Integrated Corridor Traffic Management Final Evaluation Report

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BOOZ·ALLEN & HAMILTON

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EXECUTIVE SUMMARY

In 1993, the Minnesota Department of Transportation (Mn / DOT) forged a partnership with Hennepin County and the cities of Bloomington, Richfield, and Edina to test the concept of integrated corridor traffic management (ICTM) across jurisdictional boundaries. The public sector partners launched the ICTM project in 1994 as a field operational test with partial funding provided by the Federal Highway Administration (FHWA) and additional support by private sector partners. The selected corridor was an 8-mile section of the I-494 transportation corridor south of the Twin Cities encompassing I-494, four parallel arterial streets, and seven perpendicular arterial streets crossing five jurisdictions.

The concept of ICTM was to optimize corridor capacity, traffic operations, and safety by the application of a myriad of advanced technologies including adaptive ramp metering, adaptive, traffic signals, motorist information, and surveillance systems. ICTM used Sydney Coordinated Adaptive Traffic System (SCATS) to provide adaptive traffic control technology for both freeway metered ramps and arterial traffic signals. The deployed technologies were to better accommodate locally generated short trips during recurrent congestion while leveraging capacity of the parallel arterial system to augment freeway capacity during major freeway incidents. Institutional, organizational, management and operational, as well as procedural infrastructure were also created to support the project.

Booz·Allen & Hamilton developed this evaluation report, which summarizes the ICTM evaluation recommendations, conclusions, best practices, and lessons learned based on findings derived from a variety of quantitative and qualitative data sources. These sources included travel time runs, screenline traffic counts, automated databases, written surveys and interviews with local project stakeholders, telephone interviews with 400 corridor motorists, and a variety of project documents.

The evaluation design limited the opportunity to make definitive conclusions about the *precise impacts* of ICTM system on changing traffic patterns and operations within the corridor. This was attributed to a significant time gap (3 to 5 years) separating “before” and “after” cases, allowing external factors to influence evaluation results and findings including:

- Infrastructure modifications at strategic locations within the corridor impacting network capacity, such as lane additions and deletions, new driveways, and new streets
- Operational modifications across the corridor impacting network capacity, such as signal phasing additions and deletions, exclusive phasing, and new traffic signals
- Land-use modifications both within and outside the corridor impacting the magnitude and distribution of generated traffic demand across the network.

Additionally, the operations of the arterial traffic signals under the "before" case consisted of a variety of nonintegrated control systems across jurisdictional boundaries. The east-west streets were mostly controlled by isolated traffic signals in actuated operations while the north–south streets were operated by distributed closed-loop systems whose system timings were developed during 1988/1990 period. Therefore, the evaluation compared optimized adaptive traffic operations in the "after" case with non-optimized traffic operations in the "before" case.

Summaries of the high-level conclusions and recommendations of this report are presented below.

INSTITUTIONAL BENEFITS

ICTM partnership strengthened institutional and organizational relationships, cooperation, and coordination and contributed to enhancing the corridor's overall transportation system.

ICTM deployment required a new interagency and interjurisdictional organizational structure to manage deployment, operations, and maintenance of advanced technologies. This institutional infrastructure was founded on a partnership that embraced a proactive and corridor-wide management vision and unified operational strategies. The partnership altered institutional procedures and operational policies across jurisdictional boundaries to address the transportation needs of the corridor as whole. This success was fueled by the partners' willingness and commitment to abandon their communities' independence to work together in shared jurisdictional responsibilities despite the potential for increased operational risks across jurisdictional boundaries.

Under ICTM, management and support committees were formed to oversee testing and deployment while sharing and coordinating financial, technological, know-how, and staff resources. Partners leveraged a unified voice on transportation issues as well as new institutional arrangements to secure funding for other transportation projects within the corridor. Trust, respect, and effective communication were recognized as the key contributors to ICTM's successful partnership. The high-level evaluation conclusions include:

- ICTM's partnering infrastructure was the most significant benefit achieved from deployment. It enabled project partners to leverage institutional relationships to address the corridor's transportation needs beyond the domain of the ICTM project.
- The concept of interjurisdictional strategies for integrated traffic operations, maintenance, and management was groundbreaking in Minnesota.
- Informal agreements among local public partners founded the ICTM partnership and served to result in each partner exceeding original commitments in project funding and support.
- Obtaining the SCATS software license required significant staff and time resources.
- The ICTM partners engaged local residents and businesses in the ICTM development process, obtaining community support for the ICTM concept.

SYSTEM PERFORMANCE

ICTM provided stakeholders with valuable infrastructure elements and resources for enhanced traffic management and operations. It paved the way for a paradigm change in ramp metering management and proved the concept of fail-safe adaptive ramp metering management in Minnesota. The SCATS system posed operational challenges for operating and maintaining adaptive traffic control along arterial streets caused by unstable communications network and complex adaptive technology. Emergence of the latest generation technology may address current system performance issues.

Although the public-private partnership arrangements worked well, ICTM faced challenges related to unstable communications system, project staffing, and training. The poor performance of the communications system limited the effectiveness of ICTM in meeting corridors' traffic management and operations needs. With respect to personnel, ICTM management underestimated staffing and workload requirements for operating, maintaining, and managing ICTM, and training proved a challenge. The high-level evaluation conclusions include:

- Leveraging state-of-the-art and state-of-the-practice methodology, ICTM's new generation ramp-metering system is the first application of operational adaptive ramp-metering management in the United States.
- System architecture allowed SCATS and Traffic Management Center (TMC) servers to operate concurrently while leveraging a fail-safe feature that relied on the TMC' s proven ramp-metering technology.
- Project stakeholders generally perceived SCATS' system functions and training as better than average.
- Project stakeholders perceived SCATS user interface features as "poor" making the programming and operations of SCATS software and Delta-3 controller very complex and training and support requirements extensive.
- The SCATS system required more maintenance and operations attention than did traditional traffic control systems.
- The SCATS system required extensive initial and ongoing training.
- The SCATS system required significantly more data for operational configuration than did traditional systems.
- The communication network performed poorly, thus limiting the synergistic capabilities of ICTM in meeting corridor traffic management and operations needs.

SYSTEM DEPLOYMENT

ICTM was implemented in four modules that spanned a 5-year period while facing significant deployment challenges. The project produced valuable findings, lessons learned, and deployment advice pertaining to integrated interjurisdictional application of disparate technologies for traffic management.

The size and complexity of the project, as well as Minnesota's short construction season, required a phased, or modular, approach to project deployment. Each module was assessed after its completion, providing valuable evaluation feedback before initiation of the next module. Implementation occurred in four phases at a cost of approximately $9 million. The adaptive traffic control system operated by means of complex algorithms and detectors installed in the roadway and was complemented by motorist information and incident management systems during incident conditions. The high-level evaluation conclusions include:

- The ICTM public-private partnering arrangement provided significant benefits in funding.
- The design-build procurement mechanism was the appropriate contracting technique for the ICTM motorist information system.
- The modular process provided an opportunity for incremental learning but increased evaluation difficulty and cost.
- The "force account" process enabled agencies to deploy the project with reduced budgetary impact by leveraging existing project initiatives instead of providing hard contributions.
- ICTM management underestimated staffing and workload requirements for operating, maintaining, and managing ICTM.
- It is critical to assign system management, operations, and maintenance responsibilities to the existing organizational sections responsible for system support albeit with increased staff.
- The requirement that motorist information signs be Underwriters Laboratories (UL)-approved posed unique challenges for ICTM.
- ICTM outreach and marketing efforts were successful in reaching the targeted audience.
- The overall design of the communications system should accommodate the requirements of all envisioned field devices and locations.
- The choice of specific technologies to deploy for traffic management and control should consider and reflect the availability and skill levels of support staffs and the associated training requirements.
- Given the significance of detection in an adaptive traffic control system, it is paramount to correlate detection design with motorists' stopping behavior at signalized intersections during various weather conditions.
- ICTM deployment could have benefited from resolving all implementation issues and challenges associated with one technology prior to introducing the next.
- The evaluation of the ICTM system involved assessment of the institutional processes and the operational characteristics of disparate systems and proved very challenging.

SYSTEM IMPACTS

Forged partnership across interjurisdictional boundaries, integrated interjurisdictional management strategies, and deployed technologies contributed to improving traffic operations and use of capacity within the corridor.

ICTM enhanced the opportunity for capacity management, operations management, and demand management within the corridor. This achievement was made feasible by the use of integrated management strategies and advanced technologies to accommodate changing traffic patterns and operations. Traffic congestion increased along I-494 and associated ramp meters and contributed to changing traffic patterns. ICTM's adaptive system accommodated these pattern changes. Implementing ICTM yielded benefits in traffic operations and management across diverse transportation infrastructure components and jurisdictional boundaries. The high-level evaluation findings include:

- ICTM system accommodated changing traffic patterns through improved use of corridor capacity during nonincident conditions.
- Corridor experienced traffic operations improvements during nonincident conditions.
- Motorists made more intelligent route choices during incidents because of the motorist information system and incident management strategies.
- SCATS system responded appropriately to traffic conditions during incidents.

OVERALL CONCLUSION

ICTM integrated technology and strategy for better traffic management across jurisdictional boundaries–it has been more than just technology application. It effectively combined forged relationships and partnerships, operational strategies, and advanced technologies to improve traffic operations and use of capacity across a myriad of infrastructure components and jurisdictional boundaries.

The institutional structure and interjurisdictional relationships forged during this Field Operational Test (FOT) have helped the project partners address current and future transportation issues corridorwide. The operational benefits of the deployed technologies will increase as the latest generation of traffic control technology matures and project stakeholders are provided with more user-friendly technology alternatives or enhancements. The partners have demonstrated that they can work together to address the transportation management needs of the corridor by sharing a common vision and strategic approach. Measuring the value of the ICTM experience in this context, it is clear that the project merits continued investment to sustain its concept by taking full advantage of technology improvements. Thus, the evaluation team recommends pursuit of the following ICTM steps:

Commitment: Renew the partnership commitment to address transportation needs on a corridorwide basis.

The perceived value of ICTM's institutional benefits, deployed technologies, and supporting strategies has fueled its continuation and support. The partner agencies' renewed commitment to share a common vision and strategic approach is essential in addressing the transportation management needs of the entire corridor. This, in turn, will serve to strengthen the partnership in allocating the resources needed to realize the envisioned tangible and intangible benefits.

Institutional Infrastructure: Continue the institutional framework for system support.

The ICTM institutional framework was instrumental in ensuring the execution of the ICTM concept, especially in view of the significant technical and operational challenges encountered. The management team and supporting working committees worked in unison to address ongoing challenges. The interdependence of ICTM jurisdictional networks, technologies, and management strategies requires the continuation of this institutional and organizational framework. This management and operations framework and ensuing cooperation and coordination are essential in supporting the diverse needs of the ICTM system including funding, procurement, operations, maintenance, and management.

Technology: Explore options and alternatives for resolving current technology challenges prior to system expansion.

The unstable communications system and complex system user-interface adversely affected the ICTM system. These technical issues should be resolved to realize the benefit of ICTM to traffic operations and management. Identification and resolutions of these technology issues will minimize their impact on resources and buy-in of support staffs. There are a variety of technology-based options to support ICTM system expansion and next steps. However, these options should be explored after the current technology challenges are successfully addressed.

Operational Strategy: Apply unified operational strategies for system configuration, management, and operations.

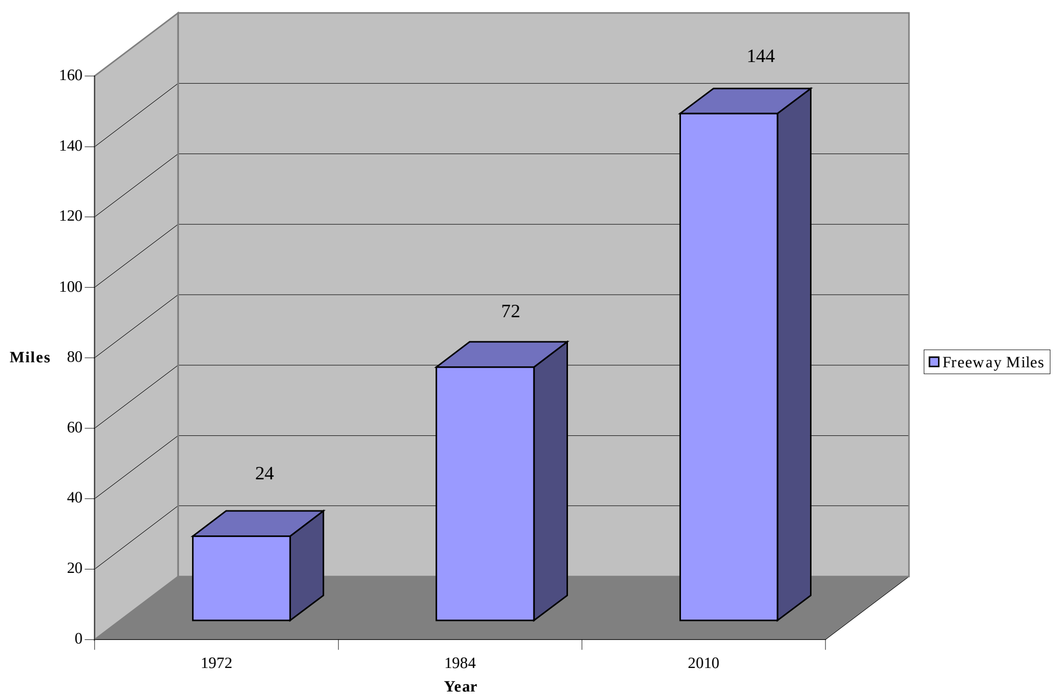
The deployment of ICTM technologies and management strategies across jurisdictional boundaries required unified operational strategies and procedures to ensure consistent and compatible traffic operations corridorwide. System upgrades, expansion, and staff turnover typically diminish understanding of support staff resulting in increased operational errors. It is recommended that the operational, maintenance, and management procedures be formally documented and shared with support staff. This will enhance interagency coordination and consistency in system operations and maintenance.

Resources: Provide necessary resources and support for continued system management and operations.

ICTM is a complex Intelligent Transportation Systems (ITS system), which includes a variety of advanced technologies and strategies. Similar to other ITS systems, ICTM has demonstrated it requires additional levels of support and training resources for quality system operations and maintenance to realize the envisioned management benefits. To realize these benefits, it is imperative to ensure the support staff is proficient in ITS system operations and equipped with needed resources, know-how, and support to properly maintain them.

INTRODUCTION

The Twin Cities Metropolitan Area (TCMA) is facing an unprecedented growth in traffic congestion. This increased congestion has many causes, including population growth, a resurgent economy, urban sprawl, and an increase in dual-income households. The congestion in the area has developed over several years. From 1972 to 1984, the number of TCMA freeway miles with severe congestion tripled from 24 to 72. In light of this trend, it is expected that the number of severely congested freeway miles in the area will double from 1984 levels by the year 2010 (see Figure 1 below). The motoring public in the TCMA makes extensive use of the freeway network to travel within and around the area, with an average trip length of 2 miles on the most congested circumferential freeways and an average trip length of 5 miles on radial



freeways.

Figure 1: Congested Freeway Miles

The Interstate-494 (I-494) transportation corridor experiences heavy congestion several hours each weekday. An environmental impact study estimated that no realistic I-494 mainline improvement would satisfy the forecasted travel demand within the southern I-494 corridor without the development of a parallel arterial system. The study also determined that the average trip length on I-494 was less than 2 miles, and that redirecting these shorter trips to a convenient, continuous, and more efficient route on the parallel arterial street system was a prudent way to reduce delays, relieve congestion, and improve overall corridor operations. This finding resulted in the formulation of an ICTM strategy crossing jurisdictional boundaries to adequately accommodate the current and future travel needs of the corridor.

In 1993, the Minnesota Department of Transportation (Mn/DOT) forged a partnership with Hennepin County and the cities of Bloomington, Richfield, and Edina to test the concept of integrated corridor traffic management (ICTM) across jurisdictional boundaries. The public sector partners launched the ICTM project in 1994 as a field operational test with partial funding provided by the FHWA and additional support by private sector partners. The selected corridor was an 8-mile section of the I-494 transportation corridor south of the Twin Cities encompassing I-494, four parallel arterial streets, and seven perpendicular arterial streets crossing five jurisdictions.

This report summarizes the ICTM evaluation findings, recommendations, results, and conclusions. Findings are based on a variety of quantitative and qualitative data sources. These sources included travel time runs, screenline traffic counts, written surveys and interviews with local project stakeholders, telephone interviews with 400 corridor motorists, and such project documents as the implementation plan, the operations plan, the maintenance plan, and the evaluation plan. The report was developed by Booz·Allen & Hamilton and is the final deliverable in Booz·Allen's contract with the Minnesota Department of Transportation, entitled "Evaluation of the ICTM System."

The report is divided into six sections in addition to this Introduction:

- Project Overview—A brief description of the ICTM project and its evaluation
- Institutional Benefits—A presentation of successful practices and lessons learned with respect to the interagency and interjurisdictional relationships forged during project deployment
- Deployment Issues—Key problems and solutions identified during the project deployment
- System Performance—Successful practices and lessons learned concerning the SCATS software and hardware, as well as communications network performance indicators
- System Impacts—Findings and lessons learned concerning ICTM traffic operations along freeway and arterial subsystems, including adaptive ramp metering and use of corridor capacity
- Action Plan—Recommendations for future actions regarding ICTM deployment
- Appendix A—Findings for ICTM system impacts
- Appendix B—Findings for conducted travel time runs
- Appendix C—Glossary of terms used throughout this report.

PROJECT OVERVIEW

The goal of ICTM was to optimize capacity, traffic operations, and safety on corridor's freeway and arterial links by application of adaptive ramp-metering and traffic signal systems as well as motorist information and surveillance systems. The deployed technologies were to better accommodate locally generated short trips during recurrent congestion while leveraging capacity of the parallel arterial system to augment freeway capacity during major freeway incidents. Institutional, organizational, management and operational, as well as procedural infrastructure were also created to support the project.

ICTM CONCEPT

The concept behind ICTM is to better balance traffic flow and use of capacity at the corridor level. This end is achieved by optimizing the operations and capacity of the freeway and arterial streets through adaptive traffic control and by enhancing corridor demand management during freeway incidents through incident management strategies and a motorist information system. Incident management and smart traffic signals and ramp meters are generally considered core technology-based solutions for enhancing corridor capacity and traffic operations. The need to test deployment of an adaptive traffic control system stemmed from an earlier study that indicated no realistic mainline improvement alone could effectively accommodate the forecasted travel demand within the I-494 corridor. This finding highlighted the need to deploy advanced technologies and strategies to improve use of corridor capacity in accommodating travel demand. Improved traffic operations were expected to encourage travelers to use local arterial streets for short local trips thus easing traffic burden on the freeway.

The ICTM concept can be expanded to other parts of the metropolitan area or the United States. The experience gained from ICTM deployment has created a unique opportunity for project partners to share lessons learned and successful practices with interested agencies contemplating similar deployments. This report is one mechanism for achieving this objective.

PROJECT DESCRIPTION

The ICTM project was formally launched in 1994. It was implemented in four phases, or modules, on a 5-year deployment schedule that took into account Minnesota's short construction season and the project's size and complexity.

The ICTM management team was very aware of the impacts that incident management strategies might have on the corridor and the community. The ICTM corridor was selected because it was predominantly commercial in character and contained the appropriate infrastructure components to support freeway traffic diversion with minimum community impact.

Figure 2 depicts the project corridor, which is located along the southern beltway (I-494) in the Twin Cities metropolitan area in Minnesota. The project corridor runs from 34th Avenue to East Bush Lake Road and includes major east–west and north–south arterial streets.

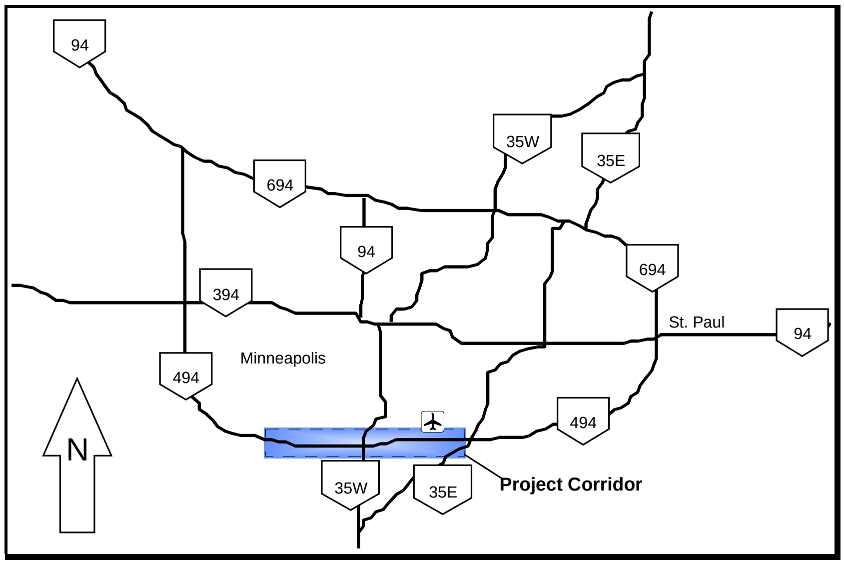


Figure 2: Project Corridor in Minneapolis–Saint Paul, Minnesota

The main objectives of the project were to—

- Deploy an adaptive traffic control strategy that rapidly responds to anticipated and unanticipated fluctuations in traffic flow under both recurrent congestion and incident conditions
- Demonstrate that multiple transportation agencies can work together to improve travel conditions throughout the I-494 corridor
- Integrate available advanced technologies for collecting and disseminating corridor information
- Provide comprehensive motorist information services.

Figure 3 depicts ICTM project limits and existing traffic control components. Figure 4 presents ICTM corridor and associated traffic control system.

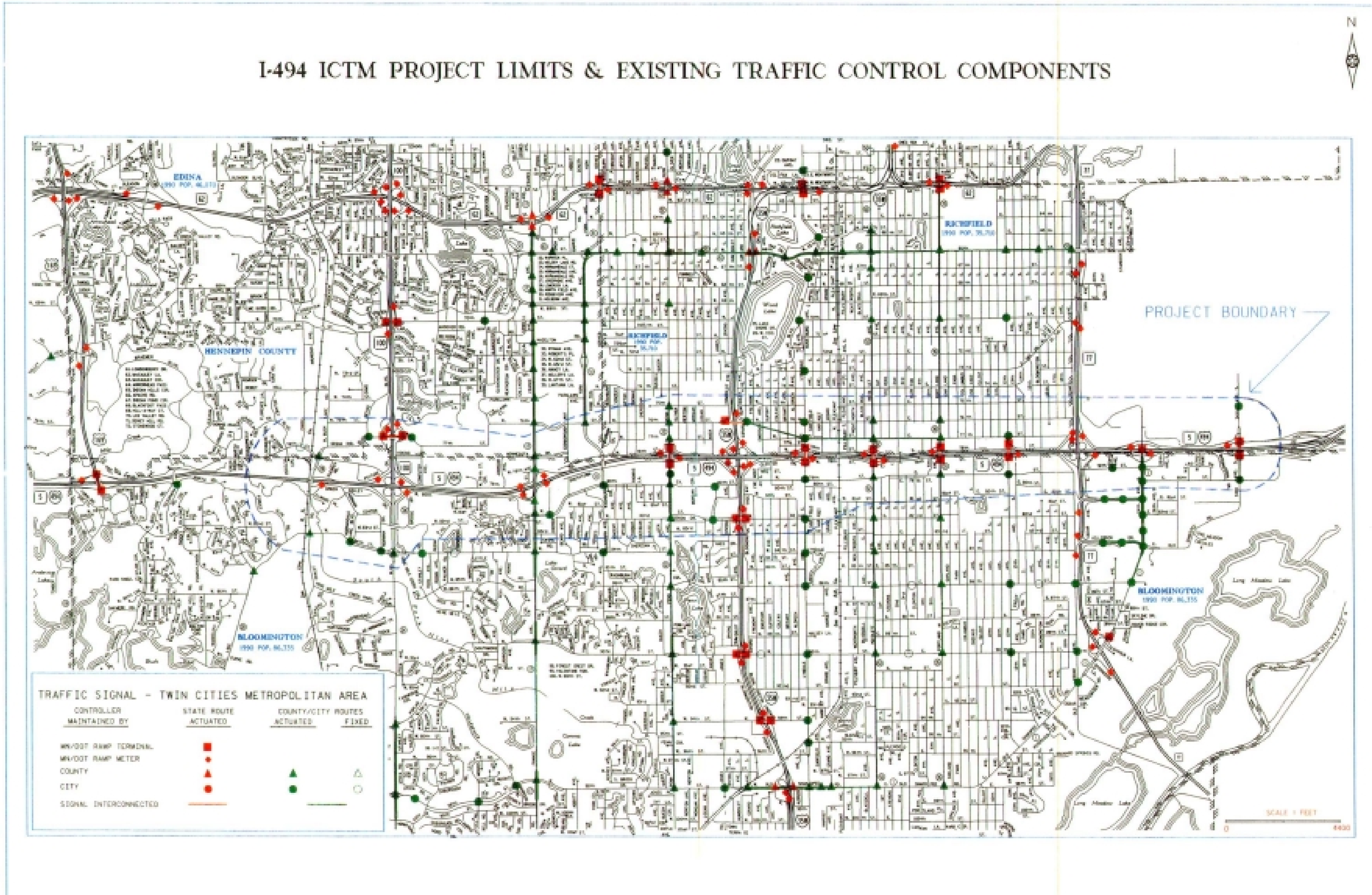


Figure 3: ICTM Project Limits and Existing Traffic Control Components

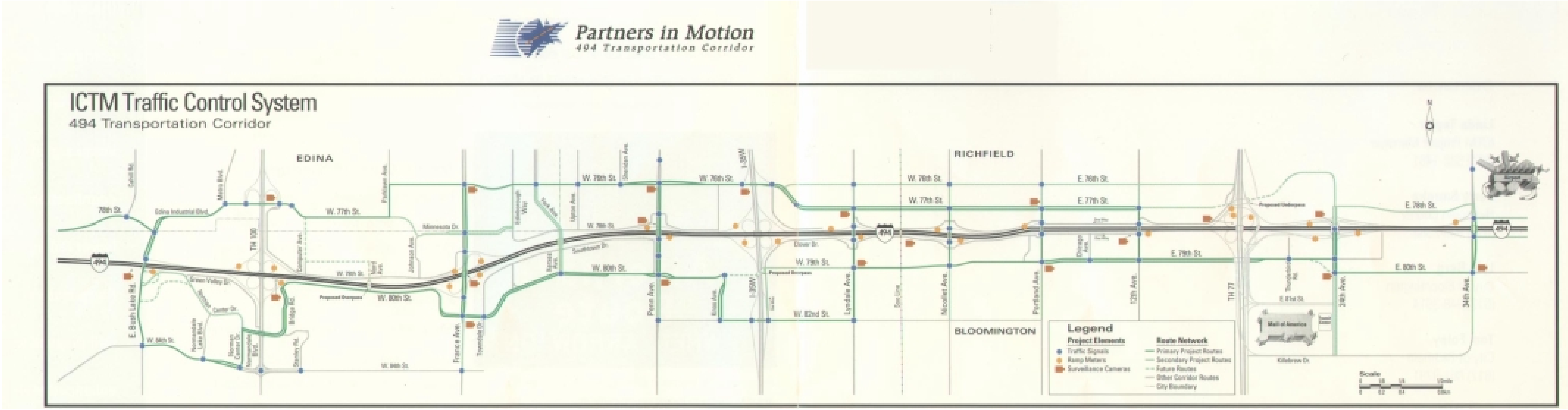


Figure 4: ICTM Corridor and Associated Traffic Control System

TRAFFIC CONTROL SYSTEM

ICTM leveraged the SCATS, developed in Australia, to control and manage 68 arterial traffic signals and 27 freeway metered ramps. Project partners selected the SCATS' adaptive traffic control system to test the ICTM concept because of SCATS unique adaptive control capabilities and the provider's willingness to develop the latest generation adaptive ramp-metering system that could meet the specific needs of the envisioned ICTM system. This vision encompassed a real-time traffic control system that could automatically adjusted traffic signals at arterial traffic signals and freeway metered ramps in response to changing traffic conditions and incidents. It would also enable the participating agencies to use the system as a dynamic tool for traffic operations and management purposes in addressing the overall transportation needs of the corridor.

INCIDENT MANAGEMENT STRATEGIES

The ICTM incident management strategies were supported by both adaptive traffic control and the motorist information system. The strategies involved diverting local and regional traffic through use of freeway and arterial surveillance and traveler information field devices. These devices were strategically located within the corridor and included 2 freeway variable message signs, 9 arterial dynamic message signs, 11 arterial closed-circuit television (CCTV) cameras, and 81 static trailblazing signs. These devices were leveraged for traffic management purposes during incidents, construction, and maintenance activities.

Motorists were provided with up-to-the-minute information on how to avoid potential problem areas. Sign priorities were built into the motorist information software, enabling partner agencies to modify changeable message signs or activate incident plans based on traffic operations data from the system. The freeway variable message signs alerted motorists to

- ❑ Problems within and beyond the I-494 corridor to provide motorists with regional route information
- ❑ Alternate route information so that motorists could use designated local streets to bypass incidents on the freeway.

Trailblazing signs installed on local streets helped direct motorists around problem areas. Dynamic message signs along major local streets provided complementary route guidance information. Collectively, this information helped motorists choose which routes to take, allowing them to bypass impacted incident areas and guiding them safely along major local streets to I-494.

PARTNERS

The ICTM project was a partnership among public agencies and private organizations. Partners combined financial and staff resources, expertise, technology, management strategies, and infrastructure. Public partners contributed existing roadways, traffic control equipment, installation, ongoing maintenance and operation of the system, and staff. Private partners contributed technical expertise, training, equipment, and advanced technologies. Table 1 presents the ICTM project partners—

Table 1: ICTM Project Partners

AFFILIATION	PARTNER
Public	Federal Highway Administration
	Minnesota Department of Transportation
	Hennepin County
	City of Bloomington City of Richfield City of Edina
Private	Skyline Products, Inc.
	AWA Traffic System
	Rennix Corporation
	Traffic Control Corporation

EVALUATION APPROACH

Booz·Allen & Hamilton was commissioned by Mn/DOT in August 1998 to assess the benefits that ICTM provided to the public and participating agencies. The original evaluation plan was developed by HNTB and turned over to Booz·Allen for modification and implementation after initial data collection was completed.

Sources of qualitative data included representatives from stakeholder agencies and corridor motorists. Four hundred motorists residing or working in and around the ICTM corridor were surveyed by telephone to capture their perceptions of traffic operations and patterns within the corridor. Additionally, 30 representatives of stakeholder agencies, consisting of system managers (19) and operators (11), were surveyed and interviewed. A variety of project documents were also reviewed, including the evaluation test plan, the implementation plan, the operations plan, the maintenance plan, and meeting minutes.

Sources of quantitative data included field surveys and automated TMC and SCATS databases. Quantitative data consisted of travel time runs (travel time, frequency of stops, space mean speed, and overall delay), traffic flow rate, detector occupancy, metering states, cycle length, degree of saturation, and phase duration. This data was used to assess traffic operations and pattern changes within the corridor under incident and nonincident conditions. No benefit/cost analysis was performed due to evaluation scope limitation.

A before-and-after testing approach based on inferential statistics and a 90-percent confidence level was used in assessing the traffic operations Measurement Of Effectiveness' (MOEs) during nonincident conditions. Descriptive statistics were used to assess traffic operations MOEs during incident conditions by comparing the mean values and dispersion of applicable MOEs for *comparable* incident and nonincident periods.

It is important to point out that the evaluation design limited the opportunity to make definitive conclusions about the precise impacts of ICTM system on changing traffic patterns and operations within the corridor. This was due to a significant time gap (3 to 5 years) separating “before” and “after” cases, allowing external factors to influence evaluation results and findings. Additionally, the potential impacts on the ICTM evaluation by the following external influences could not be differentiated:

- Infrastructure modifications at strategic locations within the corridor impacting network capacity, such as lane additions and deletions, new driveways, and new streets
- Operational modifications across the corridor impacting network capacity, such as signal phasing additions and deletions, exclusive phasing, and new traffic signals
- Land-use modifications both within and outside the corridor impacting the magnitude and distribution of generated traffic demand across the network.

Additionally, the operations of the arterial traffic signals under the "before" case consisted of a variety of nonintegrated control systems across jurisdictional boundaries. The east-west streets were mostly controlled by isolated traffic signals in actuated operations while the north–south streets were operated by distributed closed-loop systems whose system timings were developed during 1988/1990 period.

Specific qualitative and quantitative measures of effectiveness (MOE) used in the evaluation are listed in Table 2.

Table 2: ICTM Data Sources and Measures of Effectiveness

CONDITION	DATA SOURCES	MEASURE	DATES
Non-Incident	Travel time runs	Travel time, frequency of stops, spot speed, and overall delay on arterial streets	1996 and 1999
	Travel time runs	Travel time, frequency of stops, and spot speed on I-494	1994 and 1999
	TMC database	I-494 main lane flow rate, density, entrance ramp flow rate, entrance ramps on/off states	1994 and 1999
	Traffic counts	Flow rate of at two screenline locations along I-494 and east–west streets	1996 and 1999
	Phone interviews with motorists	Perception	1996 and 1999
	Agency survey	Perception	1996 and 1999
	Agency interviews	Perception	1996 and 1999
Incident	TMC database	I-494 entrance and exit ramp flow rate	1999
	SCATS database	Bypass traffic signals cycle length, critical movement degree of saturation, and phase duration	1999
	Phone interviews with motorists	Perception	1996 and 1999
	Agency survey	Perception	1996 and 1999
	Agency interviews	Perception	1996 and 1999

Evaluation Focus Areas

The ICTM evaluation focused on four areas. Each focus area was supported by several objectives. Each objective was validated by a set of MOEs, as appropriate. Evaluation focus areas and the corresponding objectives are presented in Table 3.

Table 3: ICTM Evaluation Focus Areas and Objectives

FOCUS AREA	EVALUATION OBJECTIVE
Institutional Benefits	Assess value of interjurisdictional cooperation and coordination
	Assess value of integrated interjurisdictional strategies for traffic operations, maintenance, and management
	Document multiagency agreements
	Document altered policies and procedures
System Performance	Rate accessibility of SCATS for traffic management
	Assess reliability of SCATS communication network for traffic management
	Assess effectiveness of SCATS training and support for traffic management
	Determine usefulness of SCATS automated data for traffic management
	Document SCATS characteristics
System Deployment	Document ICTM costs
	Document all fixed and ongoing costs (by system component and module)
	Document public and private sector contributions
	Document deployment issues
System Impacts	Assess ICTM's value in making use of corridor capacity
	Assess ICTM's value in improving traffic flow in the corridor
	Assess ICTM effects on traffic control systems bordering the corridor

The following sections briefly describe data requirements for pertinent system components under both incident and nonincident conditions.

Nonincident Conditions

Traffic counts, travel time runs, and the TMC detector database were the quantitative data sources used to evaluate the ICTM impacts during nonincident conditions. Each source is discussed below.

Data collection activities and consideration of operational characteristics at isolated intersections were eliminated from the evaluation because

- Travel time runs were perceived to provide sufficient data for assessing traffic operations corridorwide
- SCATS routines could optimize overall traffic operations through redistribution of operational penalties (number of cycle failures, queues, and delays) across the network, thus rendering evaluation of isolated locations imprudent
- The evaluation budget limited the opportunity to collect sufficient field data for statistically significant analyses.

Traffic Counts

Traffic counts at two "screenline" locations along I-494 and east–west arterial streets formed the basis for measuring changes in traffic flow intensity and patterns. The screenline count stations included Xerxes Avenue and Nicollet Avenue located approximately 1 mile east and west of I-35W, respectively (see Figure 5). These locations were selected based on availability of existing loops on I-494 for measuring traffic flow.

Figure 5: ICTM Screenline Locations

Before-and-after data was collected during April and May 1996 and April and May 1999, respectively. Four analysis periods were considered: weekday (7:30-8:30 a.m., 10:30-1:30 p.m., and 4:30-5:30 p.m.) and Saturday midday (4:30-5:30 p.m.). For the weekday measurements, only Tuesdays, Wednesdays, and Thursdays were considered, to minimize the potential influence of fluctuations in traffic flows typically experienced on Mondays and Fridays.

I-494 traffic counts collected during April–May 1996 were used even though the ICTM adaptive ramp-metering system was already in operation at that time. This period was selected because the use of other available data (August 1995) would have introduced a higher propensity for error by requiring the application of seasonal adjustment factors. Mean hourly traffic flow rates at each screenline location for each street, direction, and analysis period were used as the basis for identifying potential traffic pattern changes. This quantitative assessment was complemented by assessments of the perceptions of corridor motorists and agency stakeholders concerning traffic pattern changes. The qualitative assessment included the perception of agency stakeholders that the north–south streets experienced significant flow increases. This qualitative measure was used since the original evaluation design did not provide for collection of flow data on north–south streets.

Travel Time Runs

Travel time runs were conducted for all corridor routes, including I-494, and east-west and north–south arterial streets. These runs produced such measures of effectiveness as travel time, frequency of stops, space mean speed, and overall delay for each corridor route by direction and analysis period. These measures formed the basis for evaluating traffic operations corridorwide.

Before-and-after data for eastbound and northbound streets used travel time runs from April and May 1996 and April and May 1999, respectively. The before-and-after analysis for I-494 used data from travel time runs in April and May 1994 and April and May 1999. Use of 1994 rather than 1996 data was necessary because the ICTM adaptive ramp-metering system was operational in 1996 and the associated collected data did not represent nonadaptive traffic operations on I-494.

The mean values of measures of effectiveness associated with travel time runs were adjusted considering the potential influence of traffic flow changes over the 3-or 5-year period. This end was achieved by considering traffic flow *and* operations MOEs across corridor links to reach operational conclusions. For example, for a given street, direction, and analysis period, a statistically significant increase in traffic flow could result in the conclusion that mean travel time *improved* even if there was no statistically significant change in associated mean travel time.

Travel time runs were conducted using the "floating car" technique, using a JAMAR TDC-8 data collection board configured for travel time recording. The data collection effort encompassed 12 two-way routes in the ICTM corridor for each analysis period. A minimum of 10 runs were conducted for each route, with 5 runs pertaining to the peak hour of each analysis period. The data collection activity for each route and period was coordinated with a designated Mn / DOT representative before the effort began, to ensure that the collected data represented adaptive traffic operations.

TMC Detector Database

The evaluation of the ramp-metering system considered traffic operations MOEs on a zone-by-zone basis, encompassing freeway mainline traffic flow, occupancy (density and spot speed), metered and unmetered entrance ramp traffic flow, and frequency and duration of ramp metering on / off states. Queue and delay MOEs were considered but were excluded from the evaluation design because the associated data collection efforts to support a statistically significant analysis were considered cost-prohibitive.

Mn / DOT's TMC detector database automatically recorded and archived the output of strategically located detectors within each ICTM freeway ramp-metering zone, monitoring flow activity on main lanes, entrance ramps, and exit ramps. Queue detectors were installed at each metered entrance ramp within the corridor as part of the ICTM project. The evaluation compared weekday data during a.m. (7:00 to 8:00) and p.m. (4:30 to 5:30) periods for representative weekdays (Tuesdays, Wednesdays, and Thursdays). Before-and-after data pertained to April and May 1994 and April and May 1999, respectively. Inferential statistics and a 90 percent confidence level were used to identify statistically significant changes in the mean values of the MOEs.

Incident Conditions

The incident management system was designed to allow the ICTM system operator to manually activate predefined incident management plans during major freeway incidents to divert freeway traffic to alternative arterial routes via designated freeway exits. This step would cause an automatic activation of the motorist information system, consisting of electronic signs along I-494 and bypass routes and "liberation" of associated traffic signals to provide longer cycles and phase splits for critical movements. Critical movements included left, through or right maneuvers, depending on the overall configuration of the bypass route and the associated intersections along its course. The right-turn critical movements were analyzed along with the adjacent through movements if these movements shared a common lane or detector.

The evaluation of corridor traffic operations during incident conditions considered changes in

- Traffic flow rates at entrance and exit ramps upstream and downstream of each incident location on I-494 to assess travelers' willingness to divert to corridor bypass routes
- Cycle lengths, phase splits, and degrees of saturation for the critical movements at traffic signals along the bypass routes to assess SCATS responsiveness to surges in traffic demand due to traffic diversions.

The incident-condition evaluation was based on two incidents that occurred during the data collection period in 1999. The TMC detector database was used as the data source for traffic flow rates while the SCATS database was the data source for cycle length, phase splits, and degrees of saturation. Descriptive statistics were used as the statistical tool for the analysis, since it was unlikely that the frequency of "exactly similar" incidents would be sufficient to achieve statistical significance and use of inferential statistics. ***The evaluation therefore represented an approximation for identifying trends or pattern changes.*** These changes reflected travelers' route-choice behavior and SCATS' robustness in accommodating diverted freeway traffic. The evaluation also considered the perceptions of ICTM users, gathered through telephone surveys with 400 corridor residents and motorists and interviews and written surveys with stakeholder agency representatives. Queue and cycle failure impacts of incidents on critical movements were included in the evaluation design but could not be considered, due to unavailability of CCTV cameras during incident conditions to capture associated data.

The following four sections present lessons learned, successful practices, and conclusions related to each evaluation focus area (institutional impacts, system deployment, system performance, and system impacts).

INSTITUTIONAL BENEFITS

ICTM partnership strengthened institutional and organizational relationships, cooperation, and coordination and contributed to enhancing the corridor's overall transportation system.

ICTM deployment required a new interagency and interjurisdictional organizational structure for managing deployment, operations, and maintenance. This section presents the successful practices and lessons learned concerning interjurisdictional cooperation and coordination, as identified by agency participants and evaluators.

Before implementation of ICTM, agencies along the I-494 corridor worked independently of one another, sharing only limited traffic information and focusing on the communities within their individual jurisdictions. This practice resulted in a lack of integrated corridor traffic planning and in unnecessary delays on arterial streets because of nonoptimized traffic signal timing along stretches of arterial streets that crossed jurisdictional boundaries.

ICTM encouraged agencies to take another look at their institutional procedures and focus on the transportation and mobility needs of the corridor as a whole rather than the needs of separate jurisdictions. Financial, technological, and staff resources were shared and coordinated to a large degree, and management committees were formed to oversee testing and deployment.

Figure 6 below illustrates the ICTM management structure. The ICTM management structure included a management team, chaired by a Mn/DOT designated project manager, and three working committees. The ICTM Management Team was made up of representatives from public sector partners. This committee was responsible for managing the overall project. It also controlled the budget and represented the authority of respective agencies to make all project decisions.

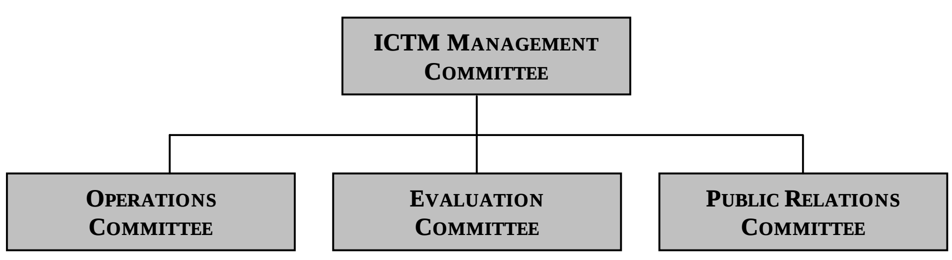


Figure 6: ICTM Management Structure

The three ICTM working committees were:

- An *Operations Committee* comprising traffic engineers and front-line operators, who operated the system and performed signal timing and coordination, system configuration, sign activation, and equipment maintenance
- An *Evaluation Committee* that oversaw development and implementation of the evaluation design
- A *Public Relations* committee that was charged with developing and implementing comprehensive motorist information and public relations plans.

Each Management Team member was responsible for his or her community support because of the members' keen familiarity with their respective city councils and communities. The management team and ICTM committees were, however, supported by the Public Relations Committee who developed communications pieces for distribution to the ICTM committees and the public.

The Evaluation Committee collected data and information related to interjurisdictional traffic operations and coordination and developed data collection agreements and procedures to support the project. The evaluation information presented in this section was collected primarily through agency interviews and surveys.

SUCCESSFUL PRACTICES

ICTM's partnering infrastructure was the most significant benefit achieved from deployment. It enabled project partners to leverage institutional relationships to address the corridor's transportation needs beyond the domain of the ICTM project.

The ICTM partnership process and structure motivated members to remain engaged, despite the emergence of significant deployment issues (see *System Deployment* section). Some benefits of this partnership included the ability to work across jurisdictions on issues aside from ICTM. In addition, the partnership gave less powerful members of the team a greater voice and more influence in obtaining transportation funds, resources, and attention from Mn/DOT (an ICTM partner). Participating partners were thus able to secure additional transportation funds for a variety of transportation improvement projects (e.g., correction of intersection and roadway geometric limitations, construction of new bridges, and acceleration of deployment of the programmed I-494 improvements). The attributes of ICTM's successful partnership included

- Trust
- Respect
- Good working relationships and communications
- Ground rules
- A common mission and vision and common objectives
- Up-front delineation of the decision making process and roles and responsibilities
- Active participation and involvement
- Shared risks and responsibilities

- The active involvement of key persons from each agency in the project management process.

The concept of interjurisdictional strategies for integrated traffic operations, maintenance, and management was groundbreaking in Minnesota.

Another significant project benefit resulted from the groundbreaking notion of coordinated interjurisdictional strategies for traffic operations, maintenance, and management. For the first time, in the partnering agencies, operational staffs crossed jurisdictional boundaries to repair equipment. For example, if there was a signal outage and a partner not responsible for the signal noticed it, that partner would stop to evaluate the situation and notify the responsible agency to undertake corrective action. This type of cooperation among partners led to considerable trust, respect, and sharing of resources and knowledge.

This sort of cooperation is complex and difficult to organize in a transportation corridor that encompasses multiple jurisdictions. Overall system effectiveness and performance depended on each partnering agency's ability and willingness to support system operations and maintenance and to implement transportation management solutions, as well as on the priority and resources that the agencies assigned to the effort. Therefore, it was critical to the success of the project that each partner live up to their commitments and partnership responsibilities.

Early in the project's development, the partnering agencies agreed to inform their respective staffs and top management of the project's status and progress. All project information including articles generated by each agency for its constituent community was shared with the other partners. To maintain esprit de corps and team cohesiveness, the partnership held periodic "appreciation luncheons" during which partners and staff were recognized for their contributions to the project. At these luncheons, guests of honor included agency staff, who were publicly recognized by their respective managers for their dedicated contribution to the project. These luncheons also provided a forum for informal presentation of the planned next steps, enabling support staff to buy into the system by helping them develop a broader perspective on the goals, direction, and value of the project.

Partnership efforts also figured heavily in the response to project challenges. For example, technical and operational challenges associated with the communications system limited the performance and effectiveness of the system (see *System Performance Section*). The management team worked persistently to resolve these communications problems. Being heavily involved from the outset of the project in plan development and requirements definition, following a joint decision-making process and team approach to problem solving, and giving partners an equal voice and vote in project direction all contributed to maintaining the cohesiveness and strength of the partnership. Decisions were based on what all project partners could "live with." Clear ground rules were established, discouraging finger-pointing, and everyone agreed to live with the consequences of the decisions made. Getting partners' buy-in on issues, involving them in the management process, actively engaging them in project development and deployment, enabling them to be decision makers, and keeping them informed of project status and ongoing issues was instrumental in retaining a quality partnership and effective project management.

Strong relationships were developed in the corridor to overcome institutional and technological barriers. A large majority (74 percent) of agency staff surveyed perceived added value from multiple agencies' working together. Each agency was kept informed about ongoing events and developments through various mechanisms, including meeting minutes, quarterly reports, project supervisor updates, appreciation luncheons, internal presentations, city and county newsletters, quarterly highlights assembled by the Mn/DOT Freeway Operations Section, and public relations efforts.

Other operational strategies that proved helpful included giving each partner the ability to access the overall ICTM system. Each public sector partner agency was given a dial-up data feed for traffic data within the corridor via workstations that allowed it to tie into the combined ICTM network. Agencies could dial into the adaptive control system and look at the SCATS system, the status of traffic signals, or the ramp-metering system. Partners also could check the ramp-metering rates and look at system status maps.

Any partner agency could modify the dynamic message signs and activate incident management plans. Other partners did not need to preapprove actions because sign priorities were built into the motorist information system. These priorities allowed the agency to activate a higher priority message, if needed. As a courtesy, whenever a sign was overridden, the affected agency was called and informed of the change.

Concerning traffic signal operations, there was a common understanding among partners that whichever agency owned and operated a signal or device would be primarily responsible for making field modifications. During system configuration, the partnership agreed on the operating parameters for the signals. This agreement allowed more uniformity and consistency in signal operations throughout the corridor. Over time, some system modifications came about based on traffic conditions, but each partner understood and was comfortable with these changes. There have been no reports of agencies' arbitrarily changing the operation of a signal within the project area.

Allowing ICTM staff to operate Mn/DOT's traffic signals, thus sharing operational control, was a change from historical precedent. The original policy was that such control was exclusively the responsibility of Mn/DOT's Traffic Engineering Section. Mn/DOT agreed to share operational control as long as the basic timing parameters were maintained and Mn/DOT was kept informed of any changes. All parties achieved a clear understanding of the roles and responsibilities for sharing control as the project progressed. Traffic signal maintenance for ramp terminal traffic signals remained the responsibility of Mn/DOT's Electrical Services Section. In addition, Mn/DOT's Traffic Engineering staff continued to generate responses to legal inquiries about the applicable traffic signals.

Operational changes also were introduced for Mn/DOT's preexisting ramp-metering system. The new ramp-metering system leveraged queue detectors, significantly more robust ramp-metering red times, and operational suspension, in 5-minute increments, of metering operations on a ramp-by-ramp basis.

Having an Operations Committee that met periodically during project deployment addressed, to some extent, the operational issues pertaining to traffic signals within the corridor. The effectiveness of this committee was founded on established relationships and the willingness and participation of the agency representatives. The ICTM Management Team was ultimately responsible for the success and/or failure of the system but was willing to grant significant leeway and autonomy to the Operations Committee to ensure project success in the face of potential risks.

Informal agreements among local public partners founded the ICTM partnership and served to result in each partner exceeding original commitments in project funding and support.

ICTM developed several agreements that defined the roles and responsibilities of public and private partners. These agreements were essential in developing, deploying, operating, and maintaining the system. The strength of the interagency agreements and associated partnerships is best demonstrated by partners' funding contributions, which exceeded each partner's original project commitment, in most cases, as presented in Table 4 and Figure 7.

Table 4: Partners' Contributions and Commitments

AGENCY	ORIGINAL COMMITMENT		ACTUAL CONTRIBUTION		CONTRIBUTION EXCEEDING COMMITMENT	
	FUNDS	PERCENTAGE	FUNDS	PERCENTAGE	PERCENTAGE	Funds
FHWA	$5,600,000	80%	$5,508,896	79%	(2%)	($91,104)
Mn/DOT	$910,000	13%	$2,140,330	31%	135%	$1,230,330
Hennepin County	$210,000	3%	$292,116	4%	39%	$82,116
City of Bloomington	$140,000	2%	$206,167	3%	47%	$66,167
City of Richfield	$70,000	1%	$120,631	2%	72%	$50,631
City of Edina	$70,000	1%	$76,693	1%	10%	$6,693

Figure 7: Funding Contributions by ICTM Partners (Commitments vs. Actual)

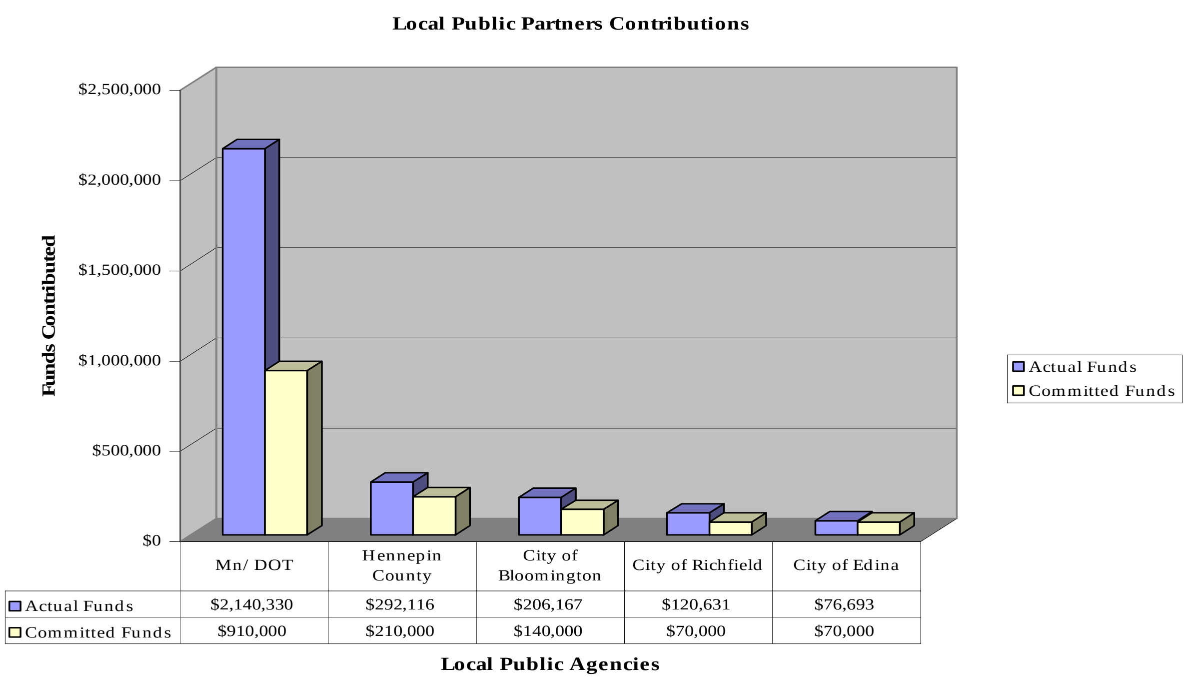


Figure 6: Funding Contributions by Local Public Partners

The key agreements established by ICTM management were

- Municipal Agreements—Agreement between Mn/DOT and local agencies based on identified cost and maintenance responsibilities in support of state construction projects
- Congestion Mitigation and Air Quality (CMAQ) Agreement—Cooperative agreement between Mn/DOT and participating agencies to establish funding and cost sharing for ICTM project staff support positions
- Software Licensing Agreement—Agreement between AWA Traffic System and the State of Minnesota covering such matters as software upgrades and technical support
- Gentleman's Agreement—Verbal agreement on a handshake basis between Mn/DOT and public sector partners, identifying the partners' contribution to the ICTM project
- Partnership Agreements—Mn/DOT to enter agreements with nongovernmental entities for research and experimentation, and allowing sharing of documents, facilities, equipment, staff, data, and services.

These agreements proved effective in developing and deploying the ICTM project and posed no legal and liability challenges for the partnership.

Obtaining the SCATS software license required significant staff and time resources.

AWA Traffic System, now acquired by TransCore Inc., distributes the SCATS system in the United States. The original software licensing agreement with RTA, the Australian government agency that provides the SCATS system, were in conflict with several Minnesota laws. These conflicts pertained to liability, indemnification, confidentiality, and data privacy. The process for reaching the SCATS software license agreement was very lengthy, involving much iteration over an 18-month period. An agreement was finally reached, which is now being used in similar deployments.

The ICTM partners engaged local residents and businesses in the ICTM development process, obtaining community support for the ICTM concept.

The ICTM Management Team effectively obtained the buy-in of the community and elected representatives by conveying the traffic diversion concept and management strategy. This concept highlighted the fact that in the event of major freeway incidents, the community had the choice of facing meandering traffic through neighborhood streets, which would be unsafe and irresponsible, or of facilitating such trips by routing them through designated bypass routes. ICTM management pointed out that orchestrated traffic diversion would minimize diversion impact and enhance safety. This localized strategy was coupled with a diversion plan across the corridor that sought to manage traffic demand to minimize the compound effects of additional traffic arriving at the incident site.

The ICTM working committees took risks by changing the operational procedures of their individual jurisdictions for the good of the corridor. Changes were sometimes controversial, especially if they made signal operations less responsive to an individual community's needs. Therefore, it was critical that community traffic engineers be on board and support ICTM when facing the corridors residents and businesses in town meetings or respective city councils.

System Performance

ICTM provided stakeholders with valuable infrastructure elements and resources for enhanced traffic management and operations. It paved the way for a paradigm change in ramp metering management and proved the concept of fail-safe adaptive ramp metering management in Minnesota. The SCATS system posed operational challenges for operating and maintaining adaptive traffic control along arterial streets caused by unstable communications network and complex adaptive technology. Emergence of the latest generation technology may address current system performance issues.

System performance is different from system effectiveness. Whereas system effectiveness addresses the potential benefits and drawbacks of a given system, system performance is simply the fulfillment of a requirement. Fulfillment of a requirement does not necessarily mean that benefits are being provided. Technology that is powerful but user-unfriendly may be as ineffective even if it meets the specified performance requirements. On the other hand, systems that add marginal value may be perceived as effective if they are easy and fun to use. The evaluation of the ICTM system performance needs to be considered in this context.

Before implementation of ICTM, the traffic signals were operated by a variety of nonintegrated systems across jurisdictional boundaries. The east-west streets were mostly controlled by isolated traffic signals in actuated operations while the north–south streets were served by distributed closed-loop systems whose system timings were developed during 1988 / 1990 period. The TMC ramp-metering system remained independent of the arterial traffic signal system, with no provision for minimizing ramp-metering queue spillover effects. The TMC operated the ramp-metering system using historical algorithms that leveraged 30-plus years of development activities for ramp-metering management.

This section presents the successful practices and lessons learned concerning the SCATS software, data, controller, and the ICTM communications system. Information for this section was gathered through interviews and surveys of partner agency personnel.

SYSTEM ARCHITECTURE

ICTM incorporated a diverse transportation infrastructure crossing jurisdictional boundaries. To insure ICTM's success, this infrastructure required technical, institutional, and procedural integration. The infrastructure also deployed various disparate technologies, including

- An adaptive traffic control system for ramp metering and traffic signals
- A motorist information system to support incident management strategies
- A surveillance system for verification of incidents and operations

- A detection system for system operations and evaluation.

A hybrid communications backbone using multiplexers (MUX) and a multidrop architecture supported the field devices. The SCATS system provided the advanced level of traffic control needed to operate 27 freeway ramp meters and 68 arterial traffic signals. This system was intended to react continuously to traffic conditions on both the arterial routes and the freeway to provide optimal regulation of traffic flow.

SCATS interfaced directly with arterial traffic signals and the TMC server. It obtained freeway traffic flow and occupancy data from TMC server, calculated ramp-metering rates and control parameters, and transmitted this information back to the TMC for implementation. SCATS was connected to the arterial traffic signal controllers by a communications network consisting of an optical fiber link between the TMC server and corridor communications shelter, and twisted-pair cables between the communications shelter and traffic signals.

The ICTM ramp-metering system was designed to function in a fail-safe mode by reverting to the TMC server if the SCATS server did not receive detector data during any 30-second reporting period. The TMC server provided processed outputs of field detectors to the SCATS server. The SCATS server optimized ramp-metering rates on a ramp-by-ramp basis within a freeway zone and provided the optimized control parameters to the TMC server for distribution to ramp-metering controllers. Ramp-metering control reverted back to the TMC server in the event of communications failures between the two servers or malfunctions of the SCATS server.

An operator at a remote workstation could monitor the operation of the system and operate elements of the system, if required. Graphics were provided on the operator workstation to show traffic signal activity at intersections, interconnected systems, or activity. The operator also had access to surveillance facilities via a CCTV camera system connected to the TMC control room by a hybrid optical fiber and twisted pair communication system. These facilities were also available remotely to the agency operators through video feeds from the video switcher.

ICTM was designed to require minimum operator intervention under both recurrent congestion and incident conditions. The implementation of incident management strategies depended on activation of predefined incident response plans that relied on adaptive traffic control and motorist information systems. Intervention involved incorporating the operator’s judgment to determine the need for and feasibility of traffic diversions and the opportune times for response plan activation and deactivation. The operator had the ability to advise drivers by providing information about traffic conditions and by directing drivers to alternate routes. Variable message signs on the freeway and trailblazing and dynamic message signs on the arterial routes provided location-specific text-message capability. Mn/DOT used the Minnesota public radio station, KBEM, to broadcast traffic information every 10 minutes.

ICTM required SCATS to support operations for which it was not originally designed. For example, the hybrid communications design incorporating fiber and copper links and MUXs was the first such application for SCATS. A multidrop communications architecture serving four local controllers on one communications line was also SCATS’ first application of that type. Therefore, it is not surprising that some performance deficiencies were noted during the evaluation period.

The ICTM adaptive ramp-metering system was designed to meet two objectives. The primary objective was to optimize the freeway zone’s traffic operations as measured by flow rate and occupancy. The secondary objective was to optimize the use and distribution of freeway net spare capacity across metered entrance ramps within the zone. Measures used in evaluating the secondary objective were entrance ramp flow rates at metered and unmetered ramps within each freeway zone.

The ICTM adaptive system controlled two eastbound and two westbound ramp-metering zones within the corridor. During the a.m. peak period, the ramp-metering strategy controlled the westbound zones, while the eastbound zones remained, for the most part, unmetered. During the p.m. peak period, all eastbound and westbound zones were controlled in response freeway operational characteristics encompassing flow and occupancy measures.

The adaptive ramp-metering system was automatically activated and deactivated for each metered entrance ramp based on an objective model that incorporated upstream freeway main lane traffic flow and occupancy, entrance ramps' traffic flow and queue length, exit ramps traffic flow, and prespecified downstream bottleneck capacity constraint. The system maintained a flexible operational strategy by allowing each metered entrance ramp to remain in either activated or deactivated mode in 5-minute increments in response to changing demand conditions.

The TMC ramp metering system used a similar zone structure and objective function except that it was limited to 6 prespecified metering rates. It also did not intermittently deactivate a metered ramp once it was activated. The TMC ramp-metering algorithm automatically controlled the activation of a metered ramp in response to traffic conditions based on:

- Occupancy values calling for ramp-metering rates of category 4 or higher for three 30-second consecutive periods. This was a ramp-based measure and activated only the metered ramp that met the threshold criterion.
- Total entering flow from the metered entrance-ramps exceeding 75%of the available zone capacity. This was a zone-based measure and activated all metered ramps within the zone.

The operational characteristics of both ramp-metering systems were as follows:

- TMC and ICTM systems authorize automatically activation of metering operations after 6:00 a.m. and 2:30 p.m. in response to flow conditions
- TMC and ICTM systems force deactivation of metering operations after at 10:00 a.m. and 8:00 p.m. unless disabled by system operators
- TMC system used to automatically activate metering operations at 7:00 a.m. and 3:30 p.m. (if not yet activated) regardless of flow conditions. This feature is now disabled allowing metering operations to engage in response to flow conditions.

- ❑ TMC system is typically deactivated by system operators manually prior to the prespecified times.

SUCCESSFUL PRACTICES

Leveraging state-of-the-art and state-of-the-practice methodology, ICTM's new generation ramp-metering system is the first application of operational adaptive ramp-metering management in the United States.

ICTM's new ramp-metering system was based on 30-plus years of ramp-metering management and development activities by Mn / DOT. It uses the same physical layout for the ramp meters that was previously used with most metered ramps operating on two-lane approaches. The system accommodates red-time intervals ranging from 0.5 to 22 seconds in 0.1-second increments, whereas the previous ramp metering system had six metering rates with 3-second minimum red times.

To minimize the likelihood of queue spillover onto the arterial streets, the new system used queue detectors on metered ramps that provided the ability to adjust ramp-metering rates of adjacent metered ramps. This capability was achieved by proportionally adjusting the green frequency for ramps with longer and shorter traffic queues while maintaining the same overall level of traffic entry to the freeway zone. The new system also tailored ramp-metering rates to be more responsive to freeway flow conditions on a ramp-by-ramp basis, including automatic enabling or disabling of each ramp meter in 5-minute increments (yellow flash mode). The previous system maintained operational status for all metered ramps regardless of freeway flow conditions unless disabled by the system operator. The new system also allowed metered ramps to be ranked in importance, providing a higher degree of operational integration across freeway-arterial border areas.

System architecture allowed SCATS and TMC servers to operate concurrently while leveraging a fail-safe feature that relied on the TMC' s proven ramp-metering technology.

The TMC used its standard type-170 controller for ramp-metering control and revised its server software to provide a communications interface with the SCATS server. The SCATS server directly controlled arterial traffic signals while optimizing ramp-metering operations via the TMC server. The TMC server provided freeway detector data to the SCATS server and received optimized ramp-metering control parameters from the SCATS server for distribution to field controllers. The system architecture allowed the two servers to operate concurrently while leveraging a fail-safe feature. This fail-safe feature allowed the transition of ramp-metering control from the SCATS server to the TMC server in cases of communications or SCATS failure.

Project stakeholders generally perceived SCATS' system functions and training as better than average.

Tables 5 and 6 present agencies' perceptions of SCATS system functions, and training and support, respectively. These findings cover such elements as data usefulness for traffic operations, maintenance, and management purposes; responsiveness to demand surges; and SCATS' training and support.

SCATS’ data output was used for system operations, troubleshooting of system problems, and system evaluation. The column entitled "status" represents the general tendency of the agency perceptions for each survey question across three potential categories: good, average, and poor. For example, 53.9 percent (46.2 percent + 7.7 percent) of the survey participants perceived SCATS data usefulness as "good" to "excellent" for traffic operations and management purposes. This compares with 7.7 percent (7.7 percent + 0 percent) of the participants who perceived SCATS data usefulness as "poor" to "very poor" and 38.5 percent perceiving SCATS data usefulness for traffic management as "average." In this case, the overall tendency finding for this question was rated as generally "good" as noted in the "status" column. The findings indicate that agency stakeholders perceived SCATS systems as useful and valuable for a variety of applications.

The use of SCATS’ data output to develop flexilink-timing plans was limited by lack of resources, absence of know-how on setting up the application, and prevalence of other priorities. SCATS automated data collection was perceived as superior to manual data collection efforts in terms of resource savings. For example, data automatically collected by the SCATS system was used in assessing traffic operations under incident conditions by comparing MOEs, such as cycle length, degree of saturation, and phase splits.

System users rated SCATS' responsiveness to traffic fluctuations along freeway and arterial streets as "good" and "average", respectively. The general perception was that SCATS ramp-metering system had improved the available capacity for metered ramps. Problems with ICTM communications system limited the opportunity for project stakeholders to formulate an opinion on SCATS' responsiveness and robustness along the arterial traffic signal systems. System operators perceived the quality of SCATS' training and support as "good" and "average", respectively.

Table 5: Agency Perceptions of SCATS System Functions

Survey Question	Excellent	Good	Average	Poor	Very Poor	Status
SCATS data is useful for traffic operations and management purposes	7.7%	46.2%	38.5%	7.7%	0.0%	Good
SCATS system alarms and flags are timely and accurate in support of system operations and maintenance	0.0%	35.7%	35.7%	21.4%	7.1%	Average
SCATS system is robust and responsive to traffic demand surges along the arterial streets during periods of recurrent congestion	0.0%	23.1%	69.2%	7.7%	0.0%	Average
SCATS system is robust and responsive to traffic demand surges along the bypass routes during major freeway incidents	0.0%	20.0%	60.0%	20.0%	0.0%	Average
ICTM RMS system is responsive to traffic demand fluctuations along I-494 in optimizing ramp-metering throughput	7.7%	61.5%	23.1%	0.0%	7.7%	Good
ICTM RMS system is responsive in optimizing traffic flow along I-494 by effectively regulating metered ramps	7.7%	46.2%	38.5%	0.0%	7.7%	Good
SCATS timing plan transitions have not been disruptive to system progression	7.7%	38.5%	23.1%	30.8%	0.0%	Good
SCATS data usefulness	0.0%	33.3%	50.0%	16.7%	0.0%	Average
SCATS features and functions for day-to day traffic management	0.0%	54.5%	27.3%	18.2%	0.0%	Good
SCATS features, functions, and adaptive algorithms for traffic operations, maintenance, and management	0.0%	58.8%	17.6%	17.6%	5.9%	Good
Perception of SCATS usefulness for traffic management	**3%**	**42%**	**38%**	**14%**	**3%**	**Good**

Table 6: Agency Perceptions of SCATS Training and Support

Survey Question	Excellent	Good	Average	Poor	Very Poor	Status
SCATS contractor support quality	8%	25%	50%	8%	8%	Average
SCATS contractor support timeliness	8%	33%	42%	17%	0%	Average
SCATS contractor support responsiveness	8%	25%	50%	17%	0%	Average
SCATS training quality	8%	54%	23%	15%	0%	Good
SCATS training timeliness	0%	58%	25%	17%	0%	Good
SCATS training comprehensiveness	17%	42%	25%	17%	0%	Good
SCATS training length	9%	36%	45%	9%	0%	Good
Perception of ICTM training and support	**8%**	**39%**	**37%**	**14%**	**1%**	**Good**

LESSONS LEARNED

Project stakeholders perceived SCATS user interface features as "poor" making the programming and operations of SCATS software and Delta-3 controller very complex and training and support requirements extensive.

The SCATS regional computer central software, Delta-3 controller, and programming read memory testing software lacked user-friendly interface features to support day-to-day operations and programming tasks. System operators rated user interface features (e.g., degree of automation, navigation intuitiveness, context sensitivity of online help, and ease of use) as "poor." The central software was not automated and lacked intuitive command structure for day-to-day management purposes. The error messages (i.e., flags and alarms) were not easy to decipher and did not provide the opportunity for corrective actions by system operators. It further lacked supportive tools for generating reports and timing optimization and required the purchase of separately available software packages (i.e., LINK) for analysis of system data. Even though, it provided a system-logging feature that allowed system operators to save significant quantity of information, it offered limited formatting and reporting capability. Working with raw data also proved very challenging. Table 7 presents the stakeholders perception of SCATS' user-interface features.

The complexity of Delta-3 controller user-interface and programming where also viewed as contributing to an increased propensity for errors and making difficult the tasks of programming and operating. Even system operators who were experienced with traditional control systems felt challenged and frustrated in applying the SCATS adaptive control terminology.

SCATS system required significantly more training and support than was originally anticipated. Even though, the quality of training and support were perceived as "good" and "average" by system operators, respectively, SCATS' system complexity and uniqueness required system operators to need more training in addition to ongoing daily involvement in programming and operations to retain the knowledge and experience gained. This complexity resulted in the ICTM management team to invest significantly more than originally planned for training and support services.

Table 7: Agency Perceptions of SCATS Interface Features

SURVEY TOPIC	EXCELLENT	GOOD	AVERAGE	POOR	VERY POOR	STATUS
System alarms and flags accuracy	0.0%	23.1%	46.2%	30.8%	0.0%	Poor
Access Quality	0.0%	50.0%	25.0%	25.0%	0.0%	Good
Access Reliability	0.0%	33.0%	42.0%	25.0.%	0.0%	Average
Access Dependability	0.0%	42.0%	33.0%	25.0%	0.0%	Good
Degree of Automation	0.0%	33.0%	25.0%	42.0%	0.0%	Poor
Software Navigation Intuitiveness	0.0%	31.0%	0.0%	23.0%	46.0%	Poor
Context Sensitivity of Online Help	0.0%	31.0%	31.0%	31.0%	8.0%	Poor
Ease of Use	0.0%	0.0%	13.0%	47.0%	40.0%	Poor
PERCEPTION OF SCATS USER INTERFACE	**0.0%**	**30.0%**	**27.0%**	**31.0%**	**12.0%**	**POOR**

The SCATS system required more maintenance and operations attention than did traditional traffic control systems.

SCATS' maintenance and operations requirements were relatively larger, given the system's size compared with the traffic system as a whole. One system operator indicated that his agency could provide only 8 percent of the 20 percent support needed for SCATS operations and maintenance if he was to pay sufficient attention to other agency traffic signal infrastructure. Thus, system operators perceived the SCATS system as excessively complex and labor-intensive operationally.

The SCATS system required extensive initial and ongoing training.

ICTM system operators found the SCATS system difficult to learn even though extensive training was provided. The operators perceived the up-front training as too abstract to adequately convey system setup and configuration requirements. This situation was remedied, to some extent by support provided by the SCATS vendor. However, some of the operators believed that it might be beneficial to outsource system setup and configuration because of the system's complexity, specialization, and infrequent application

The partnership maintained a joint training program that was administered through Mn/DOT. Each agency attempted to train two to three individuals in use of the system, even though only one person from each agency was primarily involved in system operations and maintenance. The training courses offered included

- SCATS Controller Personality Training - This course was offered twice and consisted of a 6-hour training class administered each day for 10 days.
- Practitioner Training - This course was also offered twice and consisted of a 6-hour training class administered each day for 10 days.
- ICTM Ramp Metering System Training - This course was offered once and consisted of a 4-hour training class administered each day for 4 days.

Generally, there was one individual in each agency who embraced the SCATS system and devoted the required time and focus to learn and apply the system. However, the remaining agency personnel who received SCATS training also maintained some system exposure and could rise to the occasion, if necessary, to become proficient in this area.

The ICTM management also recognized the need to invest in a more user-friendly system to maintain support flexibility, lower system operations and maintenance impacts, and increase staff willingness to embrace new technology. The management considered the size of ICTM as inevitable to meet the transportation needs of the respective communities. All system components, including the incident and motorist information subsystems and CCTV cameras were perceived to be critical to achieving the project goals and objectives. CCTV cameras were perceived as not only a tool for incident management and flow assessment but also as a valuable mechanism by which elected officials could readily observe operational problems during critical periods as they considered transportation issues and resolutions.

In-house training and outsourcing through corridor management initiative opportunities, equipment purchases and upgrades, and potential system expansion were identified as the mechanisms for meeting future training needs for the ICTM system.

The SCATS system required significantly more data for operational configuration than did traditional systems.

Defining the personality for each controlled intersection was also considered a complex undertaking, especially in unique applications. Because of SCATS' system complexity, effective operations required significant vendor support, which was not locally available, and dedicated staff who would have ongoing interaction with the system. Dedicated ICTM staff was better positioned than nondedicated staff to learn and cope with programming idiosyncrasies of the SCATS system because of this daily interaction.

The communication network performed poorly, thus limiting the synergistic capabilities of ICTM in meeting corridor traffic management and operations needs.

Both the TMC and ICTM ramp metering systems run on the same fiber-based communications backbone. The arterial traffic signals use a hybrid communication backbone with optical fiber from the TMC to the communication shelter and twisted pair from the shelter to respective traffic signals. The arterial traffic signals use multidrop communications architecture with four traffic controllers per communications channel. This multidrop architecture is a departure from the typical point-to-point communications framework used in SCATS applications.

The communications network for both the TMC and ICTM ramp metering systems operated reliably. However, the communications network supporting the arterial traffic signals operated unreliably throughout ICTM deployment. This unreliability caused the arterial traffic signals to experience ongoing communications failures. At best, the communications system remained stable at 75 percent of the corridor traffic signals. The system operators could not conclusively elaborate on contributing casual factors for the communications system problems. They cited a variety of possibilities:

- ICTM communications system could not compensate for noise induced by aged network of twisted-pair communications cable
- SCATS server was housed in the TMC center and the physical distance between the server and the corridor might have been a factor
- SCATS server or controller communications boards could induce noise in the communications system
- Multidrop communications architecture and hybrid fiber-copper communications network could have played a role.

The ongoing communications failures adversely impacted ICTM support staff by requiring a significant expenditure of resources for system maintenance, operations, and troubleshooting. This expenditure of resources significantly limited the opportunity to provide real-time adaptive traffic control and to realize potential benefits. The traffic operations along the arterial streets were adversely affected by the communications problems. Lack of time-of-day and day-of-week timing plans for maintaining coordinated operations at these traffic signals during communications failures further affected traffic operations.

Because the communications system is the backbone of the overall system, it is imperative to use proven communications architecture and design to minimize deployment risks, maintenance impact, and operational inefficiency. The design approach should effectively correlate with operational requirements of the corridor and system elements. Wireless communications or redundant system architecture should also be considered for alleviating operational impacts caused by cable cuts if significant roadway construction is anticipated within the corridor.

SYSTEM DEPLOYMENT

ICTM was implemented in four modules that spanned a 5-year period while facing significant deployment challenges. The project produced valuable findings, lessons learned, and deployment advice pertaining to integrated interjurisdictional application of disparate technologies for traffic management.

This section includes the findings concerning ICTM deployment and deployment costs. A range of deployment issues are presented, including those related to staffing, budget, legal and institutional changes, and training and support.

In 1993, Mn/DOT forged a partnership with Hennepin County and the cities of Bloomington, Richfield, and Edina to deploy ICTM. The size and complexity of the project, as well as Minnesota's short construction season mandated a modular approach to project deployment. Each module was assessed after completion, providing valuable evaluation feedback before initiation of the next module. Implementation occurred in four phases over a period of 5 years. The primary elements of each module and the implementation schedule are summarized in Table 8. Modules 1 and 2 were implemented concurrently in order to deliver the project on schedule. This deployment was delayed due to a longer period of time required for obtaining project approval and funding.

Table 8: ICTM Deployment Modules and Schedule

Module 1 (1994 - 1995)	Acquire system hardware and software Install 21 ramp terminal traffic signals Install four video detection sites Develop master communications plan Develop evaluation plan
Module 2 (1994 - 1995)	Implement system integration Deploy SCATS at 27 ramps Develop operational plans Provide training Develop evaluation design
Module 3 (1996 - 1997)	Install SCATS at 47 signals Install CCTV at 11 sites Forge partnership to develop motorist information system Install communications network
Module 4 (1998 - 2000)	Develop motorist information system Implement operations and incident plans Refine plans Collect evaluation data Install variable message signs at two freeway locations Develop final evaluation report Develop ICTM migration plan to full deployment Implement ICTM migration plan

The project was formally launched in 1994, with an initial budget of $7 million. The funding contribution was split 80-20 between FHWA and local partners. By 1999 the project had successfully negotiated the transition to full deployment and had cost approximately $9 million, with funding provided by the FHWA (60 percent), public sector partners (31 percent), and private sector partners (9 percent). Tables 9 and 10 present ICTM deployment costs and partners' contributions by module, respectively. Tables 11 and 12 summarize deployment costs in more detail. Partners used $300,000 in Congestion Mitigation and Air Quality funds as well as other contributions exceeding original commitments to meet the project's budgetary requirements.

An agreement with FHWA established that the participating partners did not need to allocate cash as matching contribution. Instead, they could contribute staff resources and equipment to meet their funding requirement. For example, Hennepin County installed hundreds of loops at traffic signals within the corridor to meet SCATS operational requirements for adaptive control. On the private sector side, Skyline Products, Inc., developed and customized software for the ICTM incident management system and provided maintenance support and training on the motorist information system as part of its contribution. AWA Traffic System provided an equipment discount, technical support, and training.

Table 9: ICTM Deployment Cost by Module

CATEGORY	CASH OUTLAY				IN-KIND CONTRIBUTION	TOTAL COST
	MODULE 1	MODULE 2	MODULE 3	MODULE 4		
Project Development	$286,351	$0	$98,959	$369,000	$141,816	$896,127
Project Deployment	$775,052	$602,285	$2,287,084	$1,296,888	$1,033,447	$5,994,756
Project Support	$295,931	$110,373	$97,922	$329,786	$1,245,540	$2,079,552
TOTAL	**$1,357,334**	**$712,658**	**$2,483,965**	**$1,995,674**	**$2,420,803**	**$8,970,435**

Table 10: ICTM Cash and In-Kind Contributions by Partner and Deployment Module

CATEGORY	PARTNER	CASH AND IN-KIND CONTRIBUTIONS				CMAQ	TOTAL COST	% OF TOTAL
		Module 1	Module 2	Module 3	Module 4			
Partnership Contributions	FHWA	$1,151,320	$1,034,864	$1,942,696	$1,140,016	$240,000	$5,508,896	60.4%
	Mn/DOT	$$348,029	$783,638	$687,174	$282,490	$39,000	$2,140,330	23.5%
	City of Bloomington	$20,887	$38,454	$44,371	$96,454	$6,000	$206,167	2.3%
	Hennepin County	$71,245	$94,640	$80,112	$37,119	$9,000	$292,116	3.2%
	City of Richfield	$13,020	$10,020	$78,481	$15,804	$3,000	$120,631	1.3%
	City of Edina	$1,762	$3,794	$66,872	$1,266	$3,000	$76,693	0.8%
	Rennix Corporation	$19,717	$3,887				$23,604	0.3%
	AWA	$84,522	$50,150	$100,202	$93,696		$328,671	3.6%
	Skyline				$403,897		$403,897	4.4%
	Traffic Control Corp	$2,284	$17,.751				$20,035	0.2%
TOTAL		**$1,712,786**	**$2,037,504**	**$2,999,908**	**$2,070,741**	**$300,000**	**$9,120,939**	**100%**

Table 11: ICTM Deployment Cost by Support Type and Module

Type	System Component	Cash Outlay				In-Kind Contribution	Total Cost
		Module 1	Module 2	Module 3	Module 4		
Project Development	Preliminary & Detailed Design & Engineering	$99,3521		$98,959	$369,000	$91,619	$658,930
	Maintenance & Operations Plan	$88,000					$88,000
	Implementation Plan	$99,000					$99,000
	Technical Support					$50,197	$50,197
Project Development	SCATS Controller / Software / Peripherals	$55,500	$15,398	$167,399	$3,049		$241,345
	SCAT Regional Server / Software / Peripherals	$68,260	$31,011				$99,271
	TMC / SCATS Interface Software	$54,000	$13,733				$67,733
	170 Controller Software Modifications	$1,674					$1,674
	Ramp Metering Software Development		$72,000			$29,508	$101,508
	Traffic Signals					$51,682	$51,682
	Communications Support					$57,133	$57,133
	Video Sensors-Autoscope	$326,286		$432		$11,182	$337,900
	Inductive Loops					$125,401	$125,401
	Motorists Information System License					$25,000	$25,000
	Motorists Information Systems Software					$348,594	$348,594
	Motorists Information Systems Platform				$14,800		$14,800
	Arterial DMS Signs				$314,100		$314,100
	SCATS Software	$165,009		$10,000	10,600		$185,609
	DEC service agreement	$2,579	$3,126	$3,189	$6,414		$15,307
	Professional Services – AWATSA	$101,745	$107,490	$133,530			$342,765
	Video connection			$21,419			$21,419
	Trailblazing Signs				$314,250		$314,250
	Construction		$359,527	$1,951,116	$633,676	$248,061	$3,192,380
	Equipment					$136,886	$136,886
Project Support	Operations & Maintenance	$125	$172	$180	$53,800	$270,955	$325,232
	Public Relations	$42,934	$3,598	$19,417	$5,507	$484	$71,940
	Administrative Support					$202,011	$202,011
	Dedicated Staff Support					$533,789	$533,789
	SCATS Training	$1,567	$2,398			$139,020	$142,985
	Evaluation Support	$251,305	$104,206	$78,325	$270,478	$99,281	$803,595
Total		**$1,357,334**	**$712,658**	**$2,483,965**	**$1,995,674**	**$2,420,803**	**$8,970,435**

Table 12: ICTM Partner Contributions by Deployment Category

Category	Public Partner					Private Partner				Total
	Mn/DOT	Hennepin County	Bloomington	Richfield	Edina	Traffic Control	Rennix	AWATSA	Skyline	
Technical Support						$8,136		$42,061		$50,197
Comm Support								$57,133		$57,133
Equipment			$13,526			$10,415	$23,604	$68,173		$115,717
Software									$348,594	$348,594
License									$25,000	$25,000
Administration								$95,823		$95,823
Meetings	$31,197	$25,478	$26,422	$16,925	$6,166					$106,188
Detection		$125,401								$125,401
Equipment		$21,169								$21,169
Planning & Design	$90,737	$883								$91,619
Data Collection	$20,350	$19,828	$21,405	$35,990	$1,707					$99,281
Training	$34,408	$17,300	$14,873			$1,484		$65,381	$5,575	$139,020
Construction	$87,097	$15,949	$14,962	$64,716	$65,336					$248,061
Operations	$74,912	$45,283	$108,979							$229,174
Maintenance	$1,477	$15,066							$24,728	$41,271
Staffing	$233,789									$233,789
Ramp Metering	$29,508									$29,508
Signals	$51,682									$51,682
State Funds	$1,443,438									$1,443,438
Locating	$510									$510
Autoscope	$11,182									$11,182
Public Relations					$484					$484
Total Contribution	**$2,110,287**	**$286,356**	**$200,167**	**$117,631**	**$73,693**	**$20,035**	**$23,604**	**$328,571**	**$403,897**	**$3,564,240**

SUCCESSFUL PRACTICES

The ICTM public-private partnering arrangement provided significant benefits in funding.

The ICTM project was not adversely affected by funding issues because the partners had effectively planned the project deployment components and schedule. The management approach focused on keeping the project within the allotted budget by reducing scope if justified by project overruns and leveraging partnerships with private partners.

ICTM effectively leveraged public-private partnerships to support project development and deployment. The public-private partnership model proved to be an effective means of stretching project dollars while minimizing development uncertainties and risks. This model also enabled ICTM to provide system training and maintenance by a private partner with a high level of involvement and commitment. A public-private partnership was used to develop technologically complex, and state-of-the-art system components including management software (e.g., the motorist information system). This arrangement resulted in willingness by both partners to share knowledge and risks to reach a common goal. It also gave the private partner an opportunity to become actively involved in the decision-making process and in development and deployment efforts. The result was enhanced cooperation and teamwork without the need to resort to the penalties and disincentives that typically plague contractual relationships. The partnering approach changed the mindset and business framework of project participants, allowing them to focus on developing common solutions, rather than on managing blame or penalties.

The public partners recognized that the private partners' motivation for participating was based on the opportunity to profit ultimately from the products they were developing and testing in the project. This recognition encouraged the public partners to strive to be fair and reasonable in their expectations while ensuring that the private partner was a true contributing partner.

Introducing competition and identifying the best private partner for teaming was critical to partnering success. The best private partner was perceived as one who had the necessary personnel, ability, and genuine interest to deliver on promises to ensure project success. The public partners examined various systems and technology alternatives and incorporated performance requirements into the joint agreement to ensure the forging of a successful partnership that could benefit all involved. Critical qualities in creating such a public-private partnership were as follows:

- Public-private partnership must be founded on a win-win theme in which both partners strive to be reasonable in their understanding of what is doable within the confines of the budget and available resources
- Private partner should have the ability to deliver the required technology and user support, understand the public partners' requirement for a cost- and time-effective solution, and be sensitive to the public partner's exposure to public scrutiny by management and the community
- Both public and private partners should understand their respective roles based on mutual trust in project delivery and remain flexible, adaptable, and team oriented in addressing development and deployment issues for the good of the project
- Public partner should understand and acknowledge the profit motive of the private partner and expect only what is fair and reasonable.

Generally speaking, the factors considered in forming public-private partnerships must include the value created by such partnerships in terms of expertise, time savings, risk management, stretching project dollars, and so on. The private partner must genuinely be part of the project team and actively engaged in the decision-making process. The private partner also must share the risks and rewards associated with project success and failure. Such partnerships are typically only as good as the relationships forged. To detect potential problems in their infancy, and early in project development and deployment, it also helps to have well-defined milestones. This approach reduces the chance that problems will become unmanageable and scarce project resources will be expended inappropriately.

The design-build procurement mechanism was the appropriate contracting technique for the ICTM motorist information system.

The ICTM management explored and deployed various contracting techniques, including the design-build procurement mechanism. The majority of the ICTM project components were deployed using the design-bid-build procurement strategy. The exception included the development and deployment of the motorists information system provided by a private partner (i.e., Skyline), which used design-build strategy as the procurement vehicle. Design-build is a project delivery system in which a single entity provides design services and constructs the project under one contract. Design-build may be effectively leveraged to overcome some of the challenges faced by traditional contracting techniques in designing and constructing technologically complex ITS projects. This technique was used to develop and deploy the ICTM motorist information system.

Design-bid-build is a technique in which a transportation agency uses the services of an engineering consulting firm (or in-house staff) to design a project, invites contractors to submit bids, and then constructs the project using the services of the contractor. The design-build procurement strategy worked well for the ICTM motorist information system because of the system's high level of technological complexity. The motorist information system was not available as a commercial off-the-shelf product and contained features and functions that required significant development efforts. For these reasons, the management team considered the design-build strategy a prudent and cost-and time-effective means of meeting system needs.

The modular process provided an opportunity for incremental learning but increased evaluation difficulty and cost.

The short construction season in Minnesota (related to the state's severe winter weather), as well as the size and complexity of ICTM technologies, dictated the use of a modular project deployment process. This approach yielded benefits that would also accrue to projects not subject to construction season constraints. Deploying the complex project in modules provided the opportunity to define each phase with concentrated work activities that could be achieved with existing resources.

In addition, the modular approach enabled agency support staff to learn to operate the system incrementally, focusing on more manageable deployment issues during each phase. Staff could more effectively plan the next module by leveraging lessons learned in the previous module. In some cases, modular deployment allowed the development and use of more mature technology than would not have otherwise been feasible.

Modular phasing did present some challenges related to increased project duration. This increased project length resulted primarily from the need to work around other construction activities. Also, stakeholders tended to lose interest in the project over the long deployment period. The long deployment period also adversely impacted project evaluation by allowing changes in corridor capacity, operations, and traffic demand to influence flow and operational data collected for evaluation purposes. Examples of these external influences included new traffic signals, traffic signal reconstruction, signal operations changes, new streets, and new developments.

With respect to project costs, the 5-year deployment schedule for the ICTM project increased the likelihood of failure of system components, resulting in higher costs. Funding challenges were also associated with this approach. The disparity in accounting systems among the partner agencies, and the evolutionary internal changes introduced to Mn/DOT's accounting system midway through the project, complicated funding and accounting processes. These complexities could have been addressed more effectively had the project been completely funded at the outset.

The "force account" process enabled agencies to deploy the project with reduced budgetary impact by leveraging existing project initiatives instead of providing hard contributions.

Force account process uses agency's internal and external resources for project deployment. Force account contributions on the ICTM project included installation of individual signal cabinet components, installation of SCATS loop detectors for arterial traffic signals, outsourcing of equipment maintenance (e.g., CCTV cameras), provision of labor hours for related project meetings, and so on.

Force account is an appropriate and practical method under certain operational conditions, as when

- Quantities of project elements or items cannot be defined in advance
- Tasks are small and in widely scattered or remote locations, making qualified construction firms less likely to bid for the work at reasonable prices
- Work must be carried out without disrupting ongoing operations
- Risks of unavoidable work interruptions are better borne by the agency than by a contractor
- There are emergencies needing prompt attention.

Using this process, the agencies could leverage existing agency resources and contracting vehicles to perform the work and acquire the needed services in a timely manner. For some qualified emergency situations, an agency could forego the formal Plans, Specifications, and Engineer's (PS&E) estimate development and the competitive bidding process and acquire the services needed to deploy components of the system (e.g., modifying in-progress traffic signal projects to bring them into compliance with SCATS requirements). The agency could use qualified expenditures as its "hard match" contribution, while the "soft match" contribution, would include the time that agency representatives spent at meetings concerning ICTM system management and operations. The matching contributions were typically submitted by the respective agency to the Mn/DOT project manager for inclusion in quarterly reports summarizing partner contributions to the FHWA.

LESSONS LEARNED

ICTM management underestimated staffing and workload requirements for operating, maintaining, and managing ICTM.

Staffing and workload requirements to support the ICTM system exceeded partners' expectations and were underestimated. Adaptive control terminology and complex user-interface for Delta-3 controller and SCATS server required significant allocation of resources and ongoing hands-on interaction for system operations, management, programming, and maintenance. The initial and ongoing training requirements also adversely impacted the support organizations. Table 13 presents the number of traffic signals maintained by each partnering agency and located within the ICTM corridor.

Table 13: Agency and ICTM Traffic Signals

CATEGORY	MN/DOT	HENNEPIN COUNTY	BLOOMINGTON	RICHFIELD	EDINA
Signals Maintained by Agency	800	419	56	7	7
Signals within the ICTM Corridor	18	23	16	6	3

Hennepin County was responsible for maintaining the majority (i.e., 45 or 70 percent) of the corridor's traffic signals (i.e., 66) and was especially impacted by the ICTM system in terms of associated staffing and workload requirements. Hennepin County provided maintenance support to approximately 150 additional traffic signals that were owned by various cities including Edina and Richfield some of which were located within the ICTM corridor. This maintenance support was provided under the auspicious of an "aid" agreement, which was based on a predefined cost reimbursement structure. Hennepin County utilized three electronic and three electric technicians to maintain these traffic signals and assigned one experienced technician for maintaining the ICTM traffic signals. This expanded signal system and complexity of SCATS' technology were noted as contributors to impacting staffing and workload resources.

Three Mn / DOT staff members were dedicated to providing management and operational support for the ICTM system. Funds from both participating agencies and congestion mitigation and air quality (CMAQ) financed the staff. The project manager was funded through the federal funding provided in support of the ICTM project.

ICTM's public partners perceived that the SCATS system required support staff who were intelligent, dedicated, and quick learners to fulfill the system's operations and maintenance needs. They believed that this requirement might become less critical as the advanced technologies improved and became more user-friendly and intuitive. ICTM management said that it had survived this challenge with half a dozen trained personnel from various jurisdictions who developed the ability to address system support requirements. The manufacturer of the SCATS controller is currently developing more user-friendly controllers that will be compatible with NEMA and Type-170 controllers.

It is critical to assign system management, operations, and maintenance responsibilities to the existing organizational sections responsible for system support albeit with increased staff.

It is imperative to obtain the level of buy-in and commitment necessary for project success from all project participants including operations and maintenance support organizations. Enhancing the staffing and resource capabilities of existing support organizations is a more effective management approach to achieve success in the long run. In the case of ICTM, dedicating staff to the project had advantages and disadvantages. The advantages included the availability of trained staff, proficient in the SCATS application, for traffic management and operations and the minimization of ICTM's impact on agency staffing and workload. However, disadvantages included creation of an environment in which the staff members of some partnering agencies could rely on the services of the dedicated staff, allowing the agency staff to take a hands-off approach to system support and to fail to buy into the system.

The dedicated ICTM staff checked system status on a daily basis and coordinated problem resolution by working closely with other agencies' operations and maintenance support staffs. Because the ICTM ramp-metering system was housed in the TMC and exclusively controlled by Mn / DOT, its operations did not require cross-agency coordination. This created the opportunity for the existing TMC operators to effectively support the ICTM ramp-metering system. However, the dedicated ICTM staff performed this function. Additionally, there were key personnel in some partner agencies who had the electronics background and skill sets needed to work with the ICTM system. However, some of the key personnel who were proficient in the use of traditional control equipment and systems found the SCATS system too complex and difficult to use. This difficulty and the availability of ICTM dedicated support staff contributed to these individuals' failure to embrace the adaptive control technology. This, in turn, was a concern for long term system operations and maintenance.

The requirement that motorist information signs be Underwriters Laboratories (UL)-approved posed unique challenges for ICTM.

During the deployment of the motorist information system, the Minnesota State Board of Electricity mandated that all electrical signs must meet the UL approval requirement. This deployment issue was finally resolved when the board granted a variance from this requirement for existing signs, under a "grandfather" ruling. However, any new sign had to fully comply with the UL approval requirement, thereby limiting future system expansion. This requirement applies to all electronic traffic management signs, including ramp control signs, portable electronic signs, and Variable Message Signs (VMS). This issue may present a challenge for future deployment of advance traveler information signs in Minnesota until signs meeting the UL approval requirement are available in the marketplace.

ICTM outreach and marketing efforts were successful in reaching the targeted audience.

ICTM public relations activities proved instrumental in educating the public on the purposes and use of the motorist information signs and in obtaining public support for traffic diversion strategies. Public partners maintained communications with local news editors and traffic reporters to ensure a high level of understanding of the system and its goals. This approach encouraged media representatives to seek partner perspectives and views before publishing or airing potentially damaging news reports. Partners also sought to maintain upward and downward communications within each partnering organization to gain buy-in and support in delivering on commitments. Technology demonstrations and information sharing on interesting system components (e.g., the motorist information system) was also helpful. These efforts were effectively supported by the Public Relations Committee who proved instrumental in producing project materials, key messages, mitigating potential problems with the media, and raising project awareness.

Forty five percent (181 of 400) of motorists survey indicated they had heard of ICTM. Of these individuals, 49.4% (84) and 42.2% (97) were corridor residents and non-residents, respectively. These motorists indicated they became aware of ICTM through a variety of mechanisms, including newspaper, radio, television, and open houses. Observance of field devices (e.g., variable message signs) also contributed to the motorists' awareness of the ICTM. The high level of awareness of the ICTM by both partner organizations and corridor motorists is indicative that ICTM outreach program was effective in reaching the targeted audience.

The overall design of the communications system should accommodate the requirements of all envisioned field devices and locations.

The design of the motorist information system components occurred several years after the design of the communications system. Consistent with the original vision of the overall system, the final design incorporated nine VMS signs located along the parallel arterial streets to provide additional guidance reinforcement during traffic diversions. The management team also considered options for installing VMS signs on arterial approaches to the I-494 freeway to guide arterial traffic to alternate routes during major freeway incidents. These options were not implemented due to funding limitations and deployment cost considerations. The management team remains interested in equipping the arterial approaches to the I-494 with VMS signs in the long run. The ICTM experience highlights the importance of designing the overall communications subsystem to support both the existing and future vision of anticipated field devices and respective locations.

The choice of specific technologies to deploy for traffic management and control should consider and reflect the availability and skill levels of support staffs and the associated training requirements.

The SCATS system required a level of knowledge and understanding that exceeded traditional traffic control systems. The support staff was required to have a broad understanding of computing and communications systems beginning with the controller and expanding to the NT operating system. The needed skill levels for SCATS exceeded what was typically required to support traditional traffic control systems. They involved application and operating software, a communications system, unfamiliar controllers and terminology, and server platforms. Unless increased staffing and staff skills are planned for in the concept of operations and funded during project deployment, it is not easy to enhance staffing levels, given competing demands and budgetary constraints. The SCATS system adversely impacted both the staffing and the workload of the support agencies. It also required a significant investment of time and resources for training in a short period of time. System operators, however, perceived SCATS training to be comprehensive and of high quality.

Given the significance of detection in an adaptive traffic control system, it is paramount to correlate detection design with motorists' stopping behavior at signalized intersections during various weather conditions.

The SCATS system required only stop-bar detectors (6 by 15 feet) for detection and accommodation of arriving demand. The original detectors were installed based on field verification of motorists' stopping behavior during non-snow conditions. It incorporated the specific locations where the motorists stopped when facing red traffic signal indications. However, the motorists stopped short of the installed loop detectors during "snow" conditions. A variety of solutions were considered and deployed to solve this problem including installation of new loop detectors, traffic signs, and stop-bars.

The ICTM evaluation did not consider SCATS' stop-bar detection architecture and operational effectiveness. However, the partners perceived that the SCATS system might be unaware of traffic activity upstream of the stop-bar detectors due to its stop-bar detection architecture. The perception was that the “ultimate” adaptive system should incorporate not only stop-bar detection for green split computation and queue management but also upstream detection for arrival prediction.

ICTM deployment could have benefited from resolving all implementation issues and challenges associated with one technology prior to introducing the next.

The overall system relied on many interdependent elements, making it susceptible to failures by one or more subsystems. If any one subsystem malfunctioned, the system could not run as a complete unit, resulting in diminished effectiveness. Some subsystems, most notably communications, performed poorly and significantly limited the system’s ability to provide the operational benefits originally intended.

The system managers pointed out that the synergistic benefits gained from the deployed technologies justified the system size and the technology diversity across the corridor infrastructure, including an adaptive ramp metering system, an adaptive arterial traffic signal system, an incident management system, and a motorist information system. However, the system operators perceived that the size and diversity of the deployed system exceeded the agencies’ levels of resources, expertise, knowledge, and experience, and therefore overwhelmed the agencies when they tried to adapt to the ensuing changes.

The items listed below provide additional guidance on developing and deploying complex ITS projects similar to ICTM.

- ❑ Start with subsystems that can easily be integrated. Start small and follow a modular deployment schedule that builds on previous successes. Proceed prudently, ensuring that each deployed system performs as intended before proceeding to the next deployment phase.
- ❑ Begin with the system components that are currently needed, but ensure that the system is designed to expand and has the capacity to support other envisioned system components. Avoid including every possible ITS feature in the first deployment. Specify systems in the order in which they are needed and the order that makes sense logically. Try not to take on the whole system at once, because there may be too many possible problems and variables (detector failures, communications failures, and camera failures). If too many system

devices fail, it may be difficult to identify and correct the problems because the understanding, experience, knowledge, and resource levels of the agencies involved may not be adequate to absorb the impact.

- Vehicle sensors and communications subsystems are the ITS components typically most prone to failure. They are also the system backbones and the most critical factors in ensuring the continued functionality of the overall system. Having the ability to automatically identify failed vehicle sensors and communications is not sufficient to correct the problem. Knowledge and resources are also required to troubleshoot and repair failures and must be provided for in the concept of operations.
- Ensure system success by recognizing that the complexity of ITS systems creates an ongoing need for funding and resources to ensure effective system maintenance, operations, and management. Training and staffing are critical. A "showcase" ITS system that is not properly maintained, operated, and managed because of a lack of operator understanding, knowledge, and training, and insufficient resources will not be on display for long and will not be able to add much value.

The evaluation of the ICTM system involved assessment of the institutional processes and the operational characteristics of disparate systems and proved very challenging.

The evaluation of the ICTM system was complex and significantly more involved than evaluations of traditional traffic operations. The evaluation design relied on a methodology that required clearly defined quantitative and qualitative measures of effectiveness, including user perceptions and acceptance. ICTM experienced ongoing challenges in evaluation design and execution, resulting in unmet expectations for project partners.

The Westwood Professional Services initiated the development of the original evaluation plan. Castle Rock Consultants subsequently finalized the evaluation plan. HNTB developed and executed the evaluation test plans during deployment of ICTM modules 1,2 and 3. In August 1998, Booz·Allen & Hamilton was commissioned by Mn/DOT to develop and execute a streamlined evaluation design based on the original evaluation test plans. The original evaluation test plans were cumbersome and difficult to decipher requiring significant revisions. The streamlined evaluation design reflected the effects of a myriad of factors including consolidation of evaluation guidelines and focus, type and availability of historical data collected, availability of agency resources for new data collection efforts, and evaluation budget. The project evaluation cost about $850,000 (10 percent of the overall project) over a 5-year deployment period.

Some lessons learned from this experience included

- Evaluation of complex and evolving systems is complex, especially when the evaluation is based on both qualitative and quantitative measures of effectiveness

- Evaluation measures should closely correlate with applicable deployment phasing and be secured with needed funds at the outset of the project to ensure continuity in system evaluation from one deployment phase to the next
- Evaluation goals, objectives, and MOEs should be manageable in quantity and complexity to ensure a focused and meaningful evaluation
- The test of “so what” in defining the evaluation plan can help sharpen the evaluation focus and guide evaluation design process.

SYSTEM IMPACTS

Forged partnership across interjurisdictional boundaries, integrated interjurisdictional management strategies, and deployed technologies contributed to improving traffic operations and use of capacity within the corridor.

The ICTM project deployed a variety of advanced technologies and integrated management strategies across jurisdictional boundaries. The management approach sought to improve traffic operations corridorwide by accommodating demand and pattern fluctuations during both incident and nonincident conditions. The specific technologies deployed to meet this objective included adaptive ramp metering, adaptive traffic signal systems, the motorist information system, and automated incident management strategies.

System components included I-494 main lanes, I-494 metered ramps, and traffic signals along east–west and north–south arterial streets within the ICTM corridor. Data collected to represent the "before" case reflected traffic signals which were operated by a variety of nonintegrated systems across jurisdictional boundaries. The east-west streets were mostly controlled by isolated traffic signals in actuated operations while the north–south streets were served by distributed closed-loop systems whose system timings were developed during 1988 / 1990 period. The TMC operated the ramp-metering system using historical algorithms that leveraged 30-plus years of development activities for ramp-metering management.

The application of ICTM integrated management strategies and advanced technologies to accommodate changing traffic patterns and operations provided the opportunity for capacity management, operations management, and demand management within the corridor. Although increases in traffic congestion along I-494 and associated ramp meters contributed to changing traffic patterns, the ICTM adaptive system accommodated these changes when it was not adversely impacted by an unstable communications system.

Viewed from this perspective, ICTM yielded traffic operations and management benefits across diverse transportation infrastructure components and jurisdictional boundaries. This section presents evaluation conclusions derived from a cross-cutting assessment of quantitative and qualitative data gathered from field observations, automated databases, and ICTM system users.

FINDINGS

ICTM system accommodated changing traffic patterns through improved use of corridor capacity during nonincident conditions.

Users perceptions and before and after traffic counts collected at two screenline locations across east–west links were used to identify traffic pattern changes within the corridor. Inferential statistics and a 90 percent confidence level were used for the before–after quantitative data. The results are presented in Tables 14 and 15 for each east–west link and analysis period. The "Y" entries in the column entitled "SS" reflect statistically significant differences between 1996 and 1999 flow-rate mean values. These results were used to generate the evaluation findings that are presented in Table 15.

Table 14: Traffic Flow Changes at Xerxes Screenline for Eastwest Links within the Corridor

DAY	PERIOD	DIRECTION	XERXES SCREENLINE FLOW RATE								
			76TH ST			80TH ST			I - 494		
			1996	1999	SS	1996	1999	SS	1996	1999	SS
Weekday	AM	EB	359	311	Y	276	325	N	5973	5747	Y
		WB	912	1281	Y	850	625	Y	6351	5625	Y
	Midday	EB	654	926	Y	1193	1093	Y	10198	10001	N
		WB	693	963	Y	1045	947	Y	9801	9683	N
	PM	EB	1002	1348	Y	1323	1038	Y	6258	6146	N
		WB	628	778	Y	574	634	N	5845	5666	N
Saturday	Midday	EB	567	778	Y	889	835	N	10325	10784	N
		WB	741	961	Y	708	635	N	9338	9811	Y

Table 16 findings are grouped into three categories, two of which represent statistically significant changes in mean values of flow rate. The "higher" and "lower" groups indicate statistically significant change and direction in the 1999 mean values of flow rate compared to 1996 values for each screenline location, street, direction, and analysis period. The group entitled "same" indicates that there was no statistically significant difference between before and after mean values for each flow rate.

Table 15: Traffic Flow Changes at Nicollet Screenline for Eastwest Links within the Corridor

DAY	PERIOD	DIRECTION	NICOLLET SCREENLINE FLOW RATE											
			76TH ST			77TH ST			79TH ST			I - 494		
			1996	1999	SS	1996	1999	SS	1996	1999	SS	1996	1999	SS
Weekday	AM	EB	81	96	N	239	234	N	185	161	Y	5418	5332	N
		WB	151	186	Y	727	857	N	381	392	N	5269	4605	Y
	Midday	EB	213	192	Y	645	691	Y	526	544	N	1767	8567	Y
		WB	147	190	Y	641	747	Y	705	682	N	7708	8884	Y
	PM	EB	262	259	N	696	789	Y	319	367	Y	6415	6548	N
		WB	141	170	Y	522	560	N	408	394	N	5162	4762	N
Saturday	Midday	EB	309	264	N	739	783	N	467	529	Y	8458	9270	Y
		WB	213	286	Y	152	245	N	563	574	N	7900	8986	Y

Table 16: Flow Rate Changes in ICTM Corridor along Eastwest Links

Period	Screen Location	Mean Flow Rate	76th	76th	77th	77th	79th	79th	80th	80th	I-494	I-494
			EB	WB	EB	WB	EB	WB	EB	WB	EB	WB
AM	Nicollet	Lower*					x					x
AM	Xerxes	Lower*	x							x	x	x
OFFWK	Nicollet	Lower*	x									
OFFWK	Xerxes	Lower*							x	x		
PM	Nicollet	Lower*										
PM	Xerxes	Lower*							x			
OFFSAT	Nicollet	Lower*										
OFFSAT	Xerxes	Lower*										
AM	Nicollet	Same	x		x	x		x			x	
AM	Xerxes	Same							x			
OFFWK	Nicollet	Same					x	x				
OFFWK	Xerxes	Same									x	x
PM	Nicollet	Same	x			x		x			x	x
PM	Xerxes	Same								x	x	x
OFFSAT	Nicollet	Same	x		x	x		x				
OFFSAT	Xerxes	Same							x	x	x	
AM	Nicollet	Higher*		x								
AM	Xerxes	Higher*		x								
OFFWK	Nicollet	Higher*		x	x	x					x	x
OFFWK	Xerxes	Higher*	x	x								
PM	Nicollet	Higher*		x	x		x					
PM	Xerxes	Higher*	x	x								
OFFSAT	Nicollet	Higher*		x			x				x	x
OFFSAT	Xerxes	Higher*	x	x								x

The frequency of findings as reflected in the "higher" and "lower" categories of Table 15 result in the conclusion that traffic patterns changed along major corridor links. This change is attributed to increased traffic congestion on I-494 and associated ramp meters, emergence of new developments, and traffic operations improvements along the arterial streets. Inclement weather also served to influence local travelers to choose arterial streets rather than I-494 to avoid congestion. Motorists also indicated that they were less likely to use I-494 and more likely to use corridor side streets for short trips to avoid congestion. These changing traffic patterns created an ideal setting for deployment of an adaptive traffic control system to manage fluctuations in traffic demand. Agency stakeholders perceived that improvements in traffic operations had contributed to changing traffic patterns and use of available capacity. Detailed evaluation findings supporting these conclusions are included in Appendix A.

Corridor experienced traffic operations improvements during nonincident conditions.

Data gathered from travel time runs along all corridor routes, along with perceptions of corridor motorists and agency representatives, was used to evaluate changes in traffic operations corridorwide. The MOEs included travel time, frequency of stops, space mean speed, and overall delay. The I-494 analysis could not use the “overall delay” because the associated “before” case data was unavailable. The analysis used inferential statistics and 90-percent confidence level to compare the mean values of these MOEs in the before–and–after cases.

The traffic operations MOEs were subsequently adjusted / interpreted to identify traffic operations "trends" that better reflect traffic flow changes resulted from a 3-year time gap between the before and after cases. The adjustment process considered statistically significant changes in mean values of flow rate in interpreting associated traffic operations MOEs. For example, an increase in the mean flow rate for a given route, direction, and analysis period would result in the interpretation that the “adjusted” mean travel time had in fact “improved” even though the “unadjusted” value had remained the “same.” Conversely, a decrease in the mean flow rate for a given route, direction, and analysis period would result in the interpretation that the “adjusted” mean travel time had in fact “worsened” even though the “unadjusted” value had remained the “same.”

Tables 17 and 18 summarize the frequency and percentages of “actual” and “adjusted” traffic operations MOEs, respectively, for various analysis periods and link orientations. Table 18 represents the effects of traffic flow changes in traffic operations MOEs. The evaluation findings resulted in the conclusions that traffic operations improved along most corridor routes as measured by volume-adjusted MOEs but remained the same when measured by nonadjusted MOEs. Motorists generally perceived operational improvements along east–west streets and a worsening of traffic operations within the other corridor links, especially along I-494 and associated metered ramps. Agency stakeholders generally perceived improvements in traffic operations within the corridor. According to stakeholders, traffic control systems bordering the corridor posed some operational challenges but proved manageable.

Detailed evaluation findings supporting these conclusions are included in Appendix A. Appendix B contains the results of analysis for travel time MOEs based on actual field data without any adjustments for traffic flow changes.

Table 17. Traffic Operations Measures of Effectiveness Unadjusted for Flow Rate Changes

Frequency (Travel Time, Number of Stops, Speed, and delay)												
Period	Eastwest Streets			Northsouth Streets			1-494			Corridor		
	Better	Worse	Same	Better	Worse	Same	Better	Worse	Same	Better	Worse	Same
AM	3	8	21	1	20	35	3	0	3	7	28	59
Midday	0	4	28	1	11	44	3	1	2	4	16	74
PM	2	3	27	1	11	44	4	0	2	7	14	73
Midday-Sat	0	6	26	3	8	45	4	0	2	7	14	73
All	5	21	102	6	50	168	14	1	9	25	72	279
Percentage (Travel Time, Number of Stops, Speed, and delay)												
Period	Eastwest streets			Northsouth streets			1-494			Corridor		
	Better	Worse	Same	Better	Worse	Same	Better	Worse	Same	Better	Worse	Same
AM	9%	25%	66%	2%	36%	63%	50%	0%	50%	7%	30%	63%
Midday	0%	13%	88%	2%	20%	79%	50%	17%	33%	4%	17%	79%
PM	6%	9%	84%	2%	20%	79%	67%	0%	33%	7%	15%	78%
Midday-Sat	0%	19%	81%	5%	14%	80%	67%	0%	33%	7%	15%	78%
All	4%	16%	80%	3%	22%	75%	58%	4%	38%	7%	19%	74%

Table 18. Traffic Operations Measures of Effectiveness Adjusted for Flow Rate Changes

Frequency (Travel Time, Number of Stops, Speed, and delay)												
Period	**Eastwest streets**			**Northsouth streets**			**1-494**			**Corridor**		
	Better	Worse	Same	Better	Worse	Same	Better	Worse	Same	Better	Worse	Same
AM	5	16	11	36	20	0	3	3	0	44	39	11
Midday	10	12	10	45	11	0	5	1	0	60	24	10
PM	13	7	12	45	11	0	4	0	2	62	18	14
Midday-Sat	11	6	15	48	8	0	6	0	0	55	14	15
All	39	41	48	174	50	0	18	4	2	231	95	50
Percentage (Travel Time, Number of Stops, Speed, and delay)												
Period	**Eastwest streets**			**Northsouth streets**			**1-494**			**Corridor**		
	Better	Worse	Same	Better	Worse	Same	Better	Worse	Same	Better	Worse	Same
AM	16%	50%	34%	64%	36%	0%	50%	50%	0%	47%	41%	12%
Midday	31%	38%	31%	80%	20%	0%	83%	17%	0%	64%	26%	11%
PM	41%	22%	38%	80%	20%	0%	67%	0%	33%	66%	19%	15%
Midday-Sat	34%	19%	47%	86%	14%	0%	100%	0%	0%	69%	15%	16%
All	30%	32%	38%	78%	22%	0%	75%	17%	8%	61%	25%	13%

Motorists made more intelligent route choices during incidents because of the motorist information system and incident management strategies.

In 1999, during a period of relative stability for the ICTM communications system, two freeway incidents occurred, one on January 4 and one on April 5, that resulted in activating the incident management system and associated electronic signs and operational strategies. These incidents provided the opportunity to collect pertinent data for evaluating traffic pattern and traffic operations changes. In both cases, nonincident data was collected on three equivalent days and periods immediately following each incident to support a comparative analysis of applicable MOEs using descriptive statistics. Traffic flow rates at entrance and exit ramps upstream of each incident location and entrance ramps immediately downstream were used to measure potential changes in traffic patterns during each incident. Cycle length, degree of saturation, and phase split were the additional MOEs considered in evaluating SCATS' responsiveness to potential traffic surges at bypass traffic signals and associated critical movements.

The evaluation findings resulted in the conclusion that traffic patterns during incidents changed in response to the ICTM incident management system and strategies. The surveyed motorists were generally satisfied with the ICTM motorist information system and indicated a preference to alter their travel behavior in response to incident management information. Agency stakeholders perceived that when additional incidents occur, the operational feasibility and benefits of traffic diversion strategies should be tested again.

The overall evaluation conclusion was that there were some traffic diversion and demand shifts within the corridor during incident conditions and that the travelers' route-choice behavior was facilitated by the deployed incident management technologies and strategies, including—

- Activation of the restrictive ramp metering system (and motorists' observance of ensuing congestion and traffic queues on both freeway and associated entrance-ramps upstream of incident location)
- Activation of the incident management system, comprising the motorist information system and messages along the bypass routes
- TMC and other radio broadcasts of incident information.

Detailed evaluation findings supporting these conclusions are included in Appendix A.

SCATS system responded appropriately to traffic conditions during incidents.

Three measures of effectiveness pertaining to two incidents were considered to evaluate SCATS' ability to accommodate diverted traffic at traffic signals along the bypass routes. These included cycle length, degree of saturation, and phase split. The bypass route for the first incident encompassed three SCATS-controlled traffic signals and critical movements, including—

- Intersection 22, France and 80th Street, southbound to eastbound movement
- Intersection 52, Xerxes and 80th Street, eastbound movement
- Intersection 41, Lyndale and 82nd St, eastbound to northbound movement

The bypass route for the second incident encompassed four SCATS-controlled traffic signals. However, only one traffic signal and critical movement could be considered for evaluation since the critical movements at the other three traffic signals were free right-turn movements, thus not controlled by the SCATS system. The traffic signal and associated critical movement was at France Avenue and 80th Street, eastbound to northbound movement.

The evaluation findings resulted in the conclusions that there were insignificant changes in traffic operations MOEs at bypass traffic signals during incident conditions. Motorists were satisfied with their decision to take alternate routes to bypass freeway congestion while expressing an increased likelihood to use these routes in the future. Agency stakeholders perceived that when additional incidents occur, the operational feasibility and benefits of traffic diversion strategies should be tested again. Detailed evaluation findings supporting these conclusions are included in Appendix A.

ACTION PLAN

ICTM is migrating from being a field operational test to full deployment.

The ICTM management has developed a plan to support the migration of the ICTM field operational test to a full permanent deployment. The plan distributes and integrates ICTM support functions within the framework of the existing support organizations. It positively reflects on the commitment of Mn/DOT, county, and city partners to maintaining and supporting the ICTM concept and system. The resources of Mn/DOT's Freeway Operations and Metro Traffic Engineering sections as well as county and city partner agencies will be used to operate and manage the ICTM system.

An ICTM dedicated staff, proficient in the SCATS system configuration and operations, has joined the Freeway Operations Section and will remain as the point of contact and technical support for the ICTM system during the transition period. Two newly approved staff positions created under the Corridor Management Initiative will be allocated to the Traffic Engineering Section to maintain and support the ICTM traffic signal system. Specifically, the plan defines the following roles and responsibilities:

- The Freeway Operations Section will operate and manage the ICTM adaptive ramp metering system. The support services will include troubleshooting complaints, assessing operational needs, upgrading software, and defining freeway zones and timing/control parameters. This Section will also support the motorist information system and SCATS NT computer system.
- The Traffic Engineering Section will operate and manage Mn/DOT-owned adaptive traffic signals. The support services will include overseeing SCATS system operations, supporting city and county partner agencies, troubleshooting complaints, and assisting with new traffic signals setup and configuration. This Section will also support and administer the incident management system in cooperation with the Freeway Operations.
- The county and city partners will operate and manage the adaptive traffic signals located in their respective jurisdictions and will be supported by the Metro Traffic Engineering section.
- Freeway Operations and Metro Traffic Engineering sections will collaborate and apply operational best practices and features gained from ICTM's adaptive ramp metering system into the TMC ramp metering system metrowide.
- ICTM project manager will continue to provide administrative and management support for the existing ICTM contracts until they are closed out. These contracts include project evaluation, SCATS software upgrade, and motorist information system training.

The migration plan seeks to improve ICTM operations effectiveness and potential system expansion throughout the Twin Cities Metropolitan Area. The migration plan will also be facilitated by Mn/DOT's current efforts to co-locate Freeway Operations and Metro Traffic Engineering sections in a regional Traffic Management Center currently under construction. This will allow for a better organizational integration and functional coordination.

The following management actions are recommended to support ICTM as a full deployment:

Commitment: Renew the partnership commitment to address transportation needs on a corridorwide basis.

The perceived value of ICTM's institutional benefits, deployed technologies, and supporting strategies has fueled its continuation and support. The partner agencies' renewed commitment to share a common vision and strategic approach is essential in addressing the transportation management needs of the entire corridor. This, in turn, will serve to strengthen the partnership in allocating the resources needed to realize the envisioned tangible and intangible benefits.

Institutional Infrastructure: Establish an institutional framework for system support.

The ICTM institutional framework was instrumental in ensuring the execution of the ICTM concept, especially in view of the significant technical and operational challenges encountered. The management team and supporting working committees worked in unison to address ongoing challenges. The interdependence of ICTM jurisdictional networks, technologies, and management strategies requires the continuation of this institutional and organizational framework. This management and operations framework and ensuing cooperation and coordination are essential in supporting the diverse needs of the ICTM system including funding, procurement, operations, maintenance, and management.

Technology: Explore options and alternatives for resolving current technology challenges.

The unstable communications system and complex system user-interface adversely affected the ICTM system. These technical issues should be resolved to realize the benefit of ICTM to traffic operations and management. Identification and resolution of these technology issues will also minimize their impact on resources and buy-in of support staffs. There are a variety of technology-based options to support ICTM system expansion and next steps. However, these options should be explored after the current technology challenges are successfully addressed.

Operational Strategy: Apply unified operational strategies for system configuration, management, and operations.

The deployment of ICTM technologies and management strategies across jurisdictional boundaries required unified operational strategies and procedures to ensure consistent and compatible traffic operations corridorwide. System upgrades, expansion, and staff turnover typically diminish understanding of support staff resulting in an increased propensity for operational errors. It is recommended that the operational, maintenance, and management procedures be formally documented and shared with support staff. This will enhance interagency coordination and consistency in system operations and maintenance.

Resources: Provide necessary resources and support for continued system management and operations.

ICTM is a complex ITS system, which includes a variety of advanced technologies and strategies. Similar to other ITS systems, ICTM has demonstrated it requires enhanced levels of support and training resources for quality system operations and maintenance to realize the envisioned management benefits. To realize these benefits, it is imperative to ensure the support staff is proficient in ITS system operations and equipped with needed resources, know-how, and support to properly maintain them.

APPENDIX A—ICTM SYSTEM IMPACTS FINDINGS

The evaluation of the *ICTM System Impacts* was based on a variety of quantitative and qualitative measures of effectiveness as well as data sources. Quantitative data representative of before (1994 or 1996) and after (1999) evaluation scenarios was collected and compared using statistical modeling (i.e., t-test) at 90 percent confidence level to address specific evaluation MOEs. Telephone interviews with 400 motorists within the corridor, written survey and face-to-face interviews with representatives from partnering agencies formed the basis for assessing the MOEs using qualitative data. The findings associated with each MOE were mapped to respective evaluation objectives to derive higher-level evaluation findings. These findings were, in turn, mapped to associated evaluation goals (noted below) as the basis for reaching evaluation conclusions.

- Assess ICTM in changing traffic patterns and use of corridor capacity during recurrent congestion and incident conditions
- Assess ICTM in improving traffic flow in the corridor during recurrent congestion and incident conditions
- Assess ICTM effects on traffic control systems bordering the corridor.

This Appendix summarizes the ICTM system impacts' evaluation conclusions and supporting findings.

ICTM system accommodated changing traffic patterns by better use of corridor capacity during nonincident conditions.

Traffic patterns changed along major corridor links.

- I-494 flow rate remained the same during most analysis periods. It predominately decreased during AM peak hour (due to increased congestion along I-494), remained the same during PM peak hour, and increased during midday period on weekdays and Saturdays.
- 76th Street flow rate mostly increased. Being the only continuous east-west street in the corridor, 76th Street demonstrated the highest occurrences of increased flow rate relative to other east-west streets.
- 77th Street flow rate remained the same during most analysis periods. It increased during the weekday midday period and peak direction of PM peak period.
- 79th Street flow rate remained the same during most analysis periods.

- 80th Street flow rate decreased in the PM peak hour and peak direction of AM peak hour while remaining the same in the nonpeak directions. The flow rate decreased during weekday midday period while remaining the same during Saturday midday period.

Motorists indicated that they were less likely to use I-494 and more likely to use corridor side streets for short trips to avoid congestion.

- 70.6 percent (327) of motorists indicated that they used I-494 for commuting to work or school. The percentage using the local streets within the corridor was generally low and ranged between 0.6 percent (Xerxes Avenue) to 8.6 percent (France Avenue).
- 95 percent (381) of the motorists indicated that they commuted to work 3 days or more.
- 74.5 percent (298), 30.2 percent (121), and 69.2 percent (277) of the motorists indicated they typically commuted to work during 6–9 AM, 9– 3 PM, and 3–6:30 PM periods.
- The majority of motorists surveyed indicated reduced likelihood to use I-494 for short trips to avoid congestion. 58 percent (232) of the motorists surveyed indicated that they are less likely to use 494 for short trips.
- 36.5 percent (146), 50.2 percent (202), and 10.3 percent (41) indicated they used I-494 more often, about the same, or less often for short trips compared with a year ago. Freeway congestion (68.5 percent, 100) and ramp metering congestion (15.8 percent, 23) were the primary causal factors cited for decreasing use of I-494 for short trips.
- 49.8 percent (163) of the motorists surveyed indicated that they were using the side streets more often than a year ago for short trips. 44 percent (144) and 4.6 percent (15) indicated they used side streets about the same or less often than a year ago for short trips. Ease of use (19.6 percent, 32) and freeway / ramp metering congestion were cited as the primary causal factors for increasing the use of side streets for short trips.
- The likelihood to use I-494 for short trips decreased from 2.49 in 1996 to 2.37 in 1999. However this finding was not statistically significant indicating that in all probabilities the likelihood for using I-494 for short trips did not change.
- The frequency of using I-494 for short trips compared to a year ago did not change from 1996 to 1999. Factors influencing the use of I-494 or side streets for short trips included time of day (39 percent, 156), time savings (16.5 percent, 66), freeway traffic congestion (33.8 percent, 135), congested ramp meters (11 percent, 44), route familiarity (12.3 percent, 49), destination / longevity of trip (11 percent, 44), and weather conditions (4 percent, 16).
- 76th Street (15.9 percent, 59) and 82nd (12.2 percent, 45), and 77th Street (11.9 percent, 44) were cited most as the side streets used for short trips.

Agency stakeholders perceived that improvements in traffic operations had contributed to changing traffic patterns and use of available capacity.

- The majority of agency stakeholders (58 percent) perceived that traffic operations improvements within the corridor had contributed to local trips using local streets rather than I-494 freeway or changing traffic patterns across the corridor (53 percent). 50 percent perceived that the application of adaptive control system had optimized the use of corridor capacity during nonincident conditions.
- Agency stakeholders perceived that flow rate on north–south streets increased significantly due to new land-use developments within and outside the corridor.

Corridor experienced traffic operations improvements during nonincident conditions.

Traffic operations improved along most corridor routes as measured by volume-adjusted MOEs but mostly remained the same when measured against nonadjusted MOEs.

- Traffic operations MOEs predominately improved on I-494 during all analysis periods.
- Traffic operations MOEs predominately improved on north–south streets, considering perceptions of increased traffic demand by agency stakeholders.
- Traffic operations MOEs along east–west streets remained almost equally divided across "better," "worse," and "same" groups indicating the absence of any overall tendency. Traffic operations generally worsened on 76th Street, 79th Street, and 80th Avenue while remaining the same for 77th Street during AM peak hour.

Traffic operations predominately remained the same along arterial streets while generally improving along I-494 if measured by "unadjusted" MOEs computed from travel time runs.

- Traffic operations MOEs generally improved along I-494.
- Traffic operations MOEs predominately remained the same for east–west streets.
- Traffic operations MOEs predominately remained the same along north–south street.

Traffic congestion on I-494 and associated metered ramps increased as measured by flow rate, density, spot speed, and metered entrance ramps' flow rates.

- All freeway zones were adversely impacted by increased traffic congestion on I-494.
- Average flow rate on I-494 deceased for all metered zones (4G and 4H) during the AM peak hour.

- Average flow rate on I-494 remained unchanged for all zones (4D, 4E, and 4G) during the PM peak hour except for one westbound zone (4H) where it decreased.
- Average freeway density increased while average spot speed decreased for all zones during AM and PM peak hours reflecting increased traffic congestion except zone 4D where it remained unchanged during PM peak hour.
- Entering flow rate for all entrance ramps decreased for all zones and analysis periods except zone 4E during PM peak hour where it increased.
- All metered entrance-ramps in all zones (4E, 4G, and 4H) except zone 4D experienced reductions in frequency of "on" states during PM peak hours. Two entrance ramps experienced significant reductions in frequency of "on" states during AM peak hour.

Motorists generally perceived a worsening of traffic operations within the corridor especially along I-494 and associated metered ramps.

- Motorists generally perceived traffic congestion increased on I-494 and associated ramp meters.
- Increased congestion on I-494 and metered ramps encouraged some local motorists to use arterial streets for short trips.
- Motorists perceived slight traffic operations improvement along east–west streets.
- There was a statistically significant increase in the level of intolerance of congestion on north–south streets. Data indicated that the average intolerance level increased from 3.71 in 1996 to 4.93 in 1999—an increase of 33 percent.
- There were no statistically significant differences between 1996 and 1999 wave years pertaining to "aggregated" east–west and north–south arterial streets. Data indicated slight decreases in perceived frequency of coordination, frequency of stops, consistency of travel time, and tolerance for traffic congestion. Because this finding was not statistically significant, it was concluded that there was no change in these measures.
- Motorists perceived that the wait time at ramp meters increased from 4.1 to 6.85 minutes—an increase of 67percent. This finding proved consistent with Mn / DOT's tracking studies for the TCMA, which found the perceived ramp meter wait time of 4.82 and 6.21 minutes in 1996 and 1999.
- Motorists' level of intolerance for wait time at ramp meters increased from 4.28 to 5.49—an increase of 28 percent. This finding proved consistent with Mn / DOT's tracking studies for the TCMA which found the perceived level of intolerance for ramp metering wait time increased from 4.56 in 1996 to 5.47 in 1999. 33.7 percent (108) of motorists indicated a high level of intolerance for ramp metering wait time as compared with 25.6 percent (101) of respondents who indicted a high level of tolerance.
- Intolerance for level of congestion along the freeway increased from 5.1 to 6.4—an increase of 25 percent. This finding proved consistent with Mn / DOT's

tracking studies for the TCMA, which found the level of intolerance for traffic congestion along I-494 increased from 5.13 in 1996 to 5.19 in 1999. 40.2 percent (161) of respondents indicated a high level of intolerance for congestion on I-494 versus 13.8 percent (55) who indicated a high level of tolerance.

- Using a scale of 1 to 10 when “1” means that travel time is not at all consistent and”10” means that it is very consistent, the respondents mean rate was 5.71. 28.3 percent (113) of respondents indicated a high level of travel time consistency when commuting along I-494 as compared to 20.6 percent (94) who indicated experiencing a high level of inconsistent travel time.
- Motorists estimated the average commute time on I-494 as 19.24 minutes with a standard deviation of 15.63. 8 percent (32) of 400 motorists interviewed indicated that they often used ICTM corridor east–west side streets to commute with 50 percent (16) using 77th Street, 25 percent (8) using 76th Street, 12.5 percent (4) using 82nd Avenue, 9.4 percent (3) using 79th Street, and 3.1 percent (1) using 80th Street.
- 41.2 percent (165), 7.5 percent (30), 14.7 percent (59), 13.5 percent (54), 6.8 percent (27) of the motorists indicated that they typically encountered ramp metering, 5, 4, 3, 2, and 1 day a week, respectively.
- 58 percent (232) of the motorists surveyed indicated that they are less likely to use I-494 for short trips. 36.5 percent (146), 50.2 percent (202), and 10.3 percent (41) indicated they used I-494 more often, about the same, or less often for short trips compared with a year ago. Freeway congestion (68.5 percent, 100) and ramp metering congestion (15.8 percent, 23) were the primary causal factors cited for decreasing use of 494 for short trips.
- 76th Street (15.9 percent, 59) and 82nd Street (12.2 percent, 45), and 77th Street (11.9 percent, 44) were cited most as the side streets used for short trips.
- 49.8 percent (163) of the motorists surveyed indicated that they were using side streets more often than a year ago for short trips. 44 percent (144) and 4.6 percent (15) indicated they used side streets about the same or less often than a year ago for short trips. Ease of use (19.6 percent, 32) and freeway/ ramp metering congestion were cited as the primary causal factors for increasing the use of side streets for short trips. Factors influencing the use of I-494 or side streets for short trips included time of day (39 percent, 156), time savings (16.5 percent, 66), freeway traffic congestion (33.8 percent, 135), congested ramp meters (11 percent, 44), route familiarity (12.3 percent, 49), destination/longevity of trip (11 percent, 44), and weather conditions (4 percent, 16).

Agency stakeholders generally perceived improvements in traffic operations within the corridor.

- The majority of agency stakeholders perceived that traffic operations improvements within the corridor had contributed to local trips using local streets rather than I-494 freeway (68.8 percent) or changing traffic patterns across the corridor (53 percent). 50 percent perceived that the application of adaptive control system optimized the use of corridor capacity during non-incident conditions.

- Agency stakeholders perceived improvements in traffic operations on east–west streets (52 percent) and ICTM ramp metering system (50 percent). The majority (64 percent) perceived that adaptive ramp metering system had optimized ramp metering capacity by being more responsive to freeway flows conditions.
- Agency stakeholders generally perceived no significant operational change along I-494 (51 percent) and north–south streets (41 percent).

Traffic control systems bordering the corridor posed some operational challenges.

The interface of adaptive and nonadaptive control systems posed unique challenges. System operators perceived that ICTM bordering areas created inefficient break points in otherwise coordinated north–south traffic controlled by traditional traffic control technologies. They cited citizen complaints at initial launching of the SCATS system as the basis for this observation. Other agency stakeholders perceived ICTM bordering traffic control system, as potential opportunity areas for system expansion in the future once current technology issues were effectively resolved. However, coordination of adaptive and nonadaptive traffic control systems may be challenging at best given the current state of technology and the systems may be operationally imprudent.

The majority (59 percent) of agency stakeholders surveyed did not have an opinion applicable to the operational effectiveness of the bordering areas. The majority (81 percent, 4) of those who had an opinion indicated there was "no change" in applicable operational measures. The operations quality of traffic signals and metered ramps interface was rated as satisfactory by 29.4 percent, unsatisfactory by 35.3 percent, and neutral by 35.3 percent of agency stakeholders surveyed.

Motorists made more intelligent route choices during incidents because of the motorists' information system and incident management strategies.

Traffic patterns during incidents changed in response to ICTM incident management system and strategies.

This conclusion was supported by the analysis results associated with both incidents. The results for Incident 1 indicated that during the period when the incident management system remained in effect—

- The net exiting traffic flow from 5 exit ramps upstream of the incident location increased by 4 percent (96 vehicles).
- The first exit ramp upstream of the incident location experienced a reduction of 89 percent (376 vehicles) in exiting traffic flow. Freeway traffic queue spillover blocking adjacent upstream exit ramp was a factor in this flow reduction.
- The net exiting flow at the remaining upstream exit ramps increased by 32 percent (471 vehicles).
- The net entering traffic to the freeway at upstream entrance ramps decreased by 28 percent (712 vehicles).

- The net entering traffic at downstream entrance ramps increased by 23 percent (222 vehicles).

The results for Incident 2 were consistent with Incident 1 findings as stated above. They indicated that during the period when the incident management system remained in effect—

- The net exiting traffic flow from 3 exit ramps upstream of the incident location decreased by 2 percent (32 vehicles).
- The first exit ramp upstream of the incident location experienced a reduction of 53 percent (267 vehicles) in exiting traffic flow. Freeway traffic queue spillover blocking adjacent upstream exit ramp was a factor in this flow reduction.
- The net exiting flow at the remaining upstream exit ramps increased by 38 percent (235 vehicles).
- The net entering traffic to the freeway at upstream entrance ramps decreased by 36 percent (1573 vehicles).
- The net entering traffic at downstream entrance ramps increased by 17 percent (219 vehicles).

Motorists were generally satisfied with the ICTM motorist information system and expressed a willingness to alter their travel behavior in response to incident management information.

- The majority of motorists surveyed indicated that they had seen the ICTM incident management signs located along the freeway and arterial streets including large overhead electronic message signs (77.5 percent, 252), small electronic message signs (34.5 percent, 112), and electronic arrow signs (48.6 percent, 158). 58.3 percent (147) of the motorists who had seen the large overhead electronic signs indicated that they had taken the side streets to avoid traffic congestion when directed by the signs to do so.
- Motorists (29 percent, 73) who elected not to divert to side streets when directed by the vehicle message signs (VMS) cited a variety of reasons for their decision. This included destination closer than accident site (20.5 percent, 15), unreliable message (15.1 percent, 11), unfamiliarity with alternate routes (15.1 percent, 11), exit blocked by traffic queues (11 percent, 8), and willingness to wait (9.6 percent, 7). 47.6 percent (70) of the motorists rated the timeliness of the information for changing their choice of routes as good to excellent while 21.1 percent considered the timeliness as poor.
- 66.1 percent (123) of the motorists who had seen the small electronic signs (186) along side streets rated these signs as helpful while only 24.2 percent (45) considered these signs as not helpful. 90.5 percent (133) of the motorists who had seen the VMSs indicated that the displayed information on electronic signs along I-494 were helpful. Primary reasons cited for helpfulness included providing traffic information and relieving stress and frustration.
- 76 percent (304) of the motorists surveyed indicated that they had taken side streets within the ICTM corridor during traffic congestion along I-494 or when

directed by traffic signs. 67.5 percent (270) of the motorists rated the traffic signals along the side streets as coordinated, while 21.5 percent considered the traffic signal coordination as poor. 85.9 percent (261) were satisfied with their decision to take the alternate route due to such cited reasons as travel time savings (42.1 percent, 110) and ease of driving / less congestion (59.4 percent, 155). Those who elected not to take alternate routes (14.1 percent, 43) cited equivalent time and congestion impact by taking side streets.

- 95.5 percent (386) of the motorists surveyed (400) indicated that they would be very likely to take side streets within the ICTM corridor if there were a major traffic problem on I-494 with excessive delays. This percentage increased only slightly (96.5 percent, 386) when the same question was repeated with the stipulation that coordinated traffic signals and signage would be provided along the side streets.

Agency stakeholders perceived the need to test the operational feasibility and benefits of traffic diversion strategies when additional incidents occur.

- The majority of the agency stakeholders perceived that it was operationally (50 percent) and politically (50 percent) feasible to divert freeway traffic to parallel arterial streets during major freeway incidents. This compares with 31.3 percent and 33.3 percent of the stakeholders respectively who disagree with these conclusions.
- The agency stakeholders are almost equally divided (38.9 percent agree, 38.9 percent disagree, and 22.2 percent remain neutral) on whether there was sufficient excess capacity available on parallel arterial streets to accommodate diverted freeway traffic during major freeway incidents. 35.2 percent of the stakeholders, on the other hand, perceived that the traffic signals along the bypass routes did not have the capacity to accommodate diverted traffic efficiently, while 52.9 percent maintained a neutral position.

SCATS system responded appropriately to traffic conditions during incidents.

There were insignificant changes in traffic operations measures of effectiveness at bypass traffic signals during incident conditions.

Analysis of Incident 1 data indicated that the phase duration and degree of saturation for the critical movement (southbound to eastbound left turn) for the bypass traffic signal located at Lyndale Avenue and 82nd Street increased significantly even though the cycle length remained mostly the same. However, these operational MOEs did not change at the remaining traffic signals along the bypass routes.

Analysis of Incident 2 data indicated there were no significant changes in operational measures of cycle length, degree of saturation, and critical phase duration at the bypass traffic signal located at 80th Street and France Avenue.

These findings suggested there were insignificant traffic diversions from the freeway during the incident condition to warrant adaptive operational adjustments.

Motorists were satisfied with their decision to take alternate routes to bypass freeway congestion and expressed an increased likelihood to use these routes in the future.

- The majority of motorists indicated they had seen the ICTM motorists' information signs on I-494 and side streets. They valued these signs as helpful in providing traffic information and relieving stress and frustration. The perceived level of helpfulness for the VMS signs increased in 1999 versus 1996 (3.42 vs. 3.2).
- Motorists used VMS signs on I-494 to avoid incident-related congestion, the majority indicating they took side streets during traffic congestion along I-494 when directed
- 67.5 percent (270) of the motorists rated the traffic signals along the side streets as coordinated while 21.5 percent considered the traffic signal coordination as poor.
- Motorists were satisfied with their decision to take alternate routes and were more likely to take side streets during future incidents. 85.9 percent (261) were satisfied with their decision to take alternate routes and cited such gained benefits as travel timesaving (42.1 percent, 110), and ease of driving/less congestion (59.4 percent, 155). Those who elected not to take alternate routes (14.1 percent, 43) cited equivalent time and congestion prevalence along side streets.

Agency stakeholders perceived the need for additional incidents to test the operational feasibility and benefits of traffic diversion strategies.

- The majority (58 percent) of agency stakeholders surveyed indicated there was no change in operational MOEs on I-494 during incident conditions while 29 percent perceived some improvements.
- Agency stakeholders generally took a neutral (38 percent) position on traffic operations MOEs on bypass routes during incident conditions while 45 percent perceived some improvements.
- The majority of agency stakeholders perceived it was feasible to divert freeway traffic to parallel arterial streets, but they remain divided on whether parallel arterial streets and signals have sufficient excess capacity to accommodate freeway diversions
- Agency stakeholders, however, came to a somewhat different conclusion. The majority of agency staff interviewed believed it was feasible to divert freeway traffic to parallel arterial streets, but they remain divided on the issue of whether parallel arterial streets and signals have sufficient excess capacity to accommodate freeway diversions.

- The majority of the agency stakeholders perceived it was operationally (50 percent) and politically (50 percent) feasible to divert freeway traffic to parallel arterial streets during major freeway incidents. This compares with 31.3 percent and 33.3 percent of the stakeholders who disagree with this conclusion.

APPENDIX B—TRAVEL TIME RUNS FINDINGS

TRAVEL TIME RUNS (UNADJUSTED FOR FLOW CHANGES)								
1996 VS. 1999								
7:30 - 8:30 AM WEEKDAYS								
ROUTE	DIR	MOE	BEFORE	AFTER	% CHANGE	BETTER*	WORSE*	SAME
76th St	EB	Delay	77.2	150.2	94.6%		x	
76th St	WB	Delay	63.8	114.8	79.9%		x	
77th St	EB	Delay	19.3	15.2	-21.4%			x
77th St	WB	Delay	31.0	87.0	180.6%		x	
79th St	EB	Delay	88.0	108.2	22.9%			x
79th St	WB	Delay	142.0	74.3	-47.6%	x		
80th St	EB	Delay	131.0	68.8	-47.5%	x		
80th St	WB	Delay	127.6	180.2	41.2%			x
France	NB	Delay	64.4	66.6	3.4%			x
France	SB	Delay	32.4	64.5	99.1%		x	
Penn	NB	Delay	62.0	113.6	83.2%		x	
Penn	SB	Delay	57.0	59.3	4.1%			x
Lyndale	NB	Delay	23.4	51.4	119.7%			x
Lyndale	SB	Delay	49.8	104.6	110.0%		x	
Nicollet	NB	Delay	16.4	58.8	258.5%		x	
Nicollet	SB	Delay	21.4	48.4	126.2%			x
Portland	NB	Delay	10.4	49.0	371.2%		x	
Portland	SB	Delay	10.6	25.4	139.6%		x	
12th Ave	NB	Delay	38.4	60.2	56.7%			x
12th Ave	SB	Delay	23.4	59.6	154.7%		x	
24th Ave	NB	Delay	38.6	64.4	66.8%			x
24th Ave	SB	Delay	26.2	20.8	-20.5%			x
76th St	EB	Speed	25.5	22.9	-10.4%		x	
76th St	WB	Speed	23.6	23.2	-1.8%			x
77th St	EB	Speed	30.8	31.9	3.4%			x
77th St	WB	Speed	26.7	24.7	-7.5%			x
79th St	EB	Speed	28.8	27.2	-5.6%			x
79th St	WB	Speed	26.9	27.7	3.1%			x
80th St	EB	Speed	25.0	27.5	10.0%			x
80th St	WB	Speed	25.4	23.6	-7.1%		x	
I-494**	EB	Speed	54.0	58.8	8.9%	x		
I-494**	WB	Speed	35.0	42.4	21.2%	x		
France	NB	Speed	30.1	29.8	-1.1%			x
France	SB	Speed	32.7	29.2	-10.7%		x	
Penn	NB	Speed	30.8	25.8	-16.3%		x	
Penn	SB	Speed	30.8	28.1	-8.8%			x
Lyndale	NB	Speed	30.1	26.3	-12.9%		x	
Lyndale	SB	Speed	29.2	24.7	-15.5%		x	
Nicollet	NB	Speed	33.2	28.8	-13.1%		x	
Nicollet	SB	Speed	31.8	29.7	-6.5%			x
Portland	NB	Speed	32.2	27.2	-15.5%		x	
Portland	SB	Speed	30.0	28.8	-4.1%			x
12th Ave	NB	Speed	25.3	25.3	0.0%			x

TRAVEL TIME RUNS (UNADJUSTED FOR FLOW CHANGES)								
1996 VS. 1999								
7:30 - 8:30 AM WEEKDAYS								
ROUTE	DIR	MOE	BEFORE	AFTER	% CHANGE	BETTER*	WORSE*	SAME
12th Ave	SB	Speed	26.7	24.8	-7.1%			x
24th Ave	NB	Speed	25.1	21.3	-15.0%			x
24th Ave	SB	Speed	25.4	24.3	-4.1%			x
76th St	EB	Stops	5.2	6.4	23.1%			x
76th St	WB	Stops	6.2	6.4	3.2%			x
77th St	EB	Stops	0.8	1.0	20.0%			x
77th St	WB	Stops	1.8	2.0	11.1%			x
79th St	EB	Stops	4.2	3.8	-8.7%			x
79th St	WB	Stops	4.2	4.4	4.8%			x
80th St	EB	Stops	6.4	4.2	-34.9%	x		
80th St	WB	Stops	6.2	6.8	9.7%			x
I-494**	EB	Stops	0.6	0.0	-100.0%			x
I-494**	WB	Stops	6.4	3.0	-53.1%			x
France	NB	Stops	2.4	2.2	-8.3%			x
France	SB	Stops	2.6	3.2	21.8%			x
Penn	NB	Stops	3.6	5.6	55.6%			x
Penn	SB	Stops	3.8	4.3	14.0%			x
Lyndale	NB	Stops	2.4	2.6	8.3%			x
Lyndale	SB	Stops	3.8	4.6	21.1%			x
Nicollet	NB	Stops	1.8	3.4	88.9%			x
Nicollet	SB	Stops	1.6	3.2	100.0%			x
Portland	NB	Stops	1.0	3.0	200.0%		x	
Portland	SB	Stops	2.4	3.2	33.3%			x
12th Ave	NB	Stops	4.6	3.5	-23.9%			x
12th Ave	SB	Stops	6.0	4.2	-30.0%	x		
24th Ave	NB	Stops	1.8	1.6	-11.1%			x
24th Ave	SB	Stops	1.2	0.8	-30.6%			x
76th St	EB	TT	8.2	9.6	16.2%		x	
76th St	WB	TT	8.1	9.3	15.6%		x	
77th St	EB	TT	3.1	3.0	-3.7%			x
77th St	WB	TT	3.6	4.3	20.3%		x	
79th St	EB	TT	6.4	6.9	7.5%			x
79th St	WB	TT	7.5	6.7	-10.4%			x
80th St	EB	TT	8.1	7.9	-2.1%			x
80th St	WB	TT	9.2	10.2	11.0%			x
I-494**	EB	TT	9.4	8.3	-12.4%			x
I-494**	WB	TT	16.9	13.2	-22.0%	x		
France	NB	TT	4.4	4.5	3.1%			x
France	SB	TT	4.0	4.7	17.3%			x
Penn	NB	TT	5.7	7.3	28.7%		x	
Penn	SB	TT	5.9	6.3	6.9%			x
Lyndale	NB	TT	4.3	5.2	20.8%		x	
Lyndale	SB	TT	4.8	6.4	33.5%		x	
Nicollet	NB	TT	4.5	5.9	31.7%		x	
Nicollet	SB	TT	4.7	5.7	22.0%		x	
Portland	NB	TT	4.0	4.9	23.8%		x	
Portland	SB	TT	4.2	4.6	10.4%			x
12th Ave	NB	TT	6.4	6.4	0.9%			x
12th Ave	SB	TT	6.1	6.6	8.3%			x
24th Ave	NB	TT	1.8	2.5	36.0%			x
24th Ave	SB	TT	2.0	2.0	-1.4%			x

* Denotes statistical significance at 90% confidence level
** Represents spring 1994 as "before" case

Travel time (TT) in minutes, stops in frequency, speed in miles per hour, and delay in seconds

TRAVEL TIME RUNS (UNADJUSTED AND BY STREET ORIENTATION & MOE)								
1996 VS. 1999								
7:30 - 8:30 AM WEEKDAYS								
STREET	MEASURE	BETTER	WORSE	SAME	TOTAL	BETTER	WORSE	SAME
Eastwest	TT	0	3	5	8	0%	38%	63%
Eastwest	Stops	1	0	7	8	13%	0%	88%
Eastwest	Speed	0	2	6	8	0%	25%	75%
Eastwest	Delay	2	3	3	8	25%	38%	38%
Northsouth	TT	0	6	8	14	0%	43%	57%
Northsouth	Stops	1	1	12	14	7%	7%	86%
Northsouth	Speed	0	6	8	14	0%	43%	57%
Northsouth	Delay	0	7	7	14	0%	50%	50%
I-494	TT	1	0	1	2	50%	0%	50%
I-494	Stops	0	0	2	2	0%	0%	100%
I-494	Speed	2	0	0	2	100%	0%	0%
Eastwest	Overall	3	8	21	32	9%	25%	66%
Northsouth	Overall	1	20	35	56	2%	36%	63%
I-494	Overall	3	0	3	6	50%	0%	50%
Corridor	Overall	7	28	59	94	7%	30%	63%

TRAVEL TIME RUNS (UNADJUSTED FOR FLOW CHANGES)								
1996 VS. 1999								
4:30-5:30 PM WEEKDAYS								
ROUTE	DIR	MOE	BEFORE	AFTER	% CHANGE	BETTER*	WORSE*	SAME
76th St	EB	Delay	173.0	176.6	2.1%			x
76th St	WB	Delay	111.8	131.0	17.2%			x
77th St	EB	Delay	40.0	15.4	-61.4%	x		
77th St	WB	Delay	54.6	66.8	22.3%			x
79th St	EB	Delay	68.8	130.6	89.8%		x	
79th St	WB	Delay	110.0	115.0	4.5%			x
80th St	EB	Delay	108.8	127.4	17.1%			x
80th St	WB	Delay	207.8	205.2	-1.3%			x
France	NB	Delay	54.0	132.6	145.6%		x	
France	SB	Delay	107.3	75.8	-29.3%			x
Penn	NB	Delay	139.8	147.6	5.6%			x
Penn	SB	Delay	55.8	38.6	-30.8%			x
Lyndale	NB	Delay	71.8	100.6	40.0%			x
Lyndale	SB	Delay	97.4	78.0	-19.9%			x
Nicollet	NB	Delay	43.8	42.4	-3.2%			x
Nicollet	SB	Delay	24.2	36.4	50.4%			x
Portland	NB	Delay	35.4	55.5	56.8%			x
Portland	SB	Delay	33.4	37.4	12.0%			x
12th Ave	NB	Delay	46.2	48.0	3.9%			x
12th Ave	SB	Delay	32.8	63.6	93.9%		x	
24th Ave	NB	Delay	22.6	83.0	267.3%		x	
24th Ave	SB	Delay	62.4	64.4	3.2%			x
76th St	EB	Speed	21.4	22.9	6.8%			x
76th St	WB	Speed	23.4	23.3	-0.5%			x
77th St	EB	Speed	26.9	28.6	6.2%			x
77th St	WB	Speed	24.7	27.1	9.4%			x
79th St	EB	Speed	28.2	25.1	-11.0%		x	
79th St	WB	Speed	25.5	26.7	4.9%			x
80th St	EB	Speed	23.0	24.7	7.8%			x
80th St	WB	Speed	23.3	23.9	2.5%			x
I-494**	EB	Speed	44.4	51.8	16.7%	x		
I-494**	WB	Speed	50.3	57.0	13.3%	x		
France	NB	Speed	33.6	23.4	-30.5%		x	
France	SB	Speed	29.0	29.1	0.1%			x
Penn	NB	Speed	23.6	24.4	3.4%			x
Penn	SB	Speed	29.0	26.8	-7.6%			x
Lyndale	NB	Speed	27.0	23.9	-11.5%		x	
Lyndale	SB	Speed	22.8	24.7	8.3%	x		
Nicollet	NB	Speed	29.9	30.2	0.9%			x
Nicollet	SB	Speed	30.6	29.0	-5.0%			x
Portland	NB	Speed	27.0	28.4	5.1%			x
Portland	SB	Speed	29.5	28.7	-2.7%			x
12th Ave	NB	Speed	25.5	25.4	-0.5%			x
12th Ave	SB	Speed	28.4	23.9	-15.9%		x	
24th Ave	NB	Speed	20.8	18.9	-9.0%			x
24th Ave	SB	Speed	22.2	21.4	-3.5%			x
76th St	EB	Stops	7.4	7.2	-2.7%			x
76th St	WB	Stops	4.2	5.8	38.1%			x
77th St	EB	Stops	1.8	1.3	-28.6%	x		
77th St	WB	Stops	2.0	1.4	-30.0%			x
79th St	EB	Stops	3.2	4.8	50.0%			x
79th St	WB	Stops	4.6	5.2	13.0%			x
80th St	EB	Stops	7.6	8.8	15.8%			x
80th St	WB	Stops	6.4	7.6	18.8%			x
I-494**	EB	Stops	0.8	1.6	100.0%			x

TRAVEL TIME RUNS (UNADJUSTED FOR FLOW CHANGES)								
1996 VS. 1999								
4:30-5:30 PM WEEKDAYS								
ROUTE	**DIR**	**MOE**	**BEFORE**	**AFTER**	**% CHANGE**	**BETTER***	**WORSE***	**SAME**
I-494**	WB	Stops	1.6	0.2	-87.5%	x		
France	NB	Stops	1.2	4.2	250.0%		x	
France	SB	Stops	2.8	2.2	-20.0%			x
Penn	NB	Stops	5.2	5.6	7.7%			x
Penn	SB	Stops	3.4	4.0	17.6%			x
Lyndale	NB	Stops	3.3	5.0	50.0%		x	
Lyndale	SB	Stops	5.8	4.6	-20.7%			x
Nicollet	NB	Stops	2.0	2.6	30.0%			x
Nicollet	SB	Stops	1.8	2.8	55.6%			x
Portland	NB	Stops	3.2	3.7	14.6%			x
Portland	SB	Stops	3.4	3.0	-11.8%			x
12th Ave	NB	Stops	5.8	3.8	-33.9%			x
12th Ave	SB	Stops	4.8	4.6	-4.2%			x
24th Ave	NB	Stops	1.8	2.2	22.2%			x
24th Ave	SB	Stops	2.2	2.0	-9.1%			x
76th St	EB	TT	10.7	10.5	-1.9%			x
76th St	WB	TT	8.5	9.0	5.7%			x
77th St	EB	TT	3.6	3.2	-10.0%			x
77th St	WB	TT	4.0	3.7	-7.3%			x
79th St	EB	TT	6.5	7.7	17.7%		x	
79th St	WB	TT	7.6	7.5	-1.2%			x
80th St	EB	TT	9.6	10.2	6.5%			x
80th St	WB	TT	10.7	11.0	2.6%			x
I-494**	EB	TT	11.7	10.4	-11.2%			x
I-494**	WB	TT	10.6	8.7	-18.2%	x		
France	NB	TT	4.0	6.2	54.6%		x	
France	SB	TT	5.6	5.0	-10.8%			x
Penn	NB	TT	8.0	8.1	1.8%			x
Penn	SB	TT	6.2	6.3	1.6%			x
Lyndale	NB	TT	5.7	6.3	11.3%			x
Lyndale	SB	TT	6.5	6.0	-8.0%			x
Nicollet	NB	TT	5.8	5.7	-2.1%			x
Nicollet	SB	TT	5.4	5.6	2.7%			x
Portland	NB	TT	6.1	6.0	-0.9%			x
Portland	SB	TT	5.9	5.7	-3.2%			x
12th Ave	NB	TT	6.6	6.5	-2.0%			x
12th Ave	SB	TT	5.8	6.9	17.6%		x	
24th Ave	NB	TT	1.8	2.7	53.8%		x	
24th Ave	SB	TT	2.7	2.7	1.4%			x

* Denotes statistical significance at 90% confidence level
** Represents spring 1994 as "before" case
Travel time (TT) in minutes, stops in frequency, speed in miles per hour, and delay in seconds

TRAVEL TIME RUNS (UNADJUSTED AND BY STREET ORIENTATION & MOE)								
1996 VS. 1999								
4:30-5:30 PM WEEKDAYS								
STREET	MEASURE	BETTER	WORSE	SAME	TOTAL	BETTER	WORSE	SAME
Eastwest	TT	0	1	7	8	0%	13%	88%
Eastwest	Stops	1	0	7	8	13%	0%	88%
Eastwest	Speed	0	1	7	8	0%	13%	88%
Eastwest	Delay	1	1	6	8	13%	13%	75%
Northsouth	TT	0	3	11	14	0%	21%	79%
Northsouth	Stops	0	2	12	14	0%	14%	86%
Northsouth	Speed	1	3	10	14	7%	21%	71%
Northsouth	Delay	0	3	11	14	0%	21%	79%
I-494	TT	1	0	1	2	50%	0%	50%
I-494	Stops	1	0	1	2	50%	0%	50%
I-494	Speed	2	0	0	2	100%	0%	0%
Eastwest	Overall	2	3	27	32	6%	9%	84%
Northsouth	Overall	1	11	44	56	2%	20%	79%
I-494	Overall	4	0	2	6	67%	0%	33%
Corridor	Overall	7	14	73	94	7%	15%	78%

TRAVEL TIME RUNS (UNADJUSTED FOR FLOW CHANGES)								
1996 VS. 1999								
10:30 AM - 1:30 PM WEEKDAYS								
ROUTE	DIR	MOE	BEFORE	AFTER	% CHANGE	BETTER*	WORSE*	SAME
76th St	EB	Delay	103.2	105.6	2.3%			x
76th St	WB	Delay	73.1	94.4	29.1%			x
77th St	EB	Delay	12.3	33.7	173.2%		x	
77th St	WB	Delay	29.6	42.6	43.9%			x
79th St	EB	Delay	12.3	33.7	173.2%		x	
79th St	WB	Delay	29.6	42.6	43.9%			x
80th St	EB	Delay	71.8	54.8	-23.7%			x
80th St	WB	Delay	131.0	148.2	13.1%			x
France	NB	Delay	74.3	77.8	4.7%			x
France	SB	Delay	58.0	57.6	-0.7%			x
Penn	NB	Delay	81.8	93.9	14.8%			x
Penn	SB	Delay	62.3	54.6	-12.4%			x
Lyndale	NB	Delay	78.1	57.6	-26.2%			x
Lyndale	SB	Delay	99.4	92.0	-7.4%			x
Nicollet	NB	Delay	40.6	48.4	19.2%			x
Nicollet	SB	Delay	15.7	20.3	29.3%			x
Portland	NB	Delay	15.1	64.3	325.8%		x	
Portland	SB	Delay	30.3	32.8	8.3%			x
12th Ave	NB	Delay	38.4	74.1	93.0%		x	
12th Ave	SB	Delay	35.7	55.0	54.1%		x	
24th Ave	NB	Delay	20.3	51.6	154.2%		x	
24th Ave	SB	Delay	23.1	17.3	-25.2%			x
76th St	EB	Speed	25.3	24.0	-5.2%			x
76th St	WB	Speed	24.4	24.6	0.6%			x
77th St	EB	Speed	30.1	29.8	-1.0%			x
77th St	WB	Speed	28.4	28.8	1.4%			x
79th St	EB	Speed	30.1	29.8	-1.0%			x
79th St	WB	Speed	28.4	28.8	1.4%			x
80th St	EB	Speed	26.0	26.8	3.4%			x
80th St	WB	Speed	25.2	24.3	-3.5%			x
I-494**	EB	Speed	58.4	63.7	9.2%	x		
I-494**	WB	Speed	59.3	63.6	7.3%	x		
France	NB	Speed	30.5	28.6	-6.2%			x
France	SB	Speed	34.4	32.1	-6.7%			x
Penn	NB	Speed	27.6	28.4	2.8%			x
Penn	SB	Speed	28.6	30.1	5.1%			x
Lyndale	NB	Speed	26.9	26.0	-3.5%			x
Lyndale	SB	Speed	25.3	25.6	1.4%			x
Nicollet	NB	Speed	28.9	29.6	2.5%			x
Nicollet	SB	Speed	32.1	30.8	-4.1%			x
Portland	NB	Speed	28.2	27.6	-2.3%			x
Portland	SB	Speed	30.9	30.8	-0.3%			x
12th Ave	NB	Speed	26.0	23.3	-10.6%		x	
12th Ave	SB	Speed	24.0	21.7	-9.5%		x	
24th Ave	NB	Speed	27.3	18.9	-30.7%		x	
24th Ave	SB	Speed	24.1	24.5	1.8%			x
76th St	EB	Stops	4.5	5.7	26.7%		x	
76th St	WB	Stops	4.6	5.3	15.2%			x
77th St	EB	Stops	1.6	1.5	-3.6%			x
77th St	WB	Stops	1.6	1.6	0.0%			x
79th St	EB	Stops	1.6	1.5	-3.6%			x
79th St	WB	Stops	1.6	1.6	0.0%			x
80th St	EB	Stops	5.9	5.2	-11.9%			x
80th St	WB	Stops	6.5	6.5	0.0%			x
I-494**	EB	Stops	0.0	0.0	0.0%			x

TRAVEL TIME RUNS (UNADJUSTED FOR FLOW CHANGES)								
1996 VS. 1999								
10:30 AM - 1:30 PM WEEKDAYS								
ROUTE	DIR	MOE	BEFORE	AFTER	% CHANGE	BETTER*	WORSE*	SAME
I-494**	WB	Stops	0.0	0.0	0.0%			x
France	NB	Stops	2.2	2.8	27.3%			x
France	SB	Stops	2.1	2.3	9.5%			x
Penn	NB	Stops	3.8	4.2	10.5%			x
Penn	SB	Stops	4.5	3.8	-15.6%			x
Lyndale	NB	Stops	4.9	3.1	-36.7%	x		
Lyndale	SB	Stops	4.8	4.4	-9.1%			x
Nicollet	NB	Stops	2.5	3.3	32.0%			x
Nicollet	SB	Stops	1.5	2.4	60.0%		x	
Portland	NB	Stops	3.0	3.8	26.7%			x
Portland	SB	Stops	2.7	2.3	-14.8%			x
12th Ave	NB	Stops	4.8	5.4	12.5%			x
12th Ave	SB	Stops	5.1	4.2	-17.6%			x
24th Ave	NB	Stops	1.2	2.4	100.0%		x	
24th Ave	SB	Stops	1.5	1.5	0.0%			x
76th St	EB	TT	8.4	8.9	5.0%			x
76th St	WB	TT	7.8	8.5	8.0%		x	
77th St	EB	TT	3.1	3.3	7.6%			x
77th St	WB	TT	3.4	3.4	-0.2%			x
79th St	EB	TT	3.1	3.3	7.6%			x
79th St	WB	TT	3.4	3.4	-0.2%			x
80th St	EB	TT	8.1	8.0	-1.9%			x
80th St	WB	TT	9.2	9.9	7.5%			x
I-494**	EB	TT	8.2	7.5	-8.3%	x		
I-494**	WB	TT	8.0	7.5	-6.8%		x	
France	NB	TT	4.5	4.8	6.3%			x
France	SB	TT	4.2	4.3	3.6%			x
Penn	NB	TT	6.4	6.8	6.0%			x
Penn	SB	TT	6.4	6.1	-3.9%			x
Lyndale	NB	TT	5.8	5.3	-8.9%			x
Lyndale	SB	TT	6.2	6.0	-2.7%			x
Nicollet	NB	TT	5.8	5.8	-0.5%			x
Nicollet	SB	TT	5.1	5.2	3.4%			x
Portland	NB	TT	5.9	6.3	5.9%			x
Portland	SB	TT	5.6	5.4	-3.9%			x
12th Ave	NB	TT	6.2	7.0	11.9%		x	
12th Ave	SB	TT	4.6	5.0	6.8%			x
24th Ave	NB	TT	1.4	2.2	60.6%		x	
24th Ave	SB	TT	1.5	1.4	-4.0%			x

* Denotes statistical significance at 90% confidence level
** Represents spring 1994 as "before" case
Travel time (TT) in minutes, stops in frequency, speed in miles per hour, and delay in seconds

TRAVEL TIME RUNS (UNADJUSTED AND BY STREET ORIENTATION & MOE)								
1996 VS. 1999								
10:30 AM - 1:30 PM WEEKDAYS								
STREET	MEASURE	BETTER	WORSE	SAME	TOTAL	BETTER	WORSE	SAME
Eastwest	TT	0	1	7	8	0%	13%	88%
Eastwest	Stops	0	1	7	8	0%	13%	88%
Eastwest	Speed	0	0	8	8	0%	0%	100%
Eastwest	Delay	0	2	6	8	0%	25%	75%
Northsouth	TT	0	2	12	14	0%	14%	86%
Northsouth	Stops	1	2	11	14	7%	14%	79%
Northsouth	Speed	0	3	11	14	0%	21%	79%
Northsouth	Delay	0	4	10	14	0%	29%	71%
I-494	TT	1	1	0	2	50%	50%	0%
I-494	Stops	0	0	2	2	0%	0%	100%
I-494	Speed	2	0	0	2	100%	0%	0%
Eastwest	Overall	0	4	28	32	0%	13%	88%
Northsouth	Overall	1	11	44	56	2%	20%	79%
I-494	Overall	3	1	2	6	50%	17%	33%
Corridor	Overall	4	16	74	94	4%	17%	79%

TRAVEL TIME RUNS (UNADJUSTED FOR FLOW CHANGES)								
1996 VS. 1999								
10:30 AM - 1:30 PM SATURDAY								
ROUTE	**DIR**	**MOE**	**BEFORE**	**AFTER**	**% CHANGE**	**BETTER***	**WORSE***	**SAME**
76th St	EB	Delay	122.0	124.3	1.9%			x
76th St	WB	Delay	71.8	117.7	63.8%		x	
77th St	EB	Delay	19.7	38.8	97.5%			x
77th St	WB	Delay	39.7	84.0	111.8%		x	
79th St	EB	Delay	89.8	109.8	22.3%			x
79th St	WB	Delay	90.8	85.8	-5.5%			x
80th St	EB	Delay	68.8	70.3	2.2%			x
80th St	WB	Delay	96.0	129.0	34.4%			x
France	NB	Delay	54.5	46.0	-15.6%			x
France	SB	Delay	70.5	44.0	-37.6%			x
Penn	NB	Delay	65.0	122.8	89.0%		x	
Penn	SB	Delay	85.3	64.5	-24.4%			x
Lyndale	NB	Delay	62.5	70.3	12.5%			x
Lyndale	SB	Delay	127.0	101.3	-20.2%			x
Nicollet	NB	Delay	37.5	60.7	61.8%			x
Nicollet	SB	Delay	30.5	34.7	13.7%			x
Portland	NB	Delay	32.8	40.8	24.4%			x
Portland	SB	Delay	20.5	37.5	82.9%			x
12th Ave	NB	Delay	56.4	70.3	24.7%			x
12th Ave	SB	Delay	30.5	47.5	55.7%		x	
24th Ave	NB	Delay	22.2	42.3	90.5%			x
24th Ave	SB	Delay	58.8	49.1	-16.5%			x
76th St	EB	Speed	24.9	25.1	0.9%			x
76th St	WB	Speed	24.9	25.6	3.1%			x
77th St	EB	Speed	28.1	27.9	-0.4%			x
77th St	WB	Speed	26.7	23.2	-13.1%		x	
79th St	EB	Speed	28.8	28.5	-1.2%			x
79th St	WB	Speed	27.5	28.4	3.2%			x
80th St	EB	Speed	25.6	26.1	1.9%			x
80th St	WB	Speed	25.2	24.4	-3.2%			x
I-494**	EB	Speed	58.8	62.9	7.0%	x		
I-494**	WB	Speed	60.3	61.8	2.6%	x		
France	NB	Speed	29.5	29.7	1.0%			x
France	SB	Speed	31.0	26.5	-14.7%		x	
Penn	NB	Speed	28.9	27.7	-4.0%			x
Penn	SB	Speed	29.8	30.1	1.2%			x
Lyndale	NB	Speed	25.9	27.0	4.2%			x
Lyndale	SB	Speed	22.3	25.4	13.9%	x		
Nicollet	NB	Speed	29.0	29.4	1.4%			x
Nicollet	SB	Speed	29.4	30.3	3.1%			x
Portland	NB	Speed	28.0	28.7	2.6%			x
Portland	SB	Speed	30.6	30.6	0.0%			x
12th Ave	NB	Speed	25.3	23.4	-7.6%			x
12th Ave	SB	Speed	27.3	25.2	-7.4%		x	
24th Ave	NB	Speed	29.0	20.8	-28.2%		x	
24th Ave	SB	Speed	20.2	24.4	20.5%	x		
76th St	EB	Stops	4.7	5.2	10.7%			x
76th St	WB	Stops	5.0	4.8	-3.3%			x
77th St	EB	Stops	1.8	2.0	9.1%			x
77th St	WB	Stops	1.8	2.3	27.3%		x	
79th St	EB	Stops	4.2	4.3	4.0%			x
79th St	WB	Stops	4.7	4.8	3.6%			x
80th St	EB	Stops	6.2	5.0	-18.9%			x
80th St	WB	Stops	5.2	6.7	29.0%		x	

TRAVEL TIME RUNS (UNADJUSTED FOR FLOW CHANGES)								
1996 VS. 1999								
10:30 AM - 1:30 PM SATURDAY								
ROUTE	DIR	MOE	BEFORE	AFTER	% CHANGE	BETTER*	WORSE*	SAME
I-494**	EB	Stops	0.0	0.0	0.0%			x
I-494**	WB	Stops	0.0	0.0	0.0%			x
France	NB	Stops	2.3	2.2	-7.1%			x
France	SB	Stops	2.5	3.0	20.0%			x
Penn	NB	Stops	3.3	4.7	40.0%		x	
Penn	SB	Stops	4.2	3.7	-12.0%			x
Lyndale	NB	Stops	4.7	3.7	-21.4%			x
Lyndale	SB	Stops	5.5	4.7	-15.2%			x
Nicollet	NB	Stops	2.5	3.3	33.3%			x
Nicollet	SB	Stops	2.2	3.7	69.2%			x
Portland	NB	Stops	2.5	2.8	13.3%			x
Portland	SB	Stops	2.7	3.3	25.0%			x
12th Ave	NB	Stops	3.8	4.3	14.0%			x
12th Ave	SB	Stops	3.7	4.5	22.7%			x
24th Ave	NB	Stops	1.2	2.0	66.7%			x
24th Ave	SB	Stops	2.8	1.4	-50.9%	x		
76th St	EB	TT	9.2	8.8	-3.9%			x
76th St	WB	TT	7.7	8.5	9.7%			x
77th St	EB	TT	3.4	3.5	2.1%			x
77th St	WB	TT	3.6	4.3	20.8%		x	
79th St	EB	TT	6.6	6.8	3.9%			x
79th St	WB	TT	6.7	6.7	0.7%			x
80th St	EB	TT	8.2	8.3	1.4%			x
80th St	WB	TT	8.7	9.6	10.1%			x
I-494**	EB	TT	8.1	7.6	-6.1%	x		
I-494**	WB	TT	7.9	7.7	-2.3%	x		
France	NB	TT	4.2	4.2	-1.2%			x
France	SB	TT	4.5	4.5	1.7%			x
Penn	NB	TT	6.0	7.3	22.1%		x	
Penn	SB	TT	6.5	6.4	-1.5%			x
Lyndale	NB	TT	5.7	5.4	-3.7%			x
Lyndale	SB	TT	6.8	6.1	-9.4%			x
Nicollet	NB	TT	6.0	5.9	-0.3%			x
Nicollet	SB	TT	5.6	5.6	0.2%			x
Portland	NB	TT	5.8	5.8	-1.4%			x
Portland	SB	TT	5.4	5.4	0.6%			x
12th Ave	NB	TT	6.7	6.7	0.4%			x
12th Ave	SB	TT	5.9	6.3	5.6%		x	
24th Ave	NB	TT	1.4	2.0	46.0%			x
24th Ave	SB	TT	2.7	2.4	-11.2%			x

* Denotes statistical significance at 90% confidence level
** Represents spring 1994 as "before" case
Travel time (TT) in minutes, stops in frequency, speed in miles per hour, and delay in seconds

TRAVEL TIME RUNS (UNADJUSTED AND BY STREET ORIENTATION & MOE)								
1996 VS. 1999								
10:30 AM - 1:30 PM SATURDAY								
STREET	MEASURE	BETTER	WORSE	SAME	TOTAL	BETTER	WORSE	SAME
Eastwest	TT	0	1	7	8	0%	13%	88%
Eastwest	Stops	0	2	6	8	0%	25%	75%
Eastwest	Speed	0	1	7	8	0%	13%	88%
Eastwest	Delay	0	2	6	8	0%	25%	75%
Northsouth	TT	0	2	12	14	0%	14%	86%
Northsouth	Stops	1	1	12	14	7%	7%	86%
Northsouth	Speed	2	3	9	14	14%	21%	64%
Northsouth	Delay	0	2	12	14	0%	14%	86%
I-494	TT	2	0	0	2	100%	0%	0%
I-494	Stops	0	0	2	2	0%	0%	100%
I-494	Speed	2	0	0	2	100%	0%	0%
Eastwest	Overall	0	6	26	32	0%	19%	81%
Northsouth	Overall	3	8	45	56	5%	14%	80%
I-494	Overall	4	0	2	6	67%	0%	33%
Corridor	Overall	7	14	73	94	7%	15%	78%

APPENDIX C—GLOSSARY

CCTV	Closed Circuit Television
FHWA	Federal Highway Administration
FOT	Field Operational Test
ICTM	Integrated Corridor Traffic Management
ITS	Intelligent Transportation Systems
Mn/DOT	Minnesota Department of Transportation
MOE	Measurement of Effectiveness
PS&E	Plans, Specifications & Services
SCATS	Sydney Coordinated Adaptive Traffic System
TCMA	Twin Cities Metropolitan Area
TMC	Traffic Management Center
UL	Underwriters Laboratories
VMS	Variable Message Signs