# MINNESOTA URBAN PARTNERSHIP AGREEMENT

# NATIONAL EVALUATION: TRAFFIC SYSTEM DATA TEST PLAN


**U.S. Department of Transportation**
**Research and Innovative Technology Administration**
**Federal Highway Administration**
**Federal Transit Administration**

**FINAL**
**November 17, 2009**
**Publication No. FHWA-JPO-10-011**

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# NATIONAL EVALUATION:
# TRAFFIC SYSTEM DATA TEST PLAN

By

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Prepared for

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16. Abstract

This report presents the traffic system data test plan for the Minnesota Urban Partnership Agreement (UPA) under the United States Department of Transportation (U.S. DOT) UPA Program. The Minnesota UPA projects focus on reducing congestion by employing strategies consisting of combinations of tolling, transit, telecommuting/TDM, and technology, also known as the 4 Ts. The test plan builds on the Minnesota UPA National Evaluation Plan. The traffic system data test plan identifies the traffic data needed to analyze the congestion reduction impacts of the Minnesota UPA projects. The data sources, data availability, potential risks, data analysis methods, and schedules and responsibilities are described.

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| | |
|---|---|
| 4Ts | Tolling, Transit, Telecommuting, and Technology |
| APC | Automatic passenger counter |
| ATM | Active traffic management |
| AVL | Automatic vehicle location |
| BRT | Bus rapid transit |
| CBD | Central Business District |
| CBA | Cost and benefit analysis |
| CRD | Congestion Reduction Demonstration |
| CVO | Commercial vehicle operator |
| FHWA | Federal Highway Administration |
| FTA | Federal Transit Administration |
| HC | Hydrocarbon(s) |
| HOT | High-occupancy tolling |
| HOV | High-occupancy vehicle |
| ITS | Intelligent transportation systems |
| ITS-OTMC | Intelligent Transportation Systems-Operational Testing to Mitigate Congestion |
| MARQ2 | Marquette and Second Avenue (downtown Minneapolis) |
| Mn/DOT | Minnesota Department of Transportation |
| MOE | Measure of effectiveness |
| MVTA | Minnesota Valley Transit Authority |
| NEF | National Evaluation Framework |
| NEP | National Evaluation Plan |
| NEPA | National Environmental Policy Act |
| NTOC | National Transportation Operations Coalition |
| O&M | Operation and maintenance |
| OTMC | Operational Testing to Mitigate Congestion |
| PDSL | Priced dynamic shoulder lane |
| RITA | Research and Innovative Technology Administration |
| ROG | Reactive organic gas(es) |
| ROWE | Results Only Work Environment |
| SOV | Single-occupant vehicle |
| TDM | Travel demand management |
| TMO | Traffic management operations |
| UPA | Urban Partnership Agreement |
| U.S. DOT | U.S. Department of Transportation |
| VII | Vehicle Infrastructure Integration |
| VMT | Vehicle miles traveled |
| VOC | Vehicle operating cost or Volatile organic compound |
| VT | Vehicle trips |

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# 1.0 INTRODUCTION

This report presents the traffic system data test plan for the National Evaluation of the Minnesota Urban Partnership Agreement (UPA) under the United States Department of Transportation (U.S. DOT) UPA program. The Minnesota UPA National Evaluation Plan includes 11 test plans. The traffic data will be used to analyze the congestion reduction impacts of the Minnesota UPA projects. It also supports the tolling, technology, goods movement, cost benefit, transit, telecommuting, safety, environmental, equity, and business impact analyses.

The test plan begins with a brief overview of the Minnesota UPA projects, the congestion analysis, and the relationship between the analysis areas and the test plans outlined in the Minnesota UPA National Evaluation Plan. The test plan presents the sources and availability of the traffic data needed to assess the congestion reduction potential of the Minnesota UPA strategies. Potential risks associated with the data and the data collection activities are discussed, and the data analysis techniques are described. The schedule and responsibilities for collecting, analyzing, and reporting on the congestion analysis are also presented.

## 1.1 The Minnesota UPA

Minnesota was selected by the U.S. DOT as an Urban Partner to implement projects aimed at reducing congestion based on four complementary strategies known as the 4Ts: Tolling, Transit, Telecommuting/Travel Demand Management (TDM), and Technology. Under contract to the U.S. DOT, a national evaluation team led by Battelle is assessing the impacts of the projects in a comprehensive and systematic manner in Minnesota and other sites. The national evaluation will generate information and produce technology transfer materials to support deployment of the strategies in other metropolitan areas. The national evaluation will also generate findings for use in future federal policy and program development related to mobility, congestion, and facility pricing.

The Minnesota UPA partners include the Minnesota Department of Transportation (Mn/DOT), the Twin Cities Metropolitan Council, Metro Transit, the City of Minneapolis, Minnesota Valley Transit Authority (MVTA), and Anoka, Dakota, Ramsey, and Hennepin counties. The Center for Transportation Studies and the Hubert H. Humphrey Institute of Public affairs at the University of Minnesota are also partners in the UPA.

The Minnesota projects are focused on reducing traffic congestion in the I-35W corridor and in downtown Minneapolis. ITS technologies underlie many of the Minnesota UPA projects, including those focused on tolling, real-time traffic and transit information, transit signal priority, and guidance technologies for shoulder-running buses. Figure 1-1 highlights the general location of the various Minnesota UPA projects, which are described below.

- **High Occupancy/Toll (HOT) Lanes**. The HOT lanes on I-35W represent a major component of the Minnesota UPA. This element includes expanding the existing HOV lanes to HOT lanes and constructing new HOT lanes. The HOT lanes will be dynamically priced. The existing HOV lanes on I-35W from Burnsville Parkway to I-494 will be expanded into dynamically priced HOT lanes. A new dynamically priced

HOT lane will be added on I-35W from I-494 to 46th Street as part of the reconstruction of the Crosstown Commons Section.

- **Priced Dynamic Shoulder Lane (PDSL)**. The second tolling element of the Minnesota UPA is the implementation of a PDSL on I-35W in the northbound direction from 46nd Street to downtown Minneapolis. The PDSL incorporates active lane management techniques and technologies, including speed harmonization.
- **Auxiliary Lanes**. An auxiliary lane and collector ramp is being constructed on I-35W in the northbound direction from 90th Street and I-494. An auxiliary lane is being constructed on I-35W in the southbound direction from 106th Street to Highway 13.
- **Park-and-Ride Facilities**. A total of six new or expanded park-and-ride facilities will be constructed as part of the Minnesota UPA. Two of the park-and-ride facilities are on I-35W north of downtown Minneapolis, one is on I-35W south of downtown Minneapolis, and three are on Cedar Avenue. The following describes the general facility locations and the anticipated number of parking spaces. A new 500-space parking ramp will be constructed adjacent to the existing 1,000-space parking lot at 95th Ave along I-35W North in Blaine. A new 460-space parking ramp will be constructed along I-35W North in Roseville. A new 750-space parking ramp will be constructed along I-35W south in Lakeville. A new 120-space parking lot with an enclosed passenger waiting facility will be constructed along Cedar Ave at Highway 13 in Eagan. A new 200-space parking lot will be constructed along Cedar Avenue at 180th Street in Lakeville. A new 500-space parking ramp, a 250-space surface lot, and a side platform station will be constructed along Cedar Ave at 155th Street in Apple Valley.
- **New Buses**. A total of 27 new buses will be purchased as part of the Minnesota UPA. These vehicles include a mix of standard, hybrid, and coach buses. The buses will be used to operate new and expanded express bus service.
- **Downtown Minneapolis Dual Bus Lanes on Marquette and 2nd Avenues**. Double contraflow bus lanes are being constructed on Marquette and 2nd Avenues in downtown Minneapolis. Called the MARQ2 project, the lanes replace existing single contraflow lanes on each avenue. The project also includes construction of wider sidewalks, and improved lighting, landscaping, and passenger waiting areas.
- **Transit Advantage Bus Bypass Lane**. A “Transit Advantage” bus bypass lane/ramp has been constructed to facilitate the movement of northbound buses at the Highway 77/Highway 62 intersection. A new bus-only left-turn lane has been constructed and new traffic signals have been installed to allow buses to make a left turn from Highway 77 to Highway 62.
- **Cedar Avenue Lane Guidance System**. A lane guidance system for shoulder-running buses will be developed, implemented, and operated on Cedar Avenue. The system includes lateral guidance assistance, collision avoidance, and AVL technology. Lane assistance feedback will be provided to the bus operator through a “heads up” windshield display, a vibrating seat, and an active steering wheel.

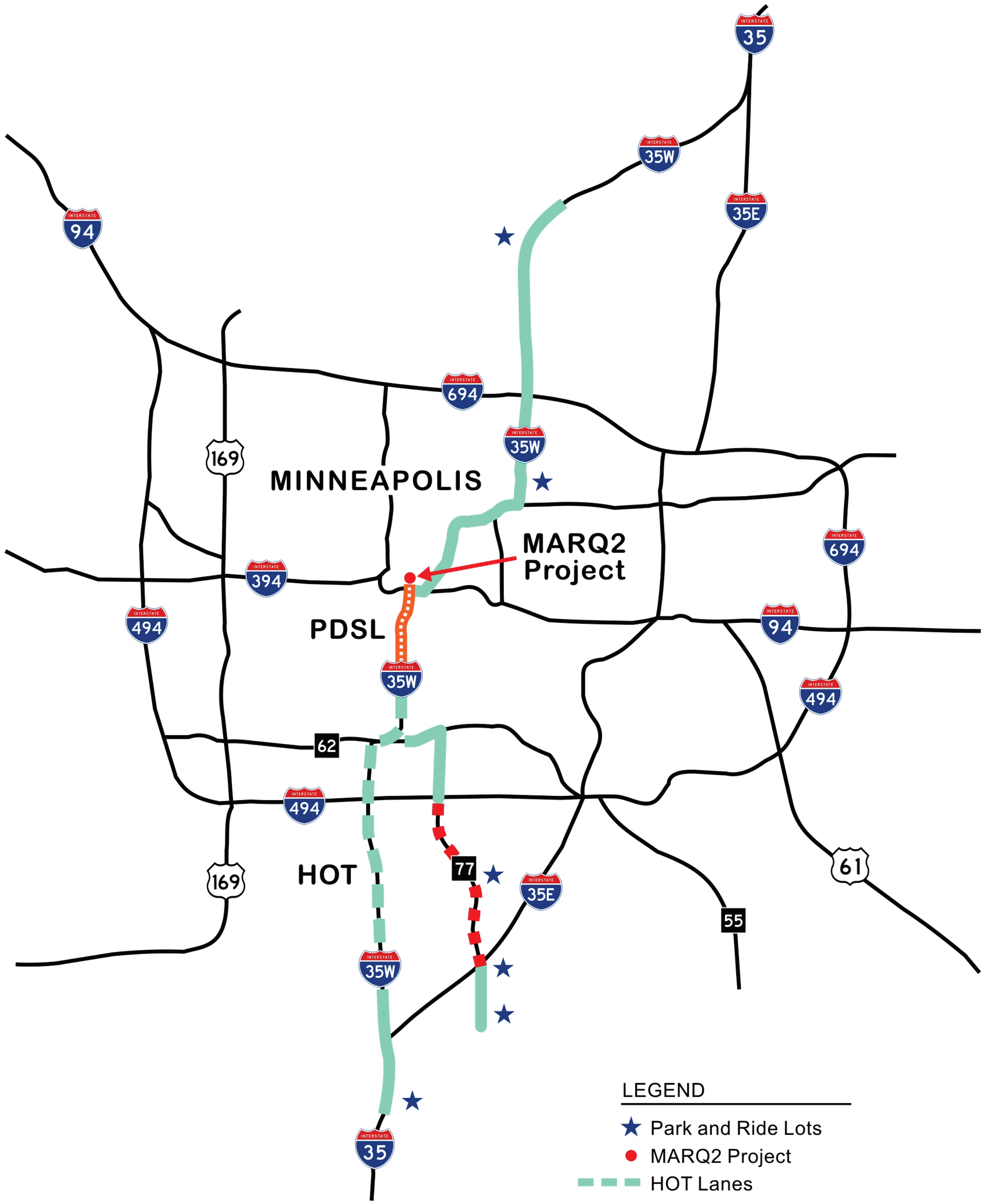


**Figure 1-1. General Location of Minnesota UPA Projects**

- **Real-Time Transit Information and Real-Time Traffic and Transit Information**. Real-time transit information, including next bus arrival information, will be provided along the MARQ2 lanes in downtown Minneapolis and park-and-ride facilities. Dynamic message signs along I-35W will display real-time traffic and transit travel times to downtown Minneapolis.
- **Transit Signal Priority**. Transit signal priority will be implemented along a contiguous stretch of Central Avenue north of downtown Minneapolis, and at selected locations around two park-and-ride facilities.
- **Telecommuting**. The telecommuting element of the Minnesota UPA focuses on increasing the use of Results Only Work Environment (ROWE), telecommuting, and flexible work arrangements throughout the region, including increasing the number of teleworkers and/or workers on flexible schedules in the I-35W corridor by 500 individuals. ROWE provides employees flexibility in the work location and hours by focusing on performance and results rather than presence at the office during standard work hours. ROWE is used extensively at Best Buy Corporation, headquartered in Minnesota. The UPA telecommuting component seeks to increase its use by other businesses in the region. The telecommuting element is funded entirely with state funds.

The Transit Advantage project became operational in December 2008. The majority of projects will be in operation by December 2009. The I-35W HOT lanes in the Crosstown Commons Section, the Cedar Avenue Lane Guidance System, and the Cedar Avenue Transit Station are scheduled for completion by October 2010.

## 1.2 Minnesota UPA National Evaluation Plan and Use of Traffic System Data

The Minnesota UPA National Evaluation Plan focuses on the 12 analysis areas outlined in the National Evaluation Framework (NEF)[1] and 11 test plans. Table 1-1 presents the relationships among the analysis areas and the test plans. In addition to the congestion analysis, the traffic system data test plan supports evaluation of the technology, goods movement, cost benefit, tolling, transit, telecommuting, safety, environmental, equity, and business impact analyses. Table 1-2 presents the traffic data elements and the measures of effectiveness and hypotheses/questions the data will be used to help analyze.

The remainder of this report is divided into three sections. Chapter 2.0 presents the data sources, data availability, and potential risks for evaluating the congestion impacts of the Minnesota UPA projects. Chapter 3.0 describes the traffic data analysis techniques that will be used to test the congestion-related hypotheses and assess the measures of effectiveness. Chapter 4.0 presents the schedule and responsibilities for completing the congestion analysis.

[1] The document is available online at following website: http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE//14446

**Table 1-1. Relationship Among Test Plans and Evaluation Analysis**

| Minnesota UPA Test Plans | Evaluation Analysis | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Congestion Analysis | Tolling Analysis | Transit Analysis | Telecommuting/ TDM Analysis | Technology Analysis | Safety Analysis | Environmental Analysis | Equity Analysis | Goods Movement Analysis | Business Impact Analysis | Non-Technical Success Factors Analysis | Cost Benefit Analysis |
| Traffic System Data Test Plan | ● | ○ | ○ | ○ | ● | ○ | ○ | ○ | ● | ○ | | ● |
| Tolling Test Plan | | ● | | | | | ○ | ○ | ○ | | | ● |
| Transit System Data Test Plan | ○ | ○ | ● | ○ | ● | ○ | ○ | ○ | | | | ● |
| Telecommuting Data Test Plan | | | | ● | | | | | | | | |
| Safety Test Plan | | | | | | ● | | | | | | ● |
| Surveys Test Plan | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | |
| Transportation Modeling Test Plan | | | | | | | | | | | | ● |
| Environmental Data Test Plan | | | | | | | ● | ○ | | | | ● |
| Content Analysis Test Plan | | | | | | | | | | | ● | |
| Cost Benefit Analysis Test Plan | | | | | | | | | | | | ● |
| Exogenous Factors Test Plan | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

● — Major Input ○ — Supporting Input

**Table 1-2. Traffic Data Elements Use in Testing Evaluation Hypotheses/Questions**

| Minnesota Data Element | Minnesota UPA Measure of Effectiveness | Minnesota UPA Hypotheses/Questions* |
|---|---|---|
| 1. I-35W general-purpose lanes travel times | • Percent change in trip-travel time in I-35W general-purpose lanes<br>• Percent change in the variability of trip-travel time in the I-35W general-purpose lanes<br>• Percent change in person travel time in the I-35W corridor<br>• Percent change in the travel- time index of travelers in the I-35W corridor<br>• Percent change and change in variability in the buffer index of travelers in the I-35W corridor<br>• Percent change and change in variability in the planning index of travelers in the I-35W corridor | MNCong-1<br>MNCong-2<br>MNTolling-2<br>MNTech-1<br>MNGoods-2 |
| 2. I-35W general-purpose lanes travel speed | • Percent change in the number of hours per day that I-35W is operating in a "congested" mode<br>• Change in the percent of congested lane miles during the peak period on I-35W that are operating in a "congested" mode | MNCong-3<br>MNCong-4<br>MNTolling-2<br>MNTech-1<br>MNEnv-1<br>MNEnv-3 |
| 3. I-35W HOT/PDSL travel times | • Percent change in trip travel times in I-35W HOT lanes<br>• Percent change in the variability of trip travel time in the I-35W HOT lanes<br>• Percent change in person travel time in the I-35W corridor<br>• Percent change in the travel-time index of travelers in the I-35W corridor<br>• Percent change and change in variability in the buffer index of travelers in the I-35W corridor<br>• Percent change and change in variability in the planning index of travelers in the I-35W corridor | MNCong-1<br>MNCong-2<br>MNTech-1<br>MNGoods-1 |
| 4. I-35W HOT/PDSL travel speeds | • Percent change in the number of hours per day that I-35W is operating in a "congested" mode<br>• Change in the percent of congested lane miles during the peak period on I-35W that are operating in a "congested" mode | MNCong-3<br>MNCong-4<br>MNEnv-3 |

**Table 1-2. Traffic Data Elements Use in Testing Evaluation Hypotheses/Questions (Continued)**

| Minnesota Data Element | Minnesota UPA Measure of Effectiveness | Minnesota UPA Hypotheses/Questions* |
|---|---|---|
| 5. Volume on I-35W | • Percent change in the number of vehicles served on I-35W<br>• Percent change in the number of vehicle-miles traveled on I-35W<br>• Percent change in the total number of people served on I-35W<br>• Percent change in the person-miles traveled on I-35W | MNCong-5<br>MNTolling-1<br>MNTolling-4<br>MNTele/TDM-1<br>MNTech-1<br>MNEquity-1<br>MNEnv-1 |
| 6. I-35W Average Vehicle Occupancy in general-purpose and HOT/PDSL lanes | • Percent change in the total number of people served on I-35W<br>• Percent change in the person-miles traveled on I-35W | MNCong-5<br>MNTolling-2 |

*Listed are acronyms corresponding to hypotheses/questions to be addressed with data from this test plan. An explanation of these acronyms can be found in Appendix A, which contains a compilation of the hypotheses/questions for all the analysis areas from the Minnesota UPA National Evaluation Plan.

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# 2.0 DATA SOURCES, AVAILABILITY, AND RISKS

## 2.1 Data Sources

As outlined in this section, the primary data sources for the traffic system test plan are the Mn/DOT Regional Transportation Management Center (RTMC) detection system, the Mn/DOT I-35W HOV lane quarterly reports, and the traffic count data from the City of Minneapolis. Data from the RTMC incident logs and Freeway Incidental Response Safety Team (FIRST) dispatch logs will also be used in the congestion analysis. These data are described in the safety test plan. Other special studies are also discussed in this section.

**Mn/DOT RTMC Detection System Data.** As part of the RTMC, Mn/DOT has deployed a system of traffic sensors to monitor traffic flow on the freeway system. These sensors are deployed in each freeway lane at approximately one-half mile intervals in both directions of travel. The sensors measure volume and loop occupancy at 30-second intervals. Mn/DOT stores and archives these data on a daily basis. These records contain the following data for each active traffic detector:

- volume – the number of vehicles passing the detector during a 30-second sampling period;
- occupancy – the percentage of time during a 30-second sampling period that the detector was occupied by a vehicle;
- flow rate – the total number of vehicles that would pass over the detector if the 30-second volume was sustained for a full hour (i.e., volume x 120); and
- speed – the average speed of all vehicles passing the detector during a 30-second sampling period. (Note: for Minnesota, speed is not a measured parameter but computed based upon the measured volume and occupancy.)

These sensor data will be used to derive travel time and throughput-based performance measures. The traffic sensors that will be used to partially derive the performance measures for the I-35W corridor, Highway 77/Cedar Avenue, and Highway 62 have been identified and documented in a separate file. Traffic sensor data will also be examined for the control corridors, which include I-394 and I-94N, and Highway 100, which represents a parallel route.

Travel time measures will be derived from the speed data while the volume data will be used to derive throughput measures. Speed values will also be used to assess whether or not a link is congested. It is envisioned that the same speed threshold (when the operating speed drops below 45 mph for any length of time) will be used to define whether or not a traffic lane is congested. The median value from the sensor data will be used to minimize the effects of outliers in the data. In developing the test plan, it is assumed that sensor data will be available for the general-purpose lanes as well as the HOT lanes and the PDSL.

These traffic sensor data could also be used to assess the effects of seasonal variations in travel and exogenous factors on traffic operations. By correlating traffic sensor data measures and exogenous factors (such as gasoline prices), it may be possible to determine the impact of these exogenous factors on traffic performance from a regional perspective.

**Mn/DOT I-35W HOV Reports**. The RTMC publishes quarterly reports on the I-35W HOV lanes and the I-394 HOT lanes. These reports include information on vehicle volumes, vehicle-occupancy levels, and vehicle classifications for the HOV and HOT lanes and the general-purpose freeway lanes. Information is also provided on the number of buses and bus riders, violation rates, and other related data. The quarterly reports have been prepared since the HOV lanes opened in the 1990s. As such, they provide both trend line information and pre-deployment information.

**City of Minneapolis Traffic Count Database System (TCDS)**. The City of Minneapolis maintains a Transportation Data Management System (TDMS) which includes the TCDS. The TCDS includes data from traffic counts conducted every two years. The TCDS is available on the City of Minneapolis website and is a searchable database. Data from the TCDS will be used to assess impacts from the UPA projects on arterials in I-35W corridor within the City of Minneapolis.

**Vehicle-Occupancy Counts**. Vehicle-occupancy rates are needed for several of the Minnesota UPA evaluation analyses, especially those focusing on how the UPA projects influence the average occupancy rates. The vehicle-occupancy level is also a critical value in computing passenger throughput at both the facility and the corridor levels. Pre-deployment and post-deployment sampling of vehicle-occupancy rates for different classes of vehicles will need to be conducted.

Transit average vehicle-occupancy rates will be determined using transit passenger count data. Visual observance is still needed for other vehicles. For the HOT lanes and the PDSL, it will be important to count the number of SOV and HOV 2+ vehicles separately in the facility. In performing the vehicle-occupancy counts, data are needed on the number of vehicles in the following vehicle-occupancy classifications – SOV, HOV2, HOV3+, vanpools, and motorcycles. At a minimum, vehicle-occupancy rates should be sampled quarterly pre- and post- deployment of the UPA projects and just prior to the opening of a new deployment section. These counts could be conducted as part of the existing Mn/DOT quarterly reporting on I-394 and I-35W HOV and HOT lanes.

## 2.2 Data Availability

Most of the traffic system data discussed in the test plan is available from Mn/DOT. Traffic sensor and incident data are routinely archived and the data are made available to the public through the Mn/DOT website (http://www.dot.state.mn.us/tmc/trafficinfo/developers.html). Battelle team members have experience accessing and downloading these data from the Mn/DOT website.

As discussed above, special studies will need to be performed to obtain data that cannot be obtained through automated sources. These special studies include the average vehicle occupancy counts on the I-35W (both the general purpose lanes, the HOT lanes, and the PDSL).

It is expected that the special data collection effort will need to be performed quarterly and/or after significant changes in operating conditions occur in the corridor (e.g., after the opening of a major segment of a UPA improvement).

## 2.3 Potential Risks

The following summarizes some of the potential risks associated with the traffic system data for the Minnesota UPA national evaluation.

- Insufficient before data due to construction activities on I-35W. Currently, a significant portion of I-35W is under construction to implement UPA and other projects. Construction activities have resulted in the closing of some ramps, restricting travel to two lanes, and short duration closing of freeway segments. As a result, the pre-deployment data is not reflective of the before conditions. In addition, it appears that some detectors on I-35W in the evaluation corridor have not been providing freeway performance data due to construction activities. Data about current operations is needed in order to perform a good "before and after" evaluation of the improvements. This potential risk can be mitigated by examining historical data before major construction was initiated on I-35W.
- Gaps in data stream due to malfunctioning loop detectors or if instrumentation is not reinstalled and/or maintained. Procedures exist for filling-in for minor gaps in the traffic detector data; however, if gaps in the data stream are large due to malfunctioning loop detectors, or missing instrumentation, this could significantly impact the quality of the analyses. This potential risk can be mitigated by Mn/DOT closely monitoring the status of freeway detectors and repairing or replacing detectors that have failed or routinely provide erroneous data.
- Insufficient traffic performance data from arterial roadways. The City of Minneapolis TCDS will be used to examine the impacts of the UPA projects on arterials in the I-35W corridor within the City of Minneapolis. The ability to draw a meaningful conclusion from the TCDS may be limited.

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# 3.0 DATA ANALYSIS

For the traffic sensor data, the analysis will focus on comparing pre-deployment measures with post-deployment measures. For the Minnesota UPA evaluation, two post-deployment periods will be examined – after expansion of the existing HOV to HOT lanes, implementation of the PDSL, and implementation of some transit projects in September-to-December, 2009, and after implementation of the new HOT lanes in the I-35W/Crosstown Commons section and other project elements in October, 2010.

## 3.1 Data Cleaning/Error Checking

After downloading the detector data, a series of quality control checks and screening procedures will be applied to the data to identify suspect or invalid data values. The evaluation team will use the quality control checks recommended in NCHRP's *Guide to Effective Freeway Performance Measurement*. Suspect data will be "flagged" for possible exclusion from the performance measures calculations and reviewed by team members who will determine the final validity and future use of the data. A "bad days" list will be compiled that includes dates, times, and road section that have failed a quality control check. "Bad days" are excluded from valid weekdays on a section-by-section basis. Where possible, procedures will be used to estimate and replace missing and/or erroneous data.

## 3.2 Data Aggregation and Control for Atypical Conditions

In its rawest form, Mn/DOT RTMC detector data is stored by travel lane per detector in 30-second intervals. To compute the performance measures, the Battelle team will aggregate data, both spatially and temporally. In addition, the data will be assessed for the influence of incidents and other atypical traffic conditions.

### Aggregation

- **Spatial Aggregation.** Figure 3-1 illustrates the process that will be used to aggregate the data spatially. At the lowest level, Mn/DOT RTMC data is collected on a lane-by-lane basis. Speed and volume data from each detector will first be aggregated across all lanes in each direction to provide detector station values. Data from the HOT lanes and the PDSL will be kept separate from general-purpose freeway lanes. Volume data from lane detectors will be summed to provide a station volume, while speed data will be averaged across all lanes to provide an average detector station speed. Data from slower-moving auxiliary lanes on the freeway will be excluded from this aggregation.

  At the next level of aggregation, detector station data will be converted to link-level data. At this level, a "zone of influence" will be assigned for each detector station. This zone of influence will be equivalent to one-half the distance to the nearest upstream and downstream sensors. Link travel times will be computed by applying the average detector station speed over the zone of influence for each detector station. Vehicle volumes will be subtotaled and multiplied by link length to estimate vehicle-miles of travel (VMT) for each link.

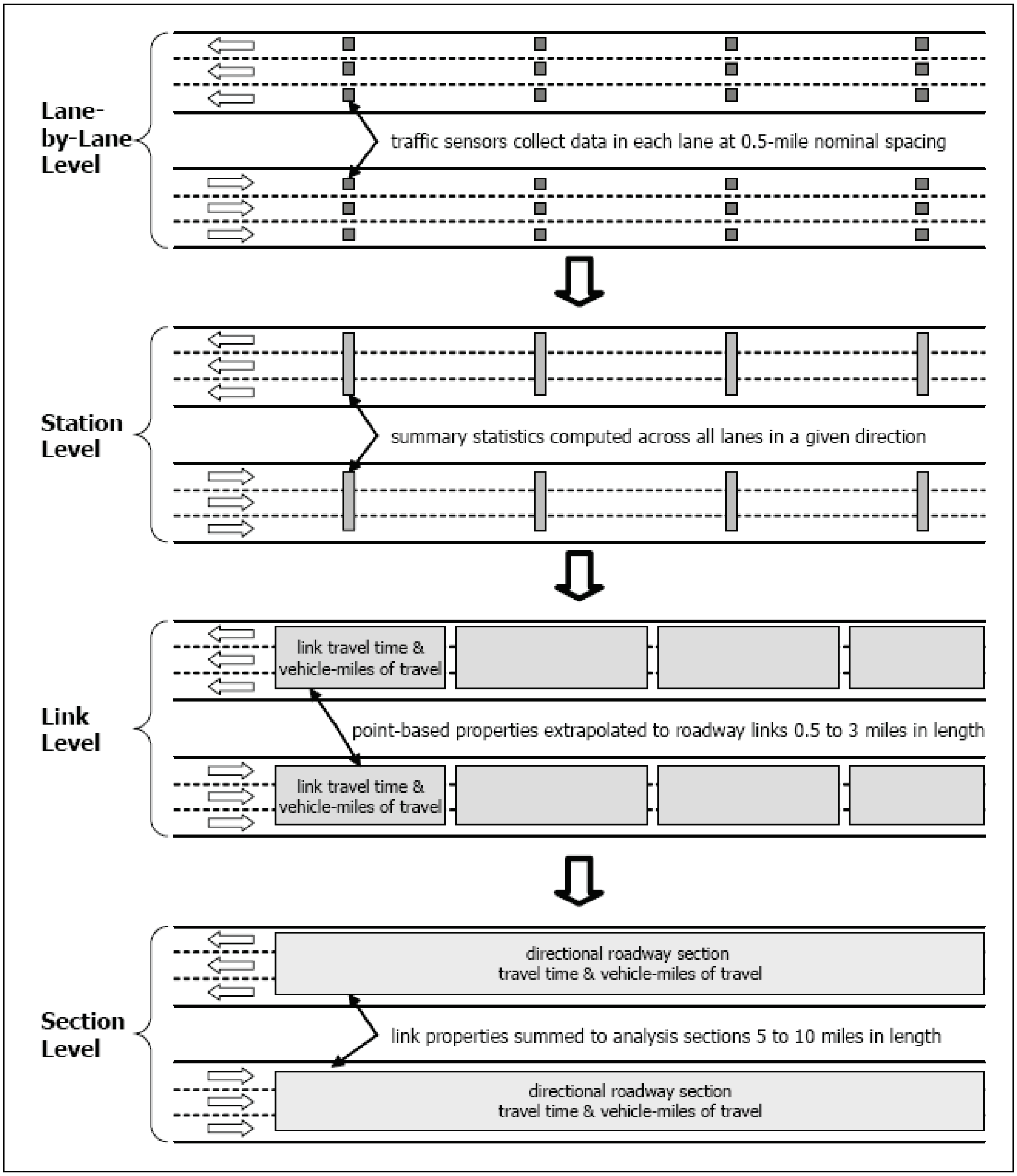


**Figure 3-1. Methodology for Aggregating Freeway Detector Data for Estimating Directional Route Travel Times and VMT from Spot Speeds and Volumes**

The link-level data will be aggregated to the section and corridor levels. For determining section travel times, the "vehicle trajectory" approach, as opposed to the "snapshot" approach, will be used. The vehicle trajectory method of computing travel time attempts to more closely estimate the actual travel times experienced by motorists. The approach "traces" vehicles trips in time as they progress through a corridor. This is done by applying the link travel time corresponding to the precise time in which a vehicle will be using a link. For example, if it takes a vehicle two minutes to traverse a link at 7:00, then the link travel time starting at 7:02 would be used as the travel time for next downstream link. This process is continued for all the links that make up section or corridor. The "snapshot" approach sums all the link travel times at the same instance in time. The vehicle trajectory method is routinely used in post hoc evaluations while the snapshot method is traditionally used to computing travel times for display on traveler information systems.

- **Temporal Aggregation.** In addition to aggregating the data spatially, the individual detector data will be aggregated temporally. Thirty-second detector data will be aggregated to 5-minute intervals. This means that each 30-second vehicle count will be summed to provide a total number of vehicles in the 5-minute interval, while speed and occupancy data will be averaged to provide an average speed and occupancy for the 5-minute interval.

**Incidents and Other Atypical Traffic Conditions.** The Minnesota UPA projects are focused primarily on addressing the effects of typical, or recurring, congestion on traffic operations; however, "atypical" (or non-recurring) conditions are also a major source of congestion in most metropolitan areas. Because incidents and other external events can be major sources of variations in travel time, the effects of these events can dramatically influence the results of the analysis. Therefore, the national evaluation will analyze the effects of the UPA projects on both recurring congestion and non-recurring congestion.

There are a number of conditions that may result in non-recurring congestion, including traffic incidents, work zones, weather, fluctuations in demand, special events, traffic control devices, and inadequate base capacity. The effects of the following non-recurring events will be examined in the evaluation.

- **Incidents.** Incidents are a source of travel time variability in the I-35W corridor. An incident is any event that unexpectedly and temporarily reduces capacity of the freeway and roadways. Incidents can range in nature from debris on the roadway to stalled vehicles blocking travel lanes, to major collisions and crashes. Those periods when traffic flow is severely impeded by incidents will be flagged in the data and their impacts will be analyzed separately from those days when traffic operations are "normal." Mn/DOT RMTC Operator logs and FIRST Dispatch Logs will be used as the primary source of information for when incident conditions exist in the I-35.

- **Inclement Weather.** Because weather can have significant impact of freeway performance, data from the National Weather Service archives as well as RMTC operator logs will be used to identify those data were inclement weather occurred. To determine when winter weather conditions might have impacted traffic operations, Mn/DOT maintenance records will be examined to determine those days when snow plowing or sanding operations occurred. National Weather service records will be used to flag days that are impacted by weather conditions. These would include days reporting limited visibility due to fog, rain or snow, and days experiencing significant ice, rainfall, or snowfall events. Days identified as being potentially impacted by inclement weather will be flagged and data from those days will be analyzed separately.

- **Roadway Construction and Maintenance.** Roadway construction and maintenance can also be as source of congestion. It will be important to also exclude days when performance of the roadway is severely impacted by roadway construction and maintenance from the "typical" day analysis and include these days in the incident data. Mn/DOT Maintenance Records and RTMC Operator logs will be used to identify when and where construction and maintenance activities on I-35W impacted operations.

## 3.3 Performance Measure Calculation Procedures

The input data and procedures for calculating the primary performance measures for the congestion analysis are described in this section. The measures presented include travel time, vehicle throughput, person throughput, VMT, person-miles of travel (PMT), the travel time index, the planning time index, the buffer index, hours of congestion, and the number of congested links.

In analyzing the effects of the UPA projects on traffic operations, the test plan focuses on the morning and afternoon peak periods. The peak period analysis is the time periods when the UPA projects are mostly likely to have a significant impact on reducing congestion. In producing their annual congestion report on the Metropolitan Freeway System, the RTMC defines the peak periods as 6:00 a.m. to 9:00 a.m. and 2:00 p.m. to 7:00 p.m. These same time periods will be used to define the peak periods for the UPA evaluation. This approach will highlight where projects had an impact on the duration of congestion, as well as the level of congestion.

**Travel Time.** Many of the analyses use performance measures that are derived from travel time, which is the amount of time required to traverse the entire length or a predefined section of a corridor or roadway. For the purpose of this evaluation, travel times will be determined using the detector data from Mn/DOT's RTMC Detection System. The input data required to compute segment and corridor level travel times are the 5-minute average link-level speeds for peak traffic periods (6:00-9:00 a.m., 2:00-7:00 p.m.) and the "zone of influences" link length for each detector stations.

**Vehicle Throughput.** Vehicle throughput is a measure of the number of vehicles that are serviced in one direction of a facility during the analysis period. Mn/DOT freeway detectors measure the vehicle throughput for each individual link, while vehicle throughput on the arterial will be measured at the screen lines. Total vehicle throughput is the sum of all types of vehicle traversing the roadway or screen line during the analysis period (peak hour, peak period and/or day).

**Person Throughput.** Person throughput, or person volume, is the total number of people serviced in the corridor during the analysis period. Person throughput is the average vehicle occupancy multiplied by the volumes of vehicles within the corridor.

$$Person\ Throughput\ (PT) = Vehicle\ volume\ (V) * \ Average\ Vehicle\ Occupancy\ (AVO)$$

For the purposes of the Minnesota UPA, the contribution of different strategies to overall person throughput is of interest. Person throughput will be computed for each travel mode and estimated using average vehicle occupancy rates for different types of vehicles. In this process, the contributions to total corridor person throughput is computed using the following equation:

$$PT_{Total} = PT_{Transit\ (External)} + PT_{TDM} + PT_{Arterial} + PT_{General\ Purpose\ Lanes} + PT_{Tolled\ Lanes}$$

Table 3-1 presents each of the elements used in computing the total person throughput in the I-35W corridor.

**Table 3-1. Component of Computing Total Person Throughput in Analysis Corridor**

| PT Contribution | Analytical Source | Description |
|---|---|---|
| $PT_{Transit\ (External)}$ | Transit Analysis | $PT_{Transit\ (External)}$ is the relative contribution of the transit-based UPA projects on other freeways/areas. (Example: park-and-ride improvements on I-35W north of the UPA corridor) |
| $PT_{TDM}$ | TDM Analysis | $PT_{TDM}$ is the relative contribution of the telecommuting program on other freeways/areas. |
| $PT_{Arterial} = PT_{Non\text{-}freeway\ auto} + PT_{Non\text{-}freeway\ transit}$ | Congestion Analysis | $PT_{Non\text{-}freeway\ auto}$. is the PT from vehicles on adjacent facilities in the I-35W corridor, excluding buses. |
| | Transit Analysis | $PT_{Non\text{-}freeway\ transit}$ is the number of persons serviced by transit routes on adjacent facilities. It is computed as the number of transit vehicle times the average occupancy rate per transit vehicle |
| $PT_{General\ Purpose\ Lanes} = PT_{GPL\ transit} + PT_{GPL\ auto}$ | Transit Analysis | $PT_{GPL\ transit}$ is the relative contribution of transit vehicle traveling on the freeway general purpose lanes. It is computed by multiplying the average occupancy per transit vehicle for any routes / partial routes that use the general purpose lanes for the I-35W corridor. |
| | Congestion Analysis | $P_{GPL\ auto}$ is the relative contribution of autos on the general purpose lanes in the I-35W corridor. |
| $PT_{Tolled\ Lanes} = PT_{TL\ Transit} + PT_{TL\ HOV2} + PT_{TL\ van} + PT_{TL\ SOV}$ | Transit Analysis | $PT_{TL\ transit}$ is the relative contribution of transit vehicle traveling in the HOT lanes and the PDSL. It is computed using the average occupancy per route for any routes / partial routes that use the HOT lanes and the PDSL in the I-35W corridor. |
| | Tolling Analysis | $PT_{TL\ SOV}$ is the PT from percentage of HOT lane and PDSL traffic that was SOV (% traffic X volume). |
| | | $PT_{TL\ HOV2}$ is the PT from percentage of HOT lane and PDSL traffic that was 2-person carpools (% traffic X number of occupants X volume). |
| | | $PT_{TL\ Van}$ is the PT from percentage of HOT lane and PDSL traffic that was vanpools (% traffic X number of occupants X volume). |

Volume counts and occupancy rates of transit vehicles on each of the facilities will be determined based on data from the transit test plan. The number of non-transit vehicles using the HOT lanes and PDSL and the I-35W general purpose freeway lanes will be computed by subtracting the number of transit vehicle using the HOT lane and PDSL and the general-purpose freeway lanes from the total vehicle count of the Mn/DOT RTMC detector. The number of non-transit vehicle using the arterial streets will be used subtracting the number of transit vehicles crossing the screen line locations.

**VMT.** VMT is a common measure of throughput. It is the product of the number of vehicles traveling over a length of roadway times the length of the segment of roadway. It is computed using the following equations:

$$(VMT)_{Link} = Volume\ (V)_{Link}\ X\ Link\ Length$$

$$VMT_{Total} = \sum VMT_{Link}$$

To compute VMT for the general-purpose freeway lanes and the HOT lane and PDSL, 5-minute vehicle counts from Mn/DOT RTMC detector systems will be used. VMT will be computed for each link. Similarly, screen-line count data will be multiplied by the segment length for which the volume counts are deemed to represent. Segment level and corridor level VMTs will be calculated by summing link-level VMTs from the freeway, HOT lanes, PDSL, and arterial links respectively. Peak hour, peak period, and daily VMT will be calculated using this approach.

When computing average index values across road sections or time periods, VMT is used to weight the calculations. VMT can also be used to weight the average travel time index calculation across all weekdays; however, in most cases, the differences are not significant (for weighted vs. non-weighted averages) when computing averages across weekdays.

**Person-Miles of Travel (PMT).** Similar to VMT, PMT is a measure of throughput and is the product of passenger throughput times the length of segment of roadway. The basic equation for computing PMT is as follows:

$$l\ (PMT)_{Link} = Person\ Throughput\ (PT)_{Link}\ X\ Link\ Length$$

$$PMT_{Total} = \sum PMT_{Link}$$

As discussed above, passenger throughput is the product of the number of specific classes of vehicles (transit, HOV, SOV vehicles) traversing a length of roadway times the average number of occupants in each vehicle class. PMT is the product of person throughput from each detector station in the corridor by the link length. Segment- and corridor-level PMT is computed by summing all the link-level PMTs across all the links defined in the segment or corridor. Peak hour, peak period, and daily PMT will be calculated using this approach.

**Travel Time Index.** The Travel Time Index (TTI) is the extra time spent in traffic during peak traffic times as compared to light traffic times. In mathematical terms, it is the peak travel time divided by the free-flow travel time as in the following equation:

$$TTI = \frac{\left[\frac{Aveage\ Speed}{Free - flow\ Speed}\ X\ VMT\right]_{Freeway} + \left[\frac{Average\ Speed}{Free - flow\ Speed}\ X\ VMT\right]_{Arteiral}}{VMT_{Freeway} + VMT_{Arterial}}$$

To compute the TTI, one first computes the free-flow travel speed for each section as the 85th percentile speed during the previous 3 months during weekday off peak times, which are defined as weekdays from 9:00 a.m. to 4:00 p.m. and 7:00 p.m. to 10:00 p.m. and weekend/ holiday times from 6:00 a.m. to 10:00 p.m. TTI is computed by dividing the free-flow traffic speed by the peak traffic speed. If the computed travel time index is less than 1.00, it will be rounded up to 1.00. The TTI for the I-35W corridor for the each day is computed by taking a VMT-weighted average of all travel time indices during peak times. Monthly average travel time index are computed by taking a simple (or VMT-weighted) average across all valid weekdays.

**Planning Time Index.** The Planning Time Index (PTI) is the extra time cushion needed during peak traffic periods to prevent being late. In mathematical terms, it is the near-worst case travel time (95th percentile) divided by the free-flow travel time.

$$PTI = \frac{\left[\frac{95th\ Percentile\ Speed}{Free-flow\ Speed}\ X\ VMT\right]_{Freeway} + \left[\frac{95th\ Percentil\ Speed}{Free-flow\ Speed}\ X\ VMT\right]_{Arteiral}}{VMT_{Freeway} + VMT_{Arterial}}$$

If using speeds in calculations, it is the free-flow traffic speed divided by the near-worst case traffic speed (5th percentile). All weekdays in the month are included in the calculation of 5th percentile speeds. The PTI is computed as the free-flow traffic speed divided by the 5th percentile traffic speed for each freeway section and 5-minute peak time period. If the planning time index is less than 1.00, it will be rounded up to 1.00. The average planning time index for each freeway section is computed by taking VMT-weighted averages across all 5-minute index values.

**Buffer Index.** The Buffer Index (BI) is the extra time (buffer) that travelers in a corridor need to allow to ensure an on-time arrival for most trips. The BI is equivalent to the extra time travelers must add to their average travel time when planning trips. With continuous data, such as the Mn/DOT RTMC detector data, the index will be calculated for each road or transit route segment, and a weighted average will be calculated using vehicle-miles or, more desirably, person-miles of travel as the weighting factor. The BI can be calculated for each road segment or particular system element using the following equations:

$$Buffer\ Index\ (BI)_{Link} = \left[\frac{95th\ Percentile\ Travel\ Time - Average\ Travel\ Time}{Average\ Travel\ Time}\right]\ X\ 100\%$$

$$BI_{Corridor} = \frac{\sum(BI_{Link}\ X\ VMT_{Link})}{\sum VMT_{Link}}$$

Note that a weighted average for more than one roadway section could be computed using VMT or PMT on each roadway section. The measure would be explained as "a traveler should allow an extra BI percent travel time due to variations in the amount of congestion delay on that trip."

**Hours of Congestion.** This measure is intended to measure the temporal extent of congestion. It is the average length of time each period and/or day that a particular facility is operating in a congested state. While each city may define when a facility is congested differently, the Minneapolis UPA national evaluation will use the threshold used by Mn/DOT in their *Metropolitan Freeway System 2007 Congestion Report,* which defines congestion when speeds on a freeway link drop below 45 mph.

Hours of congestion will be computing using the speed measures reported by Mn/DOT in the RMTC detector data. Examining the detector data, links will be flagged when the reported 5-minute average speed drops below 45 mph. The uncongested and congested links in the corridor will be counted by each 5-minute time period and the percentage of congested links will be computed. If the percentage of congested links in the corridor exceeds 20 percent, the corridor will be identified as being congested for that 5-minute time period and day. For each valid weekday in the month, the number of congested 5-minute periods will be used to determine the total duration of congestion, daily and during the peak period. Only time periods between 6:00 a.m. and 10:00 p.m. will be included in this analysis.

**Percent of Congested Lane Miles.** The percent of congested lane miles measures the spatial extent of congestion. This measure is the lane miles of roadway within the I-35W corridor that the average travel times are 30 percent longer than the unconstrained travel time. For each 5-minute time period during the analysis period, the actual travel time in each lane on a link will be compared to the unconstrained, or free-flow, travel time for that link. If the actual link travel time is 30 percent longer, then the lane on that link will be defined as congested. The performance measure, which is the percentage of congested roadways, is calculated as the ratio of congested lane miles to the total lane miles. Days where incidents have occurred, inclement weather, or maintenance and/or construction activities are present will be analyzed separately from typical workdays.

## 3.4 Time Period for Analysis

In addition to aggregating the data spatially, data and performance measures will be aggregated temporally. For the purpose of the Minnesota UPA national evaluation, performance measures will be computed for peak hours, the peak period, and daily.

Peak hour statistics provide an indication of corridor performance when congestion is at its worst. The evaluation will use two methods to define the peak hour. The first method is the traditional method of determining the peak hour by applying the *Highway Capacity Manual's* definition of peak hour, which is the one-hour period experiencing the highest hourly volume. Typically, this is the one-hour period when throughput is at its maximum, just before congestion forms; however, because the UPA projects are intended to lessen the impacts of congestion, the evaluation will also use an alternative definition to determine the peak hour. This definition is the one-hour period when travel speeds are at their lowest. This alternative definition defines when congestion is at its worst. Typically, the peak hour based on lowest speeds lags the peak hour based on highest volumes by 30 to 60 minutes. The evaluation team will compute performance statistics for both morning and afternoon peak hour using both definitions.

In addition to computing peak hour statistics, the national evaluation will also compute peak period performance statistics. The peak period is a time period that extends beyond the peak hour. It not only includes the peak hour but also incorporates the shoulders of the peak hour when traffic congestion is building and dissipating. As noted previously, Mn/DOT defines the morning peak period from 6:00 a.m. to 9:00 a.m. and the evening peak period from 2:00 p.m. to 7:00 p.m.

The national evaluation team will also compute daily performance measure statistics. Analyses using daily averages are often less useful with the Travel Time Index and the Buffer Index. Using 24-hour speeds for computing the Travel Time Index is not meaningful because the measure is meant to compare peak and off-peak travel conditions. Likewise, the Buffer Index is intended to be a measure of reliability during a peak period. Daily values wash out the impact of peak-periods with the longer off-peak periods. Where appropriate, daily statistics will consist of the time between 6:00 a.m. and 10 p.m. and will exclude late night/early morning conditions.

For the purposes of this evaluation, only data from non-holiday weekdays will be included in the analysis. Data from the weekends and from federal and state holidays will be excluded from the analysis as traffic conditions are not typical on these days. The data may also exhibit significant season variations, such as summer versus winter and school and university in sessions/out of session. While the national evaluation team does not envision needing to conduct separate analysis for different seasons, data will be examined to determine if significant seasonal variations exist that might influence the overall analysis.

## 3.5 Types of Analysis

After calculating the performance measures, several types of analysis procedures will be used to assess the effectiveness of the Minnesota UPA projects. The performance measure will be tracked from the pre- and post-deployment time periods. This trend analysis will assist in determining the following elements:

- whether or not changes in performance were due to the UPA projects or to typical daily, monthly, and seasonal variations in traffic operations in the corridor;
- whether or not the effects of the implementing the Minnesota UPA projects, pricing in particular, in the I-35W corridor were sustainable during the post-deployment period; and
- whether or not changes in the performance measures were isolated to the I-35W corridor or if similar trends in performance were occurring in other corridors in the area.

In addition to analyzing trends in the performance data, traditional statistical analysis, such as comparison of means and analysis of variance, will be performed to determine whether or not changes in level of congestion differed statistically during the pre- and post-deployment time periods. Table 3-2 presents the null and alternative hypotheses of the statistical comparisons envisioned in this evaluation. All statistical comparisons will be performed using standard statistical procedures and conducted at a 95 percentile confidence level.

**Table 3-2. Anticipated Statistical Comparisons of UPA Performance Measures**

| Analysis | Performance Measure | Null Hypothesis | Alternate Hypothesis |
|---|---|---|---|
| Quality of Service | Average Travel Time ($\overline{TT}$) | $\overline{TT}_{After} = \overline{TT}_{Before}$ | $\overline{TT}_{After} < \overline{TT}_{Before}$ |
| | Average Travel Time Index($\overline{TTI}$) | $\overline{TTI}_{After} = \overline{TTI}_{Before}$ | $\overline{TTI}_{After} < \overline{TTI}_{Before}$ |
| Reliability | Average Planning Index ($\overline{PI}$) | $\overline{PI}_{After} = \overline{PI}_{Before}$ | $\overline{PI}_{After} < \overline{PI}_{Before}$ |
| | Average Buffer Index ($\overline{BI}$) | $\overline{BI}_{After} = \overline{BI}_{Before}$ | $\overline{BI}_{After} < \overline{BI}_{Before}$ |
| Throughput | Average Vehicle-Miles of Travel ($\overline{VMT}$) | $\overline{VMT}_{After} = \overline{VMT}_{Before}$ | $\overline{VMT}_{After} > \overline{VMT}_{Before}$ |
| | Average Passenger-Miles of Travel ($\overline{PMT}$) | $\overline{PMT}_{After} = \overline{PMT}_{Before}$ | $\overline{PMT}_{After} > \overline{PMT}_{Before}$ |
| Extent of Congested | Average # of Congested Hours ($\overline{CHR}$) | $\overline{CHR}_{After} = \overline{CHR}_{Before}$ | $\overline{CHR}_{After} < \overline{CHR}_{Before}$ |
| | Average # of Congested Links ($\overline{CLK}$) | $\overline{CLK}_{After} = \overline{CLK}_{Before}$ | $\overline{CLK}_{After} < \overline{CLK}_{Before}$ |

The performance measures calculated using traffic data apply to many parts of the evaluation. Examples of the analysis to be conducted are presented below.

- Change in travel times on I-35W. The change in travel time for different user groups and different time periods on I-35W will be analyzed pre- and post-deployment. Changes in trip travel times in the general-purpose freeway travel lanes and the HOT lanes will be examined, as will changes in the Travel Time Index. Travel time measures are used not only in the congestion analysis but also in the goods movement and cost benefits analyses.
- Change in trip-time reliability on I-35W. The change in trip-time reliability for different user groups and different time periods on I-35W will be analyzed pre- and post-deployment. Changes in trip-time reliability in the general-purpose freeway lanes and HOT lanes will be examined pre- and post-deployment. The percentage change in variability, the change in the Buffer Index, and the change in the Planning Index will be examined.
- Changes in the hours per day of congestion conditions on I-35W. The number of hours I-35W operated in congested conditions (travel speeds less than 45 mph) will be analyzed pre- and post-deployment. This analysis will examine the various links and segments on I-35W, as well as the extent of congested conditions during the day.
- Change in the number of vehicles served. The change in the number of vehicles served on I-35W (vehicle throughput) will be examined pre- and post-deployment. Changes in vehicle throughput will be examined for the various links, as well as different times of the day.
- Change in the number of persons served. The change in the number of persons served on I-35W (person throughput) will be evaluated pre- and post-deployment. Person throughput will be examined for the various links, as well as different times of the day.

- Change in traffic congestion on surrounding facilities. To the extent allowed by available data, changes in traffic congestion on other facilities in the corridor will be evaluated.
- Changes in VMT and PMT. Changes in VMT and PMT on I-35W pre- and post-deployment will be evaluated. VMT is a key measure in several of the analysis areas including environmental analysis, cost benefit analysis and congestion analysis.
- Assessment of impact of traffic management strategies. The impact of UPA traffic management strategies, including speed harmonization, on traffic congestion on I-35W will be analyzed. This analysis will examine sensor and other traffic data when the speed harmonization strategies are being used, with the time periods they are not in operation. The number and duration of incidents when the active traffic management strategies are in operation and when they are not will also be examined.

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# 4.0 SCHEDULE AND RESPONSIBILITY

Table 4-1 shows the timeframe for the the pre- and post-deployment data collection efforts for each of the major UPA projects affecting traffic system data. The majority of the UPA projects are expected to be operational by December 2009. Data collection should continue through November 2011 to provide a full year of post-deployment data following the completion of the HOT lane from I-494 to 46$^{th}$ St., which will be operational by October 2011.

**Table 4-1. Time Frame for Pre- and Post-Deployment Data Collection Efforts**

| Project Element | Implementation Date | Pre-Deployment Data Collection | Post-Deployment Data Collection |
|---|---|---|---|
| HOT Lanes – Burnsville Parkway to I-494 | 10/09 | 10/08 – 10/09 | 10/09 – 11/11 |
| PSDL – 46$^{th}$ St to Downtown | 10/09 | 10/08 – 10/09 | 10/09 – 11/11 |
| Auxiliary Lanes/Collector Ramps | 10/09 | 10/08 – 10/09 | 10/09 – 11/11 |
| HOT Lanes – I-494 to 46$^{th}$ St. | 10/10 | 10/08 – 10/10 | 10/10 – 11/11 |

As described in previous sections, most of the traffic data needed to analyze the effects of the Minnesota UPA projects will be obtained from Mn/DOT's RTMC. These data are continuous and can be analyzed throughout the deployment period. Monthly downloads of the traffic sensor data will be obtained, examined, and analyzed. Due to construction in the I-35W corridor, a historic trend line will be established as part of the post-deployment data collection and analysis. This trend line is needed to account for the different travel conditions experienced during the construction period, which include some traffic lane and ramp closures, and the inoperability of some loop detectors during the construction. To account for this situation, archived loop data will be obtained and examined from 2006 and 2007 to reflect pre-deployment conditions.

Vehicle occupancy data require special data collection studies. It is recommended that these data be collected quarterly. A proposed data collection schedule is shown in Table 4-2. Note that if this data collection schedule is followed, there will be only two data collection efforts that will occur prior to the opening of the first projects.

**Table 4-2. Suggested Data Collection Schedule for Continuous and Special Data Collection Efforts**

| Type of Data/Data Source | Data Collection Frequency | Recommended Months of Data Collection |
|---|---|---|
| Mn/DOT RTMC Detection System Data | Continuous | 10/08 – 10/11 |
| Vehicle Occupancy Counts | Quarterly | 7/09,10/09 (Before)<br>1/10, 4/10, 7/10, 10/10,<br>1/11, 4/11, 7/11, 10/11 |

The responsibilities for this test plan include:

- Battelle team members will download the Mn/DOT RTMC detector system data on a monthly basis. The data checks will be performed to identify possible outlier or suspect data. Battelle team members will utilize the on-line City of Minneapolis TCDS to obtain needed arterial traffic counts.
- Mn/DOT will sponsor the vehicle-occupancy counts and will provide the results to the Battelle team.
- Mn/DOT will provide the Battelle team members with the quarterly I-35W HOT lane reports and Battelle team members will analyze the data.
- Battelle team members will analyze the data and will use the data, along with data from the RTMC Incident Logs and FIRST Dispatch Logs collected in the safety test plan, to assess the measures of effectiveness. Battelle team members will presents the results in the interim reports and the final Minnesota UPA national evaluation report.

# APPENDIX A – COMPILATION OF HYPOTHESIS/QUESTIONS FROM THE MINNESOTA UPA NATIONAL EVALUATION PLAN

| Evaluation Analysis | Hypothesis/Question Number | Hypothesis/Question |
|---|---|---|
| Congestion | MNCong-1 | Deployment of the UPA improvements will reduce the travel time of users in the I-35W corridor. |
| | MNCong-2 | Deployment of the UPA improvements will improve the reliability of user trips in the I-35W corridor. |
| | MNCong-3 | Traffic congestion on I-35W will be reduced to the extent that travelers in the corridor will experience a noticeable improvement in travel time. |
| | MNCong-4 | Deployment of the UPA projects will not cause an increase in the extent of traffic congestion on surrounding facilities adjacent to I-35W. |
| | MNCong-5 | Deploying the UPA improvements will result in more vehicles and persons served in the I-35W corridor during peak periods. |
| | MNCong-6 | A majority of survey respondents will indicate a noticeable reduction in travel times after the deployment of the UPA improvements. |
| | MNCong-7 | A majority of survey respondents will indicate a noticeable improvement in trip-time reliability after the deployment of the UPA projects. |
| | MNCong-8 | The majority of survey respondents will indicate a noticeable reduction in the duration of congestion after deployment of the UPA projects. |
| | MNCong-9 | A majority of survey respondents will indicate a noticeable reduction in the extent of congestion after the deployment of the UPA projects. |
| Tolling | MNTolling-1 | Vehicle access on the HOT lanes and PDSL on I-35W will be regulated to improve operation of I-35W |
| | MNTolling-2 | Some general-purpose lane travelers will shift to the I-35W HOT lanes and PDSL, while HOV lane travelers will remain in the HOT lane |
| | MNTolling-3 | HOV violations will be reduced |
| | MNTolling-4 | After ramp-up, the HOT lanes and PDSL on I-35W maintains improved operations |

| Evaluation Analysis | Hypothesis/Question Number | Hypothesis/Question |
|---|---|---|
| Transit | MNTransit-1 | The HOT lanes, PDSL, MARQ2 bus lanes, and Transit Advantage project, and shoulder running lane guidance system will increase bus travel speeds, reduce bus travel times, and improve bus trip-time reliability in the I-35W and Cedar Avenue corridors, and downtown Minneapolis |
| | MNTransit-2 | The new park-and-ride lots and new and expanded transit services will result in ridership increases including a mode shift to transit. |
| | MNTransit-3 | The mode shift to transit from the UPA transit strategies will reduce congestion on I-35W, downtown Minneapolis, and other roadways. |
| | MNTransit-4 | What was the relative contribution of each of the Minnesota UPA transit strategies to mode shift to transit? |
| Telecommuting /TDM | Tele/TDM-1 | Use of telecommuting, ROWE, and other flexible work schedules removes trips and VMT from the I-35W corridor. |
| | Tele/TDM-2 | Integration of telecommuting into the UPA project enhances congestion mitigation. |
| | Tele/TDM-3 | What was the relative contribution of the telecommuting strategies to overall travel behavior changes, including secondary impacts of telecommuting |
| Technology | MNTech-1 | Active traffic management strategies, including speed harmonization and DMS with transit and highway travel times, promoting better utilization and distribution of traffic to available capacity in the I-35W corridor. |
| | MNTech-2 | Active traffic management strategies will reduce the number and duration of incidents that result in congestion in the I-35W corridor. |
| | MNTech-3 | What was the relative contribution of each technology enhancement on congestion reduction in the I-35W corridors? |
| Safety | MNSafety-1 | Active traffic management will reduce the number of primary and/or secondary crashes. |
| | MNSafety-2 | The HOT lanes and the PDSL on I-35W South will not adversely affect highway safety. |
| | MNSafety-3 | The MARQ2 dual bus lanes in Downtown Minneapolis will not adversely affect safety. |
| | MNSafety-4 | The lane guidance system for shoulder running buses will not adversely affect safety. |

| Evaluation Analysis | Hypothesis/Question Number | Hypothesis/Question |
|---|---|---|
| Equity | MNEquity-1 | What are the direct social effects (tolls paid, travel times, adaptation costs) for various transportation system user groups from the I-35W HOT lanes, PDSL, transit, and other UPA strategies? |
| | MNEquity-2 | What is the spatial distribution of aggregate out-of-pocket and inconvenience costs, and travel-time and mobility benefits? |
| | MNEquity-3 | Are there any differential impacts on certain socio-economic groups? |
| | MNEquity-4 | How does reinvestment of revenues from the I-35W HOT lanes and PDSL impact various transportation system users? |
| Environmental | MNEnv-1 | What are the impacts of the Minnesota UPA strategies on air quality? |
| | MNEnv-2 | What are the impacts on perceptions of overall environmental quality? |
| | MNEnv-3 | What are the impacts on energy consumption? |
| Goods Movement | MNGoods-1 | CVOs will experience reduced travel time by using the HOV lanes and PDSL on I-35W if CVO use is permitted. |
| | MNGoods-2 | CVOs will experience reduced travel time by the overall reduction in congestion on I-35W from the UPA projects. |
| | MNGoods-3 | CVOs hauling or delivering goods will perceive net benefit of HOT and PDSL (e.g., benefits such as faster service and greater customer satisfaction outweigh higher operating costs due to tolls). The exception may be in downtown Minneapolis, where delivery and service vehicles will not be allowed to use the dual bus lanes during the peak hours. |
| Business | MNBusiness-1 | What is the impact of the UPA strategies on employers? e.g.,<br>employee satisfaction with commute<br>perceived productivity impacts<br>employee retention/hiring impacts<br>negative impacts (increased cost of doing business) |
| | MNBusiness-2 | How are businesses that are particularly impacted by transportation costs affected (e.g., taxis, couriers, distributors, tradesmen)? |

| Evaluation Analysis | Hypothesis/Question Number | Hypothesis/Question |
|---|---|---|
| Non-Technical | MNNonTech-1 | What role did factors related to “people” play in the success of the deployment?<br>People (sponsors, champions, policy entrepreneurs, neutral conveners) |
| | MNNonTech-2 | What role did factors related to “process” play in the success of the deployment?<br>Process (forums including stakeholder outreach, meetings, alignment of policy ideas with favorable politics, and agreement on nature of the problem) |
| | MNNonTech-3 | What role did factors related to “structures” play in the success of the deployment?<br>Structures (networks, connections and partnerships, concentration of power and decision-making authority, conflict-management mechanisms, communications strategies, supportive rules and procedures) |
| | MNNonTech-4 | What role did factors related to “media” play in the success of the deployment?<br>Media (media coverage, public education) |
| | MNNonTech-5 | What role did factors related to “competencies” play in the success of the deployment?<br>Competencies (cutting across the preceding areas: persuasion, getting grants, doing research, technical/technological competencies; ability to be policy entrepreneurs; knowing how to use markets) |
| | MNNonTech-6 | Does the public support the UPA/CRD strategies as effective and appropriate ways to reduce congestion? |
| Cost Benefit | MNCBA-1 | What is the net benefit (benefits minus costs) of the UPA/CRD strategies? |

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