, the data were analyzed across groups to identify differences in the effectiveness of ramp metering under the varying conditions. Finally, all data were analyzed to measure the effects of peak-period spreading. The following subsets were created with the data:

- **Pavement condition:** Dry, Wet, or Snow Covered;
- **Presence of incidents along corridor:** Yes or No;
- **Light condition:** Light (sunrise to sunset) or Dark (sunset to sunrise); and
- **Day of the week:** Monday, Friday, or Tuesday through Thursday.

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

- Data collection personnel were trained by data collection supervisors;
- Data collection supervisors made periodic spot checks on personnel in the field;
- Data were inspected on a daily basis to ensure that the data was reasonable; and
- In the event that equipment problems were encountered, backup data collection equipment was deployed, whenever possible.

Specific measures of effectiveness and their corresponding data sources are presented in the sections that follow for each of the five data types.

4.3.1 Traffic Flow Data

Traffic flow data were collected to examine the traffic flow impacts of the ramp metering system. These data included traffic volume and occupancy data from freeway mainline detector stations and volume data from alternate routes. Two different data collection methods were 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.

Freeway Mainline Traffic Volume and Occupancy – Data from the Mn/DOT Traffic Management Center (TMC) freeway loop detector stations were collected along each of the corridors under evaluation. The following information pertains to freeway data:

- **Sample Size:** Thirty-second traffic volume data per lane, 24-hours per day. Data were aggregated to 15-minute periods during the a.m. and p.m peak periods. Data were also aggregated to daily totals. Four-hour peak periods selected to allow analysis of any peak-period spreading.

- **Data Collection Methods and Tools:** Detector data were downloaded remotely/electronically from the Mn/DOT TMC. The evaluation team run daily automated checks of the data. Spreadsheets and databases were be used to process the data.

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

- **Sample Size:** Fifteen-minute volumes per lane during the a.m. and p.m. peak periods. Data were also aggregated to daily totals.

- **Data Collection Methods and Tools:** Arterial route data were collected during the same period as the corresponding freeway route. Spreadsheets and databases were be used to process the data.

4.3.2 Travel Time Data

These data were collected to examine the travel time impacts of the ramp metering system. Statistically significant samples of actual running speeds over the four freeway corridors and corresponding alternate routes were collected. Travel times and distances were recorded from probe vehicles driven along the corridor by members of the evaluation team. The "floating car" method was 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 were used to capture the travel time profiles at discrete intervals. One GPS-equipped vehicle was used on each freeway (and alternate route) corridor. Three additional vehicles were equipped with traditional distance measuring instruments (Jamar™) to gain enough travel time data to produce results meeting a 95 percent confidence interval. The specified measuring error was +/-two mph for freeways, and +/-one mph on the alternate routes.

Data were collected in both directions of travel along the corridor. 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. Further detail on the travel time data collection approach is provided below:

- **Sample Size:** The first step in determining the sample size was to identify the desired level of accuracy. The bounds of statistical error were selected based on the Institute of Transportation Engineers (ITE) Traffic Engineering Manual (pages 95 to 96). With ramp meters/without ramp meters 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. A sample size of approximately 21 travel time runs in the a.m. and p.m. peak periods each were required in order to obtain a statistically significant sample size.

- **Data Collection Methods and Tools:** The data collection team used a total of seven probe vehicles equipped with GPS and Jamar™ equipment. Probe vehicle drivers recorded weather, pavement conditions, light conditions, construction activity, and incidents; this enabled 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.

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 were 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.

- **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 were 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 were only 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.

- **I-94 Corridor –** This corridor serves traffic demand between downtown Minneapolis and downtown St. Paul. The western end of the travel time runs passed through the Lowry Hill Tunnel with a turn-around made via I-394 and Penn Avenue in Minneapolis. The eastern turn-around was at Mounds Boulevard in St. Paul. Traffic flow is primarily bi-directional with congestion experienced in both directions during both the morning and afternoon peak periods. There are two alternate routes for this corridor. To the north of I-94, University and Washington Avenues 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.

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

4.3.3 Ramp Impact Data

A variety of techniques were used to assess the operational impacts of ramp metering at freeway on-ramps. Ramp traffic volume data and ramp meter turn-on times were readily available from the TMC system. Data collected at metered ramps include ramp queue length and delay, HOV lane usage and ramp meter violations, frequency of the ramp queue backing into intersection, and quality of merge.

- **Sample Size:** Data were collected at ramps within the defined test corridors during the a.m. and p.m. peak periods Monday through Friday. All data were collected in 15-minute intervals.

- **Data Collection Methods and Tools:** Jamar equipment were used to record when vehicles entered and exited the ramp queue. At least two observers were positioned at each ramp. The Jamar software was used to calculate queue length and vehicle delay at the ramp. Spreadsheets and databases were be used to process the data.

4.3.4 Safety Impact Data

Crash data were assembled to examine the safety impacts of the ramp metering system. The TMC incident logs were 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 was reviewed to collect the number of crashes within the Twin Cities Metropolitan Area. This data were 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 were collected and analyzed as described below.

- **Data Collection Methods and Tools:** TMC incident log data were assembled for the four study corridors; the TMC documents number and duration of incidents on freeways that are monitored by the traffic management system. Metro-wide crash data were collected from Mn/DOT's automated crash log system. Crash data were also assembled for the previous two years.

- **Analysis Methods:** Crash data were separated by different facility types; by metered versus unmetered freeways; by crash type (rear-end, side-swipe, etc.); by crash severity (property damage only – PDO, injury, fatality); and by time of day (crash data while meters are in operation versus data in the off-peak while meters are off-line). Spreadsheets and databases were be used to process the data.

4.3.5 Transit Impact Data

These data were collected to examine the impacts to transit caused by the ramp metering system. Numerous data sources were used and performance measures were collected.

Transit Vehicle Travel Times and Transit Ridership Data

Transit vehicle travel times and ridership data were collected on a sample of transit routes running on the mainline and alternate travel routes on three of the four selected corridors including I-94, I-35E and I-35W. No transit data were collected on the I-494 corridor due to a lack of suburb-to-suburb transit service.

- **Sample Size:** Transit data were collected on a sampling of transit routes on the mainline and/or alternate travel routes for one week within three of the four selected corridors during the a.m. and p.m. peak periods.

- **Data Collection Methods and Tools:** Metro Transit used AVL-equipped buses to collect travel time data on I-94. Metropolitan Council used radio checks and field observations to collect travel time data on I-35E. Minnesota Valley Transit Authority used radio checks to collect travel time data on I-35W. Metro Transit, Metropolitan Council and Minnesota Valley Transit Authority collected transit ridership data using both electronic farebox data and manual driver tally sheets.

Park-and-Ride Facility Usage

Park-and-ride utilization data were collected at a sample of facilities serving transit routes on three of the four selected corridors including I-94, I-35E and I-35W. Utilization data at 12 park-and-ride facilities were collected on three days over a one-week period during both the with ramp meters and during periods. Morning peak period auto travel time data collection personnel manually collected these data through field observations directly after completion of the a.m. peak travel runs. Data included a count of the park-and-ride lot occupancy count.

■ 4.4 Focus Groups and Traveler Survey Methodology

As part of the primary market research task, a qualitative and a quantitative approach to evaluating travelers' attitudes toward ramp metering was adopted. The objective of the qualitative research was to elicit travelers' overall reactions to the operation of ramp meters in the Minneapolis/St. Paul area roadway system and the expected impact of shutting down the ramp meters on travelers' general travel patterns. The qualitative market research was structured to provide:

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

The quantitative market research was based on the design, fielding, and statistical analysis of an extensive set of surveys from travelers in the Minneapolis/St. Paul metropolitan area. These surveys included both a random sample of area travelers, as well as four corridor-specific samples that focused on the area's freeway corridors for which traffic and travel time data were also collected. These surveys were fielded twice, both before and after the experimental ramp metering shutdown resulting in a set of five "with ramp meters" and five "without ramp meters" survey samples. The quantitative market research gathered socioeconomic, travel, and attitudinal information that was analyzed to assess:

- Travel behavior and ramp usage patterns, as well as differences between the "with ramp meters" and "without ramp meters" surveys that reflect the impacts of the ramp metering shutdown,
- Changes in travelers' "with ramp meters" and "without ramp meters" attitudes toward ramp meters that could be attributed to the ramp metering experiment, and
- Differences in travel patterns and attitudes that could be attributed to the different corridors under study and the various segments of the market.

This section discusses in some detail the individual elements of the evaluation approach. It documents the objectives, recruitment criteria, and moderator guide that were used during the focus groups that were conducted to obtain qualitative insights into travelers' behavior and perceptions both before and after the shutdown (Section 4.4.1). It then summarizes the license plate data collection effort that provided the sampling frame for both waves of the corridor surveys (Section 4.4.2).

Sections 4.4.3 and 4.4.4 outline the contents and discuss the elements of the survey instruments used for the random sample and corridor samples in each survey wave. It first presents in detail the survey design for the "with ramp meters" wave of data collection and then focus on the differences in survey design that were incorporated in the "without ramp meters" data collection.

4.4.1 Focus Group Methodology

The main purpose of the 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 of the two evaluation periods:

"With Ramp Meters" Evaluation

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

"Without Ramp Meters" Shutdown Evaluation

- What are travelers' general attitudes and perceptions toward the ramp meter shutdown experiment?
- 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 ("with ramp meters") and November 14, 2000 ("without ramp meters"), two focus group sessions were held in Bloomington, MN for each of the two evaluation periods. A screener questionnaire was developed and used for the recruitment of focus group participants that met the selection criteria described below. Appendix K presents a technical report detailing recruitment techniques and focus group methodology.

Four focus group 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 northbound and southbound between I-94 and I-394, I-35W north toward Minneapolis, and I-35E northbound 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 6:00 a.m. to 9:00 a.m. or 3:00 p.m. to 6:00 p.m. Additionally, separate focus groups were conducted based on the frequency of travel as follows:

1. **Light Ramp Users –** Travelers who make a total of one to five trips per week on average; and
2. **Heavy Ramp Users –** Travelers who make a total of six 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. There were no major differences in the comments of the light and heavy ramp user groups.

4.4.2 Sampling Frame and Survey Logistics

During each of the data collection waves, before and after the ramp metering shutdown, two types of telephone surveys were conducted. A random sample of respondents in the seven-county metropolitan area was drawn along with four targeted samples of corridor users along each of the four corridors under study. This section describes the process of drawing the random and corridor samples, discusses the sample sizes for each type of survey, and outlines the survey implementation process.

Sampling Frame. The random sample was developed by means of random digit dialing and included all travelers who traveled during the a.m. peak period between 6:00 and 9:00 a.m. or during the afternoon peak period between 4:00 and 7:00 p.m. The sampling frame included Minnesota residents in the seven-county Minneapolis/St. Paul metropolitan area. Respondents working for state and local transportation agencies, media outlets, and market research firms were excluded from the sample.

The corridor-specific samples were based on license plate data collected at locations along each of the test corridors (Table 4.1). License plate data were collected over the course of seven workdays days using a total of nine staff members. A total of 58,000 license plate numbers were collected, a sample size that proved adequate for sampling purposes for both "with ramp meters" and "without ramp meters" corridor surveys.

The representativeness of the corridor sample was supported by the variety of locations in which license plate numbers were collected (Appendix A). A total of 92 shifts were spread over 45 locations in the four corridors under study. During the second day of data collection, the location of a staff member by the freeway during the evening peak period may have caused delays to I-94 users. Because of this early problem with that specific location, the data collection plan was modified to include a mix of freeway locations and ramp entrances to the corridors.

The corridor sample was limited to automobile drivers and passengers in the designated corridors. The license plate numbers were then processed by the Department of Public Safety (DPS) so that they could be converted to Minnesota residential telephone numbers and names. This database was subsequently used to contact I-494, I-35E, I-35W, and I-94 corridor users within the study area.

Table 4.1 Distribution of Survey Returns for "With Ramp Meters" and "Without Ramp Meters" Surveys

	I-494	I-35W	35E	I-94	Random Sample
"With ramp meters" Corridor Surveys					
Refused to be interviewed	25	28	36	32	133
Has not driven in corridor	91	125	145	161	–
Terminated on security	5	9	7	12	22
Has not driven on a weekday or during peak	30	55	33	27	63
Terminated during interview	6	4	10	14	19
Completed interview	126	125	125	133	253
Total	**283**	**346**	**356**	**379**	**490**
"Without ramp meters" Corridor Surveys					
Refused to be interviewed	18	15	39	29	136
Not aware of shutdown	11	12	16	31	56
Has not driven in corridor	90	152	91	122	–
Terminated on security	9	7	17	8	19
Has not driven on a weekday or during peak	15	33	18	17	52
Terminated during interview	3	5	6	4	15
Completed interview	128	128	127	127	252
Total	**274**	**352**	**314**	**338**	**530**

At the outset of the project, 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 by targeting such groups since all vehicles and passengers experience similar traffic conditions; therefore, the conclusions which emerge from the general random samples can be applied to all travelers. The desirability of including Wisconsin residents in the I-94-corridor sample was also discussed and rejected. It was the preference of the Advisory Committees to limit the sample to residents of the seven county metro area. In addition, inclusion of Wisconsin residents would have complicated the data conversion process since assistance would have been required from the Wisconsin Department of Public Safety. Since the inclusion of Wisconsin residents would have lengthened the average commuting distance of the I-94-corridor sample, their exclusion could have had some impact on the results for this one corridor given the differences in attitudes which emerged based on average trip length. However, the impact of this variable was well captured by the existing data.

Sample Sizes. A total of 1,520 telephone surveys were collected for purposes of this analysis. The total sample size was equally split between the two waves of "with ramp meters" and "without ramp meters" data collection. The sample sizes by type of survey and by data collection wave were distributed by corridor and for the entire study area as follows:

- A "with ramp meters" random digit-dial sample for the seven-county metropolitan area before the ramp meter shutdown (N = 253);
- Four "with ramp meters" random samples of travelers in each of the four corridors under study with approximately 125 observations per corridor and a total of 507 observations across the four corridors distributed as follows:
  - 126 observations for I-494 users,
  - 125 observations for I-35W users,
  - 125 observations for I-35E users, and
  - 131 observations for I-94 users.
- Five "without ramp meters" surveys were completed as part of the survey effort following the ramp meter shutdown resulting in a total sample size of 760 observations distributed as follows:
  - 252 observations for the random sample,
  - 127 observations for I-494 users,
  - 127 observations for I-35W users,
  - 127 observations for I-35E users, and
  - 127 observations for I-94 users.

Survey Implementation. The survey design was extensively tested during its development starting with informal testing in the office of the various pencil and paper versions of the survey as it evolved into its final form. Testing also continued during the conversion of the survey from a paper and pencil format to a computer-aided programmed telephone interview. The survey design was thoroughly reviewed by the project's Advisory Committees. Formal pre-testing was also conducted on 38 surveys, resulting in the elimination of 10 surveys from the sample. Finally, throughout the survey data collection effort, three monitoring stations staffed by senior staff members were used to ensure the quality of the survey effort.

A special effort was also made to keep the length of the survey as short as possible to maximize participation rates. The objective was to structure the survey so that all of the relevant information could be collected, while maintaining the interest of the respondent by keeping the length of the survey less than 20 minutes. The average length of the survey for the corridor sample was 15 minutes while the average length of the random sample survey was 12 minutes.

The response rates were very satisfactory as shown in Table 4.1 with a very high cooperation rate obtained from respondents. The refusal rate was an extremely low 8.8 percent. Another indicator of the cooperation of the respondents was the lack of missing responses across all variables in the survey. Even for the traditionally sensitive question related to respondents' income levels, only 9.4 percent of the responses were missing, indicating respondents' interest in the survey topic and their high level of cooperation. This response rate is indicative of the high level of interest in the ramp metering study in the metro region.

4.4.3 Design of the "With Ramp Meters" Surveys

An important component of the survey design was the reliance on respondent-friendly wording of questions to ensure that traffic engineering concepts were successfully communicated to travelers. Surveys were customized for each corridor and the survey questions were customized to each respondent's travel pattern to increase the realism of the survey to individual respondents and to enhance the response rate.

To avoid any ordering biases, individual questions within a sequence of questions were also rotated randomly across respondents. Furthermore, the attitudinal questions were worded using a mix of positive and negative wording for questions related to metering to minimize any response biases that could be attributed to wording. Finally, the surveys were programmed and data were collected using a computer-aided telephone survey to minimize data entry and processing errors and to facilitate the tabulations of "with ramp meters" and "without ramp meters" for statistical analysis.

The structure of the "with ramp meters" telephone survey included the following groups of questions (Appendix 4A):

- **Screener questions** that included the identification of travel in one of the corridors 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. were selected for the interview. Interviews with respondents working for Mn/DOT, planning agencies, media outlets, and city/county public works departments were discontinued.

- Information on the characteristics of the last typical **peak period trip** on the freeway corridor, including the following:

  – Trip purpose, origin, and destination both at the town/suburb level and at the intersecting street level of detail;

  – Vehicle occupancy and by-pass lane usage;

  – Estimated total travel time and freeway travel time;

  – Ramp entrance and exit to/from the freeway of interest;

  – Wait time at ramp entrance meter and at any other freeway-freeway meter(s);

  – Frequency of using the freeway during a week;

  – Experience with longer ramp wait times and willingness to wait at a ramp; and

  – Experience with alternate routes, shifts in departure time, and use of alternate ramps.

- A battery of **attitudinal statements** regarding their travel experiences in general and their experience with ramp meters in particular. Ramp-related questions included travelers' attitudes toward ramp wait times, safety considerations, predictability of travel, and the usefulness of ramp by-pass lanes.

- **Demographic** information that was used to control for potential differences among respondents.

- A **polling** question that asked respondents their opinion whether the meter system should be kept "as is," modified in some way, or shut down permanently and the suggestions respondents had if they thought that modifications were needed.

4.4.4 Design of the "Without Ramp Meters" Surveys

The sampling frame, survey design, and data collection effort for the telephone surveys that were distributed after the ramp meter shutdown followed the process adopted for the "with ramp meters" surveys. The intent was to replicate as closely as possible all elements of the survey process to ensure that the resulting two sets of databases were comparable.

The differences between the "with ramp meters" and "without ramp meters" survey instruments reflected the changes that were introduced by the ramp meter shutdown experiment. The differences between the "with ramp meters" and "without ramp meters" surveys can be summarized as follows:

- All questions related to ramp **meter wait times** were dropped, since meters were not in operation during the without period.

- A set of **retrospective questions** was added to assess whether travelers felt they were better or worse off in the absence of ramp metering. Respondents were asked if their total travel time, freeway travel time, and traffic conditions had improved; stayed the same; or deteriorated as a result of the meter shutdown.

- The battery of **attitudinal questions** that assess travelers' perceptions of the ramp meter system in the "without ramp meters" survey were worded in the past tense to make reference to the impact of the shutdown. An introductory statement was also added to aid travelers in their response.

- A question to address whether there was a potential **media bias** in reporting the shutdown was also included in the survey.

■ 4.5 Benefit/Cost Analysis

The benefit/cost analysis extrapolated the findings from the field data for the selected corridors and market research to produce estimates of regionwide impacts. A traditional spreadsheet benefit/cost model was used to conduct the regional extrapolation of data and benefit/cost analysis.

The analysis method involved the use of spreadsheet models to extrapolate data from the four selected corridors to the regional scale. All regional corridors were classified similar to the selected corridors. Metered corridors in the Twin Cities metropolitan area were categorized based on the following criteria:

- Geographic location and roadway attributes,
- Level of congestion and directionality of traffic,
- Geometric constraints and availability of alternative routes, and
- Traveler market segments based on the traveler survey results.

Corridors not fitting completely within a single category were assigned to two or more categories using percentages. Table 4.2 shows the corridor categorization scheme used in the benefit/cost analysis.

Observed traffic flow impacts from the selected corridors were then applied to all ramp metered corridors according to their specific corridor type. Impact values were applied to the resulting performance measures and formed the basis for the benefit/cost analysis. This methodology is well accepted for conducting analysis of this type and was applied in an expedient manner suitable to the project schedule requirements.

In developing an estimate of system costs associated with ramp metering, the CS team considered equipment and other costs directly associated with ramp metering, as well as portions of the supporting infrastructure. The cost analysis methodology accounted fully for costs directly attributable to the ramp metering system (e.g., ramp signals); and also accounted for a proportion of costs for supporting deployments based on percentage of overall functions devoted to ramp metering. This approach provides a full accounting of equipment without accruing costs attributable to unrelated systems. Other costs incorporated in the analysis include:

- Operational costs (electricity, communications, etc.);
- Operational personnel costs;
- Maintenance costs (replacement equipment, etc.);
- Maintenance personnel costs;
- Management costs; and
- Research and development costs (ramp meter wait time indicators, evaluation studies).

In order to ensure a conservative approach, all costs related to the operation of the entire congestion management system (CMS) in the Twin Cities region were then measured against the estimated benefits of only ramp metering. This study did not take into account benefits resulting from the operation of other CMS components, including incident management, changeable message signs, and camera surveillance equipment, which remained fully operational throughout the study.

Table 4.2 Categorization of Metered Corridors in the Twin Cities

		Corridor Type				
Corridor	**Between**	**A**	**B**	**C**	**D**	
I-35E	I-35 Junction and TH77		60%		40%	
I-35E	TH77 and I-494		60%		40%	
I-35E	I-494 and Downtown St. Paul			10%	90%	
I-35E	Downtown St. Paul and I-694				100%	*
I-35W	I-35 Junction and I-494		100%			*
I-35W	I-494 and Downtown Minneapolis			30%	70%	
I-35W	Downtown Minneapolis and I-694			10%	90%	
I-35W	I-694 and Lexington		80%		20%	
I-94	Century Avenue and Downtown St. Paul		10%	10%	80%	
I-94	Downtown St. Paul and Downtown Minneapolis			100%		*
I-94	Downtown Minneapolis and I-694			30%	70%	
I-94 (I-694)	I-694 Junction and CR30	100%				
I-394	Downtown Minneapolis and TH100			60%	40%	
I-394	TH100 and TH169			30%	70%	
I-394	TH169 and I-494			10%	90%	
I-494	Mississippi River and TH54	90%		10%		
I-494	TH5 and TH169	25%		75%		
I-494	TH169 and I-394	80%		20%		
I-494	I-394 and I-94 Junction	100%				*
I-694	I-35W and I-94 Junction	100%				
TH10	University and Round Lake (Anoka Co.)		80%		20%	
TH36	I-35E and I-35W	10%		20%	70%	
TH62	TH55 and I-35W	10%		70%	20%	
TH62	I-35W and TH100	10%		70%	20%	
TH62	TH100 and I-494	20%		70%	10%	
TH77	I-35E and I-494		100%			*
TH77	I-494 and TH62			10%	90%	
TH100	I-494 and TH62			70%	30%	
TH100	TH62 and I-394			70%	30%	
TH169	I-494 and TH62			40%	60%	
TH169	TH62 and I-394	5%		40%	55%	
TH169	I-394 and I-94/I-694	15%		20%	65%	

Type A = Freeway section representing the I-494/I-694 beltline (commuter, heavy commercial, and recreational traffic);

Type B = Radial freeway outside the beltline (with a major geographic constraint presenting limited alternative routes);

Type C = Intercity connector; and

Type D = Radial freeway.

*Denotes actual test corridors.

To annualize ramp meter costs, the evaluation team developed a current year snapshot cost estimate of all equipment currently deployed. This annual cost estimate includes:

- Capital costs of equipment based on total cost divided by the anticipated equipment life, and
- Annual operation and maintenance costs added to average annual capital cost to calculate total annual cost.

This method provides a snapshot of costs for the current year suitable for comparison with the estimation of benefits for the same year. The Technical and Advisory Committees provided significant input in the development of the cost analysis methodology.

4.6 Secondary Research

The purpose of this activity was 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. The CS team reviewed, verified, and validated a currently unpublished Texas Transportation Institute (TTI) ramp meter comparison study. Activities in this task included:

- 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.
- A summary of the benefits, impacts, and costs of ramp metering from studies done across the country.

The CS team also identified and searched 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, including:

- 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 also interviewed and/or surveyed individuals from two metropolitan areas with ramp meters to fill in any missing gaps in the TTI study. The two telephone interview sites included Phoenix, AZ; and Seattle, WA. The two sites were selected so as to represent different ramp metering strategies across the United States.