I-90 GATE OPERATIONS SYSTEM

RESEARCH REPORT

I-90 & US 71 at Jackson, Minnesota

Prepared for

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July 31, 2001

Prepared for Minnesota Department of Transportation
Office of Advanced Transportation Systems

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Table of Contents

EXECUTIVE SUMMARY – page 3

INTRODUCTION – page 4

1. EXAMINATION OF RESEARCH ON GATE SYSTEMS BY OTHER STATES – page 5

2. INVESTIGATION OF AVAILABLE TECHNOLOGIES FOR GATE OPERATIONS – page 12

- Conventional Barrier Arm
- No gate – Use series of warning signs
- Virtual gate: light/laser, inflatable, and others

3. DETECTION AND RECORDING OF MOTORISTS THAT IGNORE BARRIERS –page 18

4. COMMUNICATIONS SYSTEMS COMPARISON – page 22

5. RECOMMENDED METHOD & ALTERNATIVE METHOD FOR DEPLOYMENT – page 25

6. MANUFACTURERS WARRANTY INFORMATION – page 34

ATTACHMENTS:

Attachment A. Montana Road Closure Gate Plans

Attachment B. Wyoming Road Closure Gate FHWA Approval Letter

Attachment C. Wyoming Road Closure Gate, Transportation Research Record 1528

Attachment D. WAECorp. Summary of Jackson Wyoming System

Attachment E. B & B Gate FHWA Approval Letter

Attachment F. Loop Detector Data On HOV Ramp At Snelling Ave. & I-94, St. Paul

Attachment G. Wyoming Gate Design (has not arrived)

Attachment H. I-90 Gate Manual (view at www.state.mn.us/guidestar/projects.html

Attachment I. I-90 & I-94 Gate study (view at www.state.mn.us/guidestar/projects.html

EXECUTIVE SUMMARY

A. The purpose of this report is to document the results and recommendations of research conducted by ThomTech Design in developing a freeway management system at the 1-90 and US 71 interchange at Jackson, Minnesota. Currently there is a manually operated gate system in place at the interchange and it is desired to install an automated system, using ITS techniques, that can be managed from the Windom office of Mn/DOT about 18 miles north.

B. Research was conducted in six areas including:

1. Examine research conducted by other states regarding winter highway gate operations;
2. Investigate available technologies for gate operations;
3. Different methods of detecting and recording gate violations;
4. A comparison of communications systems to monitor, detect, and control systems;
5. Recommend methods and alternatives of I-90 solutions;
6. Provide manufacturers warranty information.

C. Recommendations are provided for the three major subsystems:

1. Gate subsystem – combination hard and soft closure system
2. Detection subsystem – autoscope solo pro configuration
3. Communications subsystem – wireless internet access connectivity

D. Ten documents pertaining to related studies were obtained, reviewed, and researched for ideas, supporting data, and deployment options. Nine states were contacted, inmost cases more than one point of contact was questioned about similar or related systems in this area. A list of ten basic questions with several follow-up questions were prepared and used as a format for the state representative's responses. Twenty two equipment manufacturers were contacted for designs, drawings, configurations, capabilities, and cost versus performance information. Additionally assistance was provided by the University of Minnesota and University of Chicago.

E. A comprehensive summary of the existing projects as well as the state transportation representative response is presented in a three page table. The report is 35 pages with an additional section of nine attachments that provide drawings, photos, test data, and brochures.

F. The objective of this document is to provide background information and a framework for discussion in selecting an appropriate course of action. Examples of these issues are provided below:

- Hard versus soft closure, that is, a physical blockage (barrier arm) or a virtual gate (sign)
- FHWA approved equipment, fielding an innovative system may involve equipment not yet approved, tested, or evaluated for road usage.
- Communications path, access to intersection information and control, internet or intranet.
- Considerations regarding scalability, video throughput, motorist warnings, and violations.

INTRODUCTION

The purpose of this report is to document the results and recommendations of research conducted by ThomTech Design in developing a freeway management system at the 1-90 and US 71 interchange at Jackson, Minnesota. Currently there is a manually operated gate system in place at the interchange and it is desired to install an automated system, using ITS techniques, that can be managed from the Windom office of Mn/DOT about 18 miles north.

The State of Minnesota's contract with ThomTech Design Inc. for the I-90 and US 71 interchange project includes "*seeking new and innovative partnership arrangements between State and the private sector to meet the needs of controlling traffic through the use of gates. It is the goal of this project to test different technologies, communications, and public/private operational and maintenance partnering scenarios to develop the optimal freeway management system for I-90 at the interchange of I-90 and US 71 just north of Jackson, Minnesota.*"

Research was conducted in six areas including:

- Examine research conducted by other states regarding winter highway gate operations;
- Investigate available technologies for gate operations;
- Different methods of detecting and recording gate violations;
- A comparison of communications systems to monitor, detect, and control systems;
- Recommend methods and alternatives of I-90 solutions;
- Provide manufacturers warranty information.

To begin the research a questionnaire was prepared and a phone survey was conducted with appropriate transportation persons in Minnesota, N. Dakota, S. Dakota, Iowa, Idaho, Illinois, Montana, Nebraska, New Mexico, Washington, and Wyoming. The results of the questionnaire are summarized in the chart labeled Summary of State DOT Contacts. A library and Internet search for additional research information was conducted. Other persons having an interest in the project were contacted for input and the I-90/US71 interchange was revisited. Manufacturers of various gate and sign systems were contacted for comments and input and a member of the team attended the International Municipal Signal Association 106th annual conference. Several communications service providers were contacted and two wireless radio manufacturers were contacted.

During the information gathering, a large number of issues surfaced, such as what local services are available at selected interchanges, if a road is closed. These are important factors that will influence the final project determinations. Some, but not all of these issues were addressed in the report. In conducting the research, it was evident that this topic has generated a significant amount of interest, by other states, in the project and it's results. Several of the respondents requested copies of the research. As a result of this interest, the determinations made in this project will play a significant role in similar projects in Minnesota and other states.

1. EXAMINATION OF RESEARCH ON GATE SYSTEMS BY OTHER STATES

Mn/DOT staff provided ThomTech Design Inc. copies of research documents collected on gate systems in other states. Included were the following documents:

- Mn/DOT Research on Road Closure Issues for Winter Blizzards, Sept 1997 – George Welk
- Mn/DOT Documentation and Assessment of Mn/DOT Gate Operations report prepared October, 1999 by BRW Inc. – www.dot.state.mn.us/guidestar/pdf/gatereport.pdf
- South Dakota DOT, School of Mines and Technology report on Automated Road Closure Gate study SD2000-11, May 2000 – www.state.sd.us/dot/pe/research/projects/SD00-11final.pdf
- Avalanche Hazard Reduction for Transportation Corridors Using Real-time Detection and Alarms, Robert Rice Jr. etal.
- Road Management and Engineering Journal, March 1, 1997 Article Wyoming Adopts New Breakaway Gate for Winter Weather Road Closures
- Mn/DOT, I-90 GATE CLOSURE MANUAL for Districts 6B, 7A, and 7B which spells out the process for operation of the gates on I-90

Jerry Baldwin (651) 297-4532, at Mn/DOT's Library, was contacted and he conducted a national library search of gate documentation for the project. One additional research document on gate systems or virtual signs was found, that is:

- Wyoming Road Closure Gate, report in the Transportation Research Record 1528, by King Mak, Roger Bligh, & William Wilson.

The Wyoming Department of Transportation provided a copy of the test they had conducted by the Texas Transportation Institute, The Texas A & M University System, College Station, Texas:

> Testing and Evaluation of Wyoming Road Closure Gate, Sponsored by: Wyoming Department of Transportation, January 1997

The TRB, TRIS site lists an additional research project that is underway in Wyoming to automate the avalanche warning lights and road closure gates on the west side of Teton Pass. The contact is Wyoming DOT, District 3 Maintenance Engineer, Ted Wells at (307 352-3600. Mr. Wells was interviewed in the process of contacting state agencies and his comments are incorporated in the Summary of State DOT Contacts chart. The associated document title is included below.

- Automation of the West Teton Pass Lights and Closure Gate, Wyoming DOT, Ted Wells.

Idaho Assistant Maintenance Engineer, Byron Breen (208) 334-8417 provided a copy of the Idaho storm warning test documentation.

- Idaho Storm Warning System Operational Test, prepared by the National Institute for Advanced Transportation Technology at University of Idaho

Dean Larson has been looking at gate systems for several years, including checking for articles in national, international, state, and federal magazines and reports. He is not aware of any additional documentation or articles. ThomTech Design conducted a search on the World Wide Web for articles or research on gate systems. No documents that contributed to this project were found.

To research what other states were doing a questionnaire was prepared for use in calling the states. The questionnaire included the following ten questions:

1. What kind of gate systems are you using and how many do you have?
2. Are any of these automated or of special design with communications or sensors?
3. How were they obtained, commercially, from maintenance design and installation?
4. Have you done any research on gates, or your systems?
5. How do your gates interface with RWIS, advance dynamic message signs, radio etc.?
6. Opinions on their use?
7. In retrospect, would you do something different and other comments?
8. Where do you see freeway closure systems going in the future?
9. Other contacts we should make?
10. We are planning a field review of gate systems, who should we contact?

Contact was made with eleven state maintenance engineers and or other knowledgeable contact persons. Each contact was asked the above questions, and follow-up questions, as appropriate. Responses were recorded and are tabulated in the chart labeled Summary of State DOT Contacts.

The respondents were generally very interested in the Minnesota I-90 project at Jackson and some requested requested to be placed on the distribution list for project results. In several cases the contacts stated they were waiting for the "Minnesota project" before they proceeded with their programs. No significant additional research projects or documentation was found from the states contacted.

Wyoming with 283 manual gates, TTI testing of their gate, and FHWA approval of their gate is the clear state leader in gate systems. Judges there require a physical barrier to traffic. They are in the process of automating some of their gates, but would not release plans yet.

Montana had prepared plans sheets for a Road Closure Gate, Mark Baum (406) 444-7628 supplied a copy. The Montana design are shown in Section 2, Conventional Barrier Arm.

The following state contacts were made and their responses have been tabulated in the Summary of State DOT Contacts:

Idaho – Byron Breen, Assistant Maintenance engineer (203) 334-8417
Iowa – Dennis Burkheimer (515) 239-1355
Illinois – Ken Jonack, ITS on Kennedy Expressway, (847) 705-4140
Minnesota – George Welk, Windom – 7B (507) 831-1201, Mark Wikelius (651) 297-3590, Mark Flygare, (507) 389-6874, Jan Foules (218) 847-1540, Dennis Redding (218) 847-1575

Montana – John Blacker, State Maintenance Engineer (406) 444-6158, & Mark Baum, State Construction Engineer (406) 444-7628
New Mexico –Terrance Doyle, ITS Engineer District 3, (505) 841-4891 referred me to Leonard Rivera, (505) 896-8773 who was with Dist 3, now City of Rio Rancho.
Nebraska – Larry Fisher, District maintenance, (308) 262-1920
North Dakota – Jerome Horner, State Maintenance Engineer, Bismarck (701) 328-6900
South Dakota – John Forman, State Maintenance Engineer, Pierre (605) 773-5155

Wyoming – Ted Wells, District 3 Maintenance Engineer, Rock Springs (307) 352-3032, Bill Wilson, State Construction engineer, (307) 777-4216, Joel Meena, Asst. State Traffic Engineer, (307) 777-4374, Michael J. Patritch, Research Coordinator (307) 777-4182
Washington – Terry Kukes, District maintenance, (509) 577-1907

In addition to the contacts made in other states the following contacts were made:

District 7 ITS project, Design Work Team, Brian Scott from SRF and Janelle Monette from ADDCO Inc. were contacted, but the State contract is not yet underway and they were unable to provide details at this time. As soon as the Design Work Team is formed, it will be important for both team leaders to coordinate efforts.

AURORA Program, National Director Curt Pape, Mn/DOT at (651) 297-1798 was contacted for research, other appropriate documentation and comments. www.aurora-program.org. The Aurora program is contemplating using highway gates.

Mike Weiss, P.E., Mn/DOT State Signing Engineer, (651) 284-3440. Mike had no specific research, however he provided important suggestions on signing. The updated MUTCD, just now being published, will probably not be adopted by Mn/DOT for another year since some of our rules are more restrictive. In absence of gates, people ignore signs (not documented). Mike also suggested we look at blank-out signs which could be placed on the I-90 directional signs along US 71. He also suggested we look at using attention getting devices on the road closed signs on I-90 since these can become hard to see during severe storms.

Marcus Flygare, PE, Mn/DOT Dist 7 Traffic Engineer, (507) 389- 6874. He did not know of additional research materials. He stated that, on road closures, complete closures are hard to do. There may be reasons for less than total closure, he thought that this issue could use additional discussion as part of the final decision process.

The International Municipal Signal Association held its 106th Annual Conference and 24th Annual School at the Radisson in St. Paul, July 23 – 26. Dean Larson attended the conference including the exhibits and a session titled “Alternative Detection Systems”. Exhibitors from most of the major traffic control manufacturers were there and he questioned them on gates, gate research, signing, and detection systems. A significant amount of literature was collected and is included in the project file. www.imsasafety.org.

David Kopacz, FHWA Safety & Traffic Operations Engineer (651) 291-6126 recommends that any system implemented for this project needs to meet NCHRP Report 350 requirements for crashworthiness.

Andy Halvorson, Mn/DOT Assistant Design Standards Engineer, (651) 296-3032 Andy serves as the Mn/DOT technical advisor to the Midwest States Pooled Fund Study which conducts crash testing of roadside objects. Andy estimates that a crash test for a gate would cost in the neighborhood of $25,000 to $30,000. He was instrumental in obtaining FHWA approval of the swing gates used in District 4

Major Mike Astleson, State Patrol (651) 297-2306. His comments are included in Section 3 of this report in the enforcement section.

Kevin Schwartz, P.E., Mn/DOT HOV Operations Engineer (651) 582-1278. He discussed the "virtual gate" at I-94 and Snelling, the HOV "on" ramp. This ramp originally had a gate arm, along with the lights and signs, but Mn/DOT felt the maintenance didn't warrant keeping the gate operational and the arm was removed. Mr. Schwartz provided data on violations of the closed ramp for the week of May 13 – 19 and the gate is further discussed in Section 2 of this document.

Vehicle Detector Clearinghouse, New Mexico State University, John Hamrick (208) 342-2983. This is a state pooled-fund project to provide information to transportation agencies on commercially available vehicle detectors, including testing. Details on this report are included in Section 3 of this report. www.nmsu.edu/~traffic

There is a 300 foot antenna tower about 1 mile south of the intersection. The City of Jackson owns the tower. The point of contact is Dean Albrecht, 507 847-4410. He states that it is a policy of the city council not to rent space for antennas, however, the policy is somewhat dated and if the state approached them, the city council may reconsider.

In addition the following equipment manufacturers contacted for information: (In Process)
Hy-Security Gate Systems – (South Dakota recommended Purchase of Commercially Made Automated Road Closure Gate) www.hysecurity.com
Jordan Controls – Manufactured S. Dakota Liner Actuator www.jordancontrols.com
Safetran – Manufactured So. Dakota Gate arm www.safetran.com
ADDCO – DMS www.addcoinc.com
3M – DMS Julie Burke (651) 733-1411
Winter/Alpine Engineering Corp. (WAECorp) Salt Lake City, UT 84103 (801) 585-7787
Bob Rice, Steve Putnam (801) 521-6438, Dr. Rand Decker (801) 581-5477
Traffic Technologies, Todd Foster, P.E. (612) 521-2111 ext 204, LLC, Colorado Springs, Jim Fanning (719) 532-1688, makers of sound detection systems.
B&B - Gates and Barriers (800) 367-0387
Roadway Manufacturing Co - Gates (256) 332-2060
Eagle Traffic Controls - Traffic products including gates (512) 837-8371
Quantum-lite - signs (305) 887-9526
CLARY Continous Power - Uninterruptible Power Systems (612) 521-2122
Peek Traffic Systems
Brown Traffic Products Inc.
deMco Technologies - Blank out signs (219) 670-6774
nu-metrics - Detectors (724) 438-8750
Millerbernd - Steel Poles for lighting (320) 485-2111

Summary of State DOT Contacts

Location	Number of Gates/ Number Auto-mated	Automated Type, Manuf-acturer	Commun-ications	Interface Advance warning, RWIS, or other	Research Efforts	Future Plans	Other Comments
Idaho	? None	None	None	None	Preliminary on State 21 conducted by University of Utah, Ron Decker. Did test of visibility sensors, will send copy of report	Did some trial work in avalanche area. If avalanche system works it would be applicable to other areas.	Would like to feed into the gates in future. We have situations in a number of areas and are looking for solutions.
Illinois	Kennedy Express-way I-90 & 94. 60 gates All auto	Aluminum Swing gates with 4' rubber tip to prevent car damage	Yes to TOCC 20 miles	Yes, also flashers	Had a consultant research Seattle, Texas and other locations to look at their systems.	Would go to fiber optic signs instead of drums. Are building a automatic swing gate on a ramp to control congestion on I-290	Reversible lane gates angle 45, 60, 70 and 90 deg from barrier wall. Gates are recessed in wall and trip if hit. Also have a dragnet barrier beyond gates. Work good, can be hand set.
Iowa	46 None	Farm gates	None	None	Researched what other states are doing. Very little information.	Can see real advantages. Have a location between Mason City and Ames where visibility is a problem and would like to automate.	Problem is can the public see gates. It's hard to make a decision to close and notify everybody up and down road. Must alert media and rest areas.
Minnesota	65 None	None	None	None	Researched Road Closure Issues for Winter Blizzards 9-97. Also, Documentation & Assessment of MN Gate Operations 10-99.	Automate DMS along 1-90 as part of ADDCO project. Swing gates were first generation, now trying 2nd generation, 3rd generation might be holograms.	Automated gate project and test is under contract on I-90 at Jackson MN. Its tough to have gates at different interchanges closed in a coordinated manner.
Montana	4 None	None	Gates have flashing lights, no electronics	Have lots of VMS, but no interface	Like the Wyoming gate.	In the process of upgrading to electronic type of gate that will be operated locally.	Automated gates are a construction project, contact them.

Nebraska	? None	Some DOT made, some manufactured	Some gates have flashing lights no comms.	Have advance warning, not interfaced	Looked at different types of gate, Wyoming's and Kansas. Ours were crash tested and approved.	We will make progress with better gates and even automated systems. They are worthwhile to put up.	They are a big help to field people. No problems, but weather is not your friend when you need to close them.
New Mexico	Dist 3 – 10 None	None	None	Future	Dist 3, ten gates is a research, evaluation project. Not yet installed. Decided to use manual gates at this time.	The current project is for evaluation. On I-10 they want to put up automated gates for sand storms. Also want to do some on I-25 at Raton Pass next year.	Trying to incorporate ITS features on the gate. Basic design is Wyoming, with some modified features and use of advance warning signs.
N. Dakota	30-35 None	None	None	None Patrol notifies media	Looking at Wyoming gate system and like it.	Working with ITS for a TOCC in Fargo and could include automated gates, 3-5 years.	Do not fully close the road. Redoing I-29 and may go to automated gates in the contract.
S. Dakota	About 6 None	None	None	None	Did a study of automated gate system but it was not installed on road. SD 2000-11 Developing a new research project.	Going to add some message boards late this summer and will tie into gates to say road closed.	Kind of waiting on Minnesota on 1-90. Looking at Wyoming gate. Had a meeting a month ago.
Wyoming	283 1 test automated 2 Auto avalanche warning	WAECorp?	Avalanche sensor to advance warning sign	Yes, turns on advance warning sign	An evaluation of the Wyoming road closure gate was conducted by TTI in 1997. Gate has FHWA approval. (Copy in project file.) Patrol and maintenance agree with hard closure, but on lower volume roads we have road closed when flashing signs.	Our gates use a hand crank. We are in the process of contracting to automate some of our gates using a DC wench. Need to improve battery backup system capabilities. Detectors for people who circumvent the system.	Having a lot of calls about our gate system, and don't want to give plans out now. Avalanche sensor turns on flashing lights on advanced warning signs saying ROAD CLOSED WHEN FLASHING AVALANCHE State has a law that supports this.
Washington	? Some barrels None on mainline	None	None	Use VMS, not linked and Variable Speed Limits	Visited Donner pass to see what they are doing	Looking at changing for this winter, trying to come up with a gate or other metering device so can limit the number of vehicles in the pass	Gates are manual made in the early 80's. Are interested in contracting with a private company to help install and manage chain-up areas.

2. INVESTIGATION OF AVAILABLE TECHNOLOGIES FOR GATE OPERATIONS

Conventional Barrier Arm –The following manufacturers provide gates, barriers and other road closure systems. Literature packages from the manufacturers are included in the project file. In addition to the gate manufacturers, the states of Wyoming and Montana supplied copies of their gate designs.

Roadway Manufacturing – Gates

B&B – Gates & Barriers

SAFETRAN Systems – Gates, railroad types

Hy-Security Gate & Barriers

Winter/Alpine Engineering Corp – Gates closure automation systems for Wyoming. See attached letter with cost estimates.

Magnetic Automation Corp. Sarasota Florida – Unable to contact phone disconnected

New York Gate Manufacturing, - Not located

Eagle Traffic Control Systems, Bruce May (512) 837-8371. They currently have gates with up to 24 ft. arms supplied by Siemens. They are willing to design a gate with a longer arm and they would look at getting FHWA approval. Also gate control system could interface with advance warning signs so they could turn on warning signs before closing the gate. Would need a minimum order of 30 to do the engineering.

Montana DOT supplied a copy of their design for a Road Closure Gate. The Montana design calls for a two gate system on a divided highway installation and the gates are mounted on steel luminaire poles for added stability. Page one of the Montana plans is included as Attachment A, and the full set of the Montana plans are in the project file. (Attachment A)

Wyoming DOT has 283 hand crank gates using an FHWA approved design that attaches to lumnaire poles. Wyoming DOT builds these gates themselves, using Safetran gate arms. They are in the process of automating a number of these systems and have been working to develop a DC wench system to operate them. A problem is developing involving an appropriate battery backup system and solar system where necessary. They are about 6 months away from having plans ready and the Assistant State Traffic Engineer, Joel Meena (307) 777-4374 did not want to release their plans at this time because they have received so many calls and the designs are not solid. They are also finishing a design on a CCTV system with automated gates, but it is not completed. Mr. Meena felt it was

important to not let motorists turn around through the median, but to require them to go through the interchange. Gates need to be simple and 100% reliable. They are trying to get funds for an I-80 corridor program. (Attachments B, C, & D provide more details of the Wyoming Gate Systems)

A special gate system is used to allow bus access to westbound highway 36 from the frontage road at the intersection of Highways 61 and 36 in the St. Paul area. At this cloverleaf intersection, buses on the frontage road can obtain access, through a gate system, directly to the Highway 62 southbound ramp - Highway 36 westbound entrance. Buses approaching the gate use a Smart Pass card to activate the gate with a 22 foot arm. The Smart Pass control is model Al 1604 manufactured 6/97 from AMTECH 17304 Preston Rd. E100, Dallas, TX 75252, www.amtech.com (800) 923-4824. and the gate mechanism is from Magnetic Automation Corp, Sarasota FL 34234 (phone 941 359-1402 has been disconnected) and the 22 ft. aluminum arm has 3 lights mounted above the arm.

Gate entrance at highway 61 on-ramp to highway 36

No gate – Use series of warning signs - Note: Mn/DOT is currently participating in a project for Measurement of Driver Reactions to Advanced Warning Flashers. In the study advanced warning flashers are placed at 215 or 260 meters ahead of a signalized intersection and are timed to provide an advanced warning to drivers (by flashing yellow wig-wag indicators on either side of "BE PREPARED TO STOP WHEN FLASHING" signs. This project is in its early stage of development but may provide valuable information on the placement of warning signs for the I-90 & US 71 project. Mn/DOT Project manager is Beverly Farraher, P.E., (651) 779-5192.

Placement of Dynamic Message Signs and or other flashing warning signs is certainly an option for this project. At this time a key consideration is will drivers respect the signs and exit from I-90 or at an entrance ramp not enter I-90. One

positive consideration is that emergency vehicles are able to operate without the restriction of a gate to be opened by a key or other means. When the emergency vehicle operator approaches a full closure gate and does not have a key, they would be delayed until they are able to call a TOCC and have the gate opened.

Dynamic Message Signs and flashing warning signs aer available from a number of manufacturers. Placement of these signs for the road closure test is discussed in Section 5. of the report in recommendations.

Wyoming uses an avalanche sensor that turns on flashing lights on advanced warning signs saying ROAD CLOSED WHEN FLASHING AVALANCHE. One site also includes a gate.

In Minnesota we have a major use of a series warning signs in our metropolitan area ramp metering system. In the ramp metering system there are advance warning signs and the "virtual gate" are red stop lights that turn green to allow one vehicle to enter the freeway at a time. While there are many similarities to a possible installation at Jackson, the major difference is the ramp metering system would not allow traffic to enter the freeway when it is operational. On the other hand drivers approaching a metered ramp expect to enter the freeway directly if the ramp metering system is off, or have a delayed entrance if the ramp metering system is on. This system has been operational for many years and drivers are used to, but not excited about ramp meters.

Minnesota Virtual Gate?

An example of an Interstate on ramp closure system, without gates, is on I-94 at Snelling Ave. in St. Paul. There are two entrance ramps to Eastbound I-94 from the south frontage road. The first is a typical metered ramp, and the second, about 1000 feet further east is an HOV & bus entrance ramp that is only turned on at specific times of the day. The second HOV ramp is closed except between 3:30 and 5:30 when it is open under certain traffic conditions and when the ramp meter from Snelling to East I-94 is operating. As a motorist approaches the closed HOV ramp, there is a sign with a lighted CLOSED which also says HOV RAMP 2 PERSON CAR POOLS BUSSES & MOTORCYCLES ONLY. There are also two "blank-out" signs at the ramp entrance which when lighted say DO NOT ENTER. In the picture below the right sign is not lighted for some unknown reason.

This ramp originally had a gate arm, along with the lights and signs, but Mn/DOT felt the maintenance didn't warrant keeping the gate operational and the arm was removed. Mr. Kevin Schwartz, P.E., Mn/DOT HOV Operations Engineer (651) 582-1278 provided data on violations of the closed ramp for the week of May 13 – 19. (Attachment F)

In reviewing the data, one should keep in mind that this is a very heavily traveled intersection, and other than the signs, or appearance of law enforcement nearby, there is no apparent reason to not just go ahead and use the ramp to access I-94. Some vehicles approaching on Pascal would need to detour around many blocks to reach the regular I-94 on ramp from Snelling, so they have a significant interest in violating the closed signs. The reason Mn/DOT does not fully open the ramp is that it is not up to full Interstate standards and the violations are considered minimum. The approximate number of violations for the week of July 15-22, 2001 are: Sunday-31; Monday-39; Tuesday-34; Wednesday-37; Thursday-35; Friday-51; and Saturday-45.

At issue, is this situation relevant to Jackson and the I-90/US 71 interchange during a severe storm, with radio and other announcements indicating the roads are closed.

Virtual gate: light/laser, inflatable arm, and others - Another option for the gate type would be a "virtual gate." A virtual gate has come to mean any type of gate that is not a barrier (does not physically prevent the motorist from moving on to the freeway. There were several ideas that have been proposed for a virtual gate. A few of them are discussed below. Sometimes, this issue is addressed as a soft closure versus a hard closure.

Use of holograms for virtual gates, even signs was considered for this project. The concept would be to insert "or project" a holographic image of a sign on, or over the roadway that would appear to a motorist as a road closure gate. However our research found no hologram manufacturer or other source that provided any significant development of the concept. Dean Larson has looked for developments, in magazines and research documents, of this holographic image concept for 10 years or more without any significant success. As Dean recalls, several years ago SEGA had a "holographic image" quick draw game in the Minneapolis St. Paul International Airport game room. What looked to be a holographic image appeared standing about 9 inches tall on a small platform. There was 360 degree viewing of the image, and you could insert your hand through the image. To view the image a dark background was required as light from the room would wash-out the image when it was viewed against a light background. One major question for hologram technology remains. If a large holographic image, of a gate could be inserted on the Interstate, would that gate image be completely washed-out by the ambient light at the site?

RETRACTOR Lane Delineators used as gates. This technology uses posts (possibly plastic) that retract down into the pavement. When remotely activated the posts are raised vertically above the pavement forming a road closure system. Generally these systems are sold as lane delineators or as channelizing devices. A drawback is they are relatively small to be placed across an Interstate mainline and would need to be placed fairly close together and in the shoulder area a to fully close the road. Instead of lights, they generally use reflective tape for visibility.

Nets are used in Illinois on I-290 expressway reversible lanes to fully stop wrong way intrusions. While this is a gate system that fully prevents all traffic flow it is used only as an add-on to a gate. Gates need to be provided to stop traffic, and the net system becomes a positive closure backup system for cars going up to 75 mph.

Advanced signing. A physical gate is not used, but rather a series of signed signals visible to the motorist that the road/ramp is closed. The signal may take the form of an existing or conventional form such as – ROAD CLOSED AHEAD – or – ROAD CLOSED WHEN FLASHING – or – VIOLATORS SUBJECT TO $500 FINE FOR ENTERING ROADWAY WHEN CLOSED. The premise is that the motorist is not physically prevented from entering the roadway. The motorist is deterred from proceeding through standard signing. The signs could be changeable message signs, these would allow highway officials a means for providing more information to the motorist, although this actually may be less effective in reducing the number of violators. One thought is that changeable message signs do not imply regulatory but rather information. Motorists are inclined to read VMS as advisory, not demanding. Thus, a more regulatory sign such as a DO NOT ENTER WHEN FLASHING, may be more appropriate.

Laser Gate. Another type of gate that was investigated is the laser gate. The use of a visible laser beam (probably red or green) placed across the roadway. Again the motorist is not physically prevented from crossing the path of the laser beam but it does present a visible barrier. We talked with the scientists at Argon labs associated with the University of Chicago. The primary point of contact is Perry Plotkin. Several issues indicate that this solution is not feasible. The problem is creating a laser beam that would be visible in bright sunlight. For the hours of darkness, a laser beam has some merit, but to see the beam in daylight would require extensive power. The laser would actually be very harmful to anything within reach of the laser beam. The power needed to generate a visible laser beam is excessive for a remotely located interchange. This makes the laser beam gate unfeasible.

Inflatable arm gate. The inflatable arm gates are a possibility. One concept of this gate is to inflate a barrier gate arm from the side of the roadway that would extend across the ramp/lane. The arm would not be a physical barrier as the motorist could just drive through it and the inflatable arm would move out of the way. There aren't any manufacturers that have an inflatable arm gate on-the-shelf or even on the drawing board. Although we approached one of the largest manufacturers of inflatable life boats, Bob Swanson of Survival Systems in Saint Paul. The issues that are relevant for this type of gate include retractability, can the gate be deflated and inflated again, in cold weather.

A design proposed by Argon Labs: Develop an inflatable arm similar to the noise-makers for a new year's eve party. Compressed air blown into them from reusable pressurized air canisters, they could unroll across the road. Activation can be done remotely signaling the air compressor to activate. Otherwise, a fan system of tanks with compressed air could be used for when there was the fear of power failures. A number of magnetic switches encased in the roll could signal if it was fully extended or not. A loss of pressure would cause the "arm" to roll back up due to plastic or metal coils creating the basic structure around which a life-raft type material or kevlar would actually handle the inflation aspect. As for visibility: a number of lights could be mounted above, or else have fiberoptic cables, the type used for interior decorating, built into the arm so that it would light up itself. (filling it with indiglo gas, like on wristwatches). Remote sensing systems that recognize the type of vehicle driving through a gate can also be installed. Lastly, a diode banner display like that used on most major expressways could be placed above or before the gate, notifying drivers of the conditions ahead and the gate being closed.

Another inflatable solution is to use a fan driven inflatable arm that is erected as a series of cones, this type of arm would be retractable using series of springs. In this way, air compression chambers are not required the gate is activated by the direction of the fan blades. More research is required to properly assess the inflatable arm options. Also, FHWA approval is an issue for all of the soft closure alternatives with the exception of the advanced signing.

3. DETECTION AND RECORDING OF MOTORISTS THAT IGNORE BARRIERS

Note: Mn/DOT is currently conducting a test of non-intrusive vehicle detection systems on I-394 in Minneapolis. Phase I of the test was completed in May 1997 and the report is available as the "NIT I and II, Non-Intrusive Technology report" on the Internet at www.state.mn.us/guidestar/projects.html. Phase II of the test is underway and a report is due in 2001. Phase II is looking at some of the specific products that are mentioned in this research report and when completed it could provide additional reference material on the capabilities of different detectors and systems. The Mn/DOT contact is Farideh Amiri at (651) 296-8602.

The Vehicle Detector Clearinghouse (VDC), a multi-state, pooled-fund project at New Mexico State University and sponsored in cooperation with the FHWA, published a summary of vehicle detection systems. Published November 30, 2000, this document, is entitled "A Summary of Vehicle Detection and Surveillance Technologies used in Intelligent Transportation Systems." It is an excellent 211 page document and was used in our survey of detection and recording methods. Found at www.nmsu.edu/~traffic/ , select What's New, Reports/Papers/Surveys online, then the Summary document. A copy of the complete document is included in the project file. The following descriptions are from this VDC document.

Cameras and non-intrusive technologies

The quest for an alternative reliable and cost-effective vehicle detection and tracking system, which can be installed and maintained with safety and minimal disruption of traffic and can provide traffic data at least as accurate as the inductive loop detector, has been underway for some time. Recent evaluations have shown that modern aboveground sensors produce data that meet the requirements of many current freeway and surface street applications. Aboveground sensors can be mounted above the lane of traffic they are monitoring or on the side of a roadway where they can view multiple lanes of traffic at angles perpendicular to or at an oblique angle to the flow direction., The technologies currently used in aboveground sensors are video image processing, microwave radar, laser radar, passive infrared, ultrasonic, passive acoustic array, and combinations of sensor technologies such as passive infrared and microwave Doppler or passive infrared and ultrasonic. Like the subsurface sensors, the aboveground sensors measure vehicle count, presence, and passage. However, many also provide vehicle speed, vehicle classification, and multiple-lane, multiple-detection zone coverage.

Loop detectors and intrusive sensors

Intrusive sensors include inductive loops, magnetometers, microloop probes, pneumatic road tubes, piezoelectric cables and other weigh-in-motion sensors. These devices are installed directly on the pavement surface, in saw-cuts or holes in the road surface, by tunneling under the surface, or by anchoring directly to the pavement surface as in the case with pneumatic road tubes. The operation of most of these sensors is well

understood as they generally represent applications of mature technologies to traffic surveillance. The drawbacks to their use include disruption of traffic for installation and repair and failures associated with installations in poor road surfaces and use of substandard installation procedures. Resurfacing of roadways and utility repair can also create the need to reinstall these types of sensors.

Others

On site personnel, either State Patrol, Maintenance staff, or others who can physically count the vehicles entering the road, ignoring Virtual Road Closing Signs or around gate systems and calling the information in by voice telephone. This option is not feasible.

Enforcement

To complete the investigation of the detection and recording of motorist that ignore winter highway gate barriers and/or remain on I-90 after the highway has been closed comments from law enforcement are included. Also to facilitate discussion about hard closures and soft closures, a copy of the appropriate Minnesota Statutes that refer to the enforcement of gates and barriers is quoted below.

Wyoming DOT was advised by the Highway Patrol that it would be extremely difficult to enforce highway closures without using physical barriers.

North Dakota does not use "hard closures" choosing to close to mid-point in the passing lane and Highway Patrol takes the lead in advising people not to travel. The patrol does give citations, but it's a murky area. Public reaction to closures has not been totally supportive.

Major Mike Astleson, Minnesota State Patrol, (651) 297-2306. He states that he really has doubts about compliance with something that doesn't fully close the freeway. He has experience with barricades and if the highway is not completely closed, the people go around them. "So, we need to dump snow at them to block the road. With a sign on the side of the road, there is not a willingness to comply. One of the problems is Mn/DOT does an exceptional job of keeping roads drivable and people are used to the open road and are spoiled into thinking it's OK to go."

The Major also indicated that there is no compliance problems with gates. One reason for that success is there is usually a law enforcement officer posted at the closure. "You need to talk to the people who are out there in the storm at the gate. Currently Mn/DOT includes the cost of a State Trooper on site at any major construction sited to control violations of the barricades." He suggested a number of contacts for additional comments from the State Patrol and the following State Statutes.

Minnesota Statutes Ch 160.27, Subd. 5. (13) and Subd. 8.

160.27 Particular uses of right-of-way; misdemeanors.

Subd. 5. **Misdemeanors.** (a) Except for the actions of the road authorities, their agents, employees, contractors, and utilities in carrying out their duties imposed by law or contract, and except as herein provided, it shall be unlawful to:

(14) drive over, through, or around any barricade, fence, or obstruction erected for the purpose of preventing traffic from passing over a portion of a highway closed to public travel or to remove, deface, or damage any such barricade, fence, or obstruction.

(b) Any violation of this subdivision is a misdemeanor.

Subd. 8. **Trunk highway closure; authority, notice, civil penalty.** (a) The commissioner may restrict the use of, or close, any state trunk highway for the protection and safety of the public or for the protection of the highway from damage during and after storms if there is danger of the road becoming impassable or if visibility is so limited that safe travel is unlikely.

(b) To notify the public that a trunk highway is closed or its use restricted, the commissioner shall give notice by one or more of the following methods:

(1) erect suitable barriers or obstructions on the highway;

(2) post warnings or notices of the closing or restricting of a trunk highway;

(3) place signs to warn, detour, direct, or otherwise control traffic on the highway; or

(4) place personnel to warn, detour, direct, or otherwise control traffic on the highway.

(c) A person is civilly liable for rescue costs if the person (1) fails to obey the direction or instruction of authorized personnel at the location of the closed highway, or (2) drives over, through, or around a barricade, fence, or obstruction erected to prevent traffic from passing over a portion of a highway closed to public travel. "Civilly liable for rescue costs" means that the person is liable to a state agency or political subdivision for costs incurred for the purpose of rescuing the person, any passengers, or the vehicle. Civil liability may be imposed under this subdivision in addition to the misdemeanor penalty imposed under subdivision 5. However, civil liability must not exceed $10,000. A fine paid by a defendant in a misdemeanor action that arose from the same violation may not be applied toward payment of the civil liability imposed under this subdivision.

(d) A state agency or political subdivision that incurs costs as described in paragraph (c) may bring an action to recover the civil liability and related legal, administrative, and court costs. A civil action may be commenced as is any civil action.

Meeting the Challenge of the I-90 & US 71 freeway management system:

On site law enforcement probably provides the best detection system for motorists that ignore barriers. Their presence will not only deter violations, they can detect violations, and they can enforce laws against the violators. The on-site officer can detect emergency situations and provide an source of information to motorists who are unable to complete their planed trip and/or who are confused as to their options and available emergency services.

Cameras for detection and recording of motorists that ignore barriers. In our proposal, ThomTech Design specified use of the Autoscope Solo Pro. This system was selected because it offers: Automated gate by-pass detection; Automated incident detection; Extraction and archival of volume, speed, and other traffic data; Color Autoscope video display at TOCC; Remote electronic zoom from TOCC, Dual-mode sensor operation, both Automated detection and Pan-tilt-zoom; and Automated detection of visibility degradation.

With a camera system the system operator can also be alerted to vehicles stuck, pedestrians, and other emergency situations within the intersection area. Visibility that could be a problem for the camera can also be viewed to determine current conditions at the intersection. Other less expensive CCTV systems are available, including Pelco, Iteris Vantage, and others. A significant advantage of the Autoscope system brings to this test program is that it is a local company that brings excellent product engineering and related services to the test program.

Acoustic Sensors are another option that was reviewed for detection of motorists that ignore barriers. There are several brands, however the acoustic Sensor we looked at is Model SAS-1 from SmarTek Systems Inc. 295 Waycross Way, Arnold, MD 21012 (410) 315-9727, www.smarteksys.com. These acoustic sensors could sense intrusions across up to 5 lanes and are priced much less than CCTV. According to the manufacturer they are not affected by visibility problems like cameras. The big disadvantage is they do not offer the visual image of gates closed or open, vehicles intruding or stuck, or other potential emergency situations within the intersection area. An emergency phone system at the on-ramp may offer help during extreme conditions at isolated locations.

Intrusive sensors like loop detectors were not generally viewed as an option for the detection of motorists that ignore barriers at this intersection. They would need to be placed in the pavement at several locations. However, their big disadvantage is they do not offer the visual image of gates closed or open, vehicles intruding or stuck, or other potential emergency situations within the intersection area. (See Attachment F as an example of the output of a loop detector systems output). An emergency phone system at the on-ramp may offer help during extreme conditions at isolated locations.

At the IMSA conference, July 23, 2001, a speaker in the technical session on Alternative Detection Systems said he use the following cost estimates: $8500 for cameras; $1000 to $1500 for loop detectors.

4. COMMUNICATIONS SYSTEMS COMPARISON

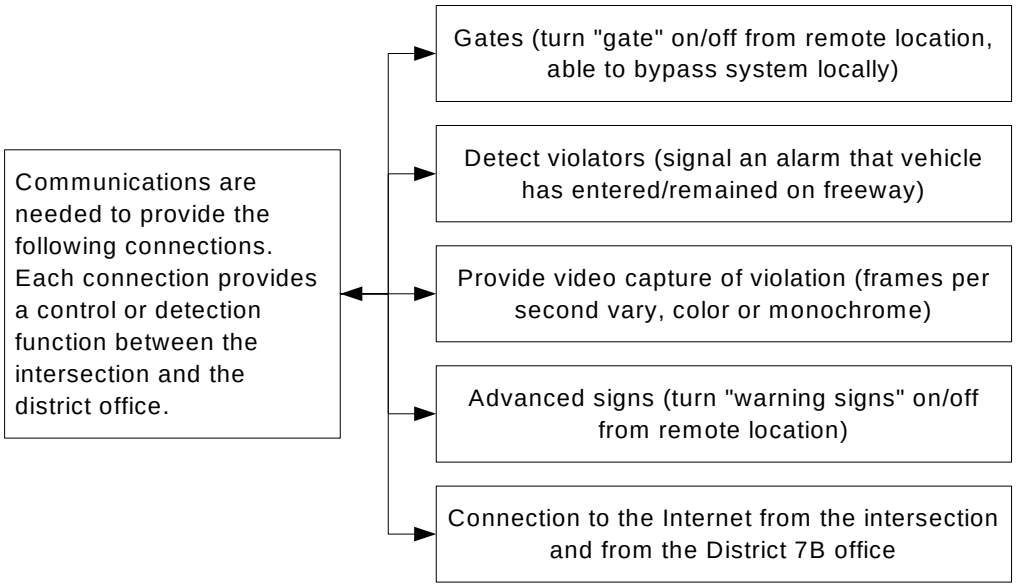
Communications. The communications subsystem is a critical part of making the I-90 Gate Closure solution and effective, responsive system. The communications considerations are significant. The following list of necessary communications paths, each provide a unique challenge to ensure reliability, flexibility, and still meet the distance, bandwidth, and throughput requirements. In addition, the communications subsystem needs to be replicatable at each intersection, cost effective, and not affect existing operations.

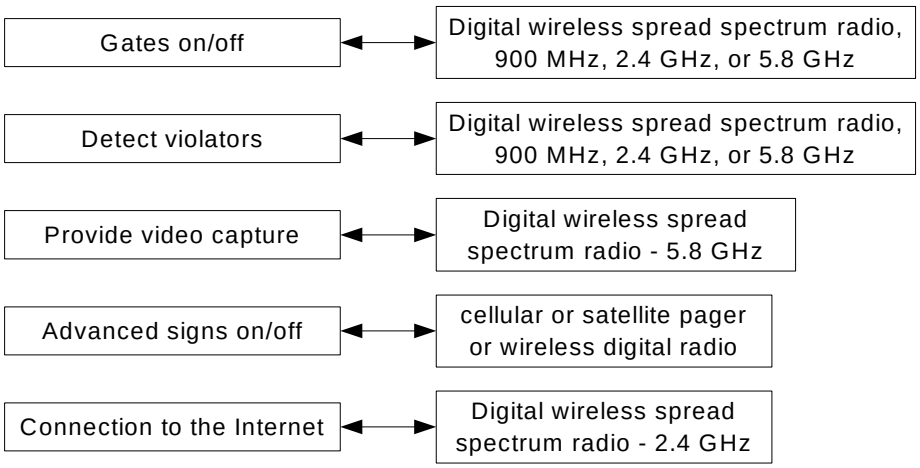
- Connection to the Internet from the intersection and from the District 7B office
- Gates (turn "gate" on/off from remote location, able to bypass system locally)
- Detect violators (signal an alarm that vehicle has entered/remained on freeway)
- Provide video capture of violation (frames per second vary, color or monochrome)
- Advanced signs (turn "warning signs" on/off from remote location)

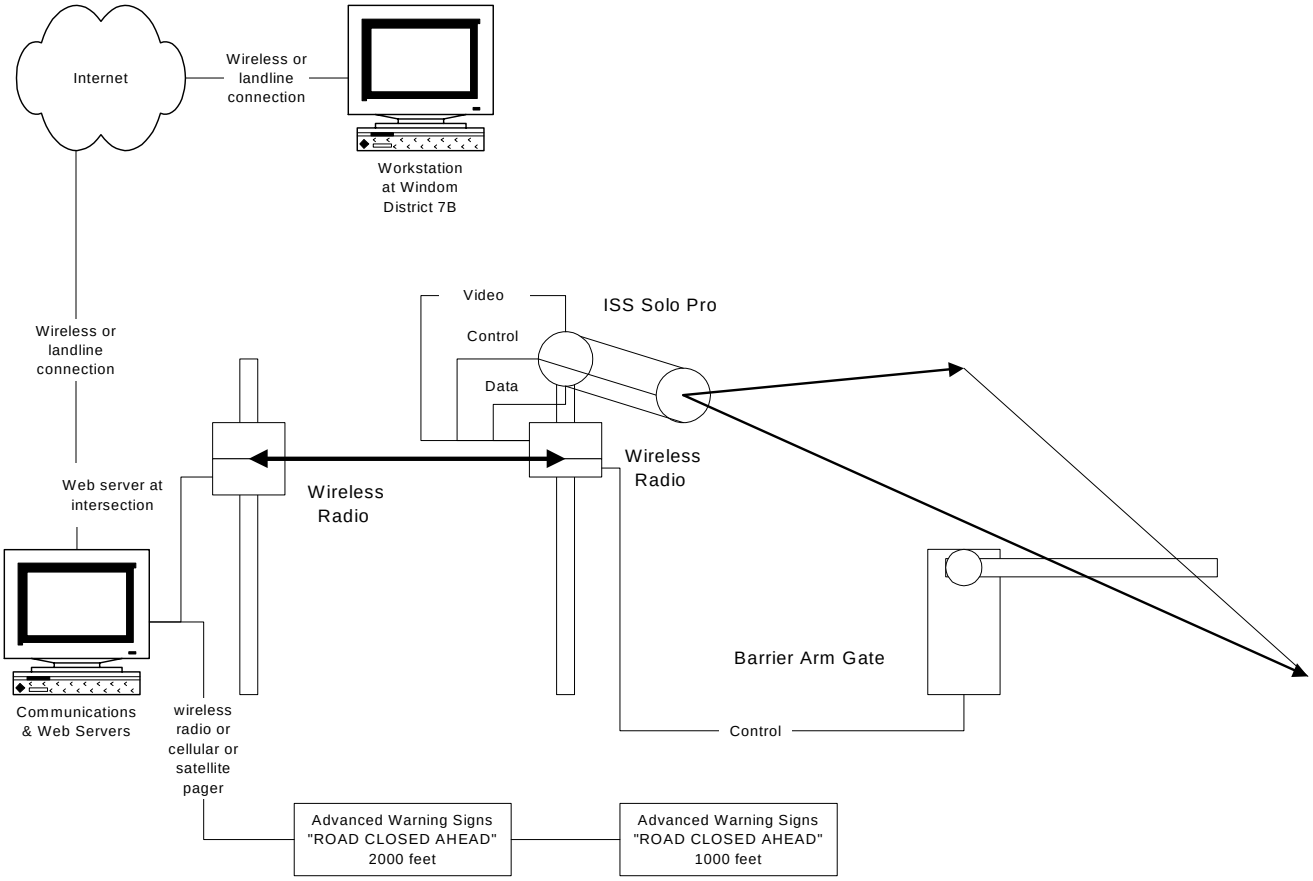
Connection of the intersection control and detection features to the District 7B office in Windom, MN. The intersection of I-90 and US 71 is 18 miles from the District office. This is a substantial distance for transmitting full/partial motion video from four different cameras at the intersection. Another consideration is scalability, where in actual practice the District office would need to control several intersections during a snow incident. Thus transmitting several data, control, and video feeds to a workstation to perform gate operations involving several intersections is a significant undertaking.

Ideally, a fiber optic path between intersections and the district office would be the best solution. However, it is not feasible to install fiber or wait for fiber to be installed under other projects. Fiber optic cable meets the necessary requirements for reliability, flexibility, and, throughput. Another solution is to use conventional telephone or POTS lines, these can take the form of standard phone line or 56K frame relay dedicated lines. IN both cases, this solution is reliable, yet is limited on throughput for video, begins to be costly over several intersections, and may not be available at isolated intersections. Nevertheless, this method of communications is an ideal form for backup or to implement control and data features without video.

Significant advances in wireless communications, and in particular, internet wireless communications allow the I-90 Gate Operations Project to take advantage of collecting the data at each intersection onto a web site or several web sites (each intersection could have a web page). This allows the throughput (specifically the video, frames/second and color/mono) to be determined by the level of internet service at the district. This allows Mn/DOT personnel, with the proper access codes (passwords), to control the intersection operations wherever they have access to the internet. The higher the speed of the connection at the district office, the better the video and perhaps the larger the number of intersections. The following figures provide block diagrams and recommended solutions for each of the paths.


Communications are needed to provide the following connections. Each connection provides a control or detection function between the intersection and the district office.
Gates (turn "gate" on/off from remote location, able to bypass system locally)
Detect violators (signal an alarm that vehicle has entered/remained on freeway)
Provide video capture of violation (frames per second vary, color or monochrome)
Advanced signs (turn "warning signs" on/off from remote location)
Connection to the Internet from the intersection and from the District 7B office


Gates on/off
Digital wireless spread spectrum radio, 900 MHz, 2.4 GHz, or 5.8 GHz
Detect violators
Digital wireless spread spectrum radio, 900 MHz, 2.4 GHz, or 5.8 GHz
Provide video capture
Digital wireless spread spectrum radio - 5.8 GHz
Advanced signs on/off
cellular or satellite pager or wireless digital radio
Connection to the Internet
Digital wireless spread spectrum radio - 2.4 GHz


Internet
Wireless or landline connection
Workstation at Windom District 7B
Wireless or landline connection
Video
Control
Data
ISS Solo Pro
Wireless Radio
Wireless Radio
Web server at intersection
Barrier Arm Gate
Communications & Web Servers
wireless radio or cellular or satellite pager
Control
Advanced Warning Signs "ROAD CLOSED AHEAD" 2000 feet
Advanced Warning Signs "ROAD CLOSED AHEAD" 1000 feet

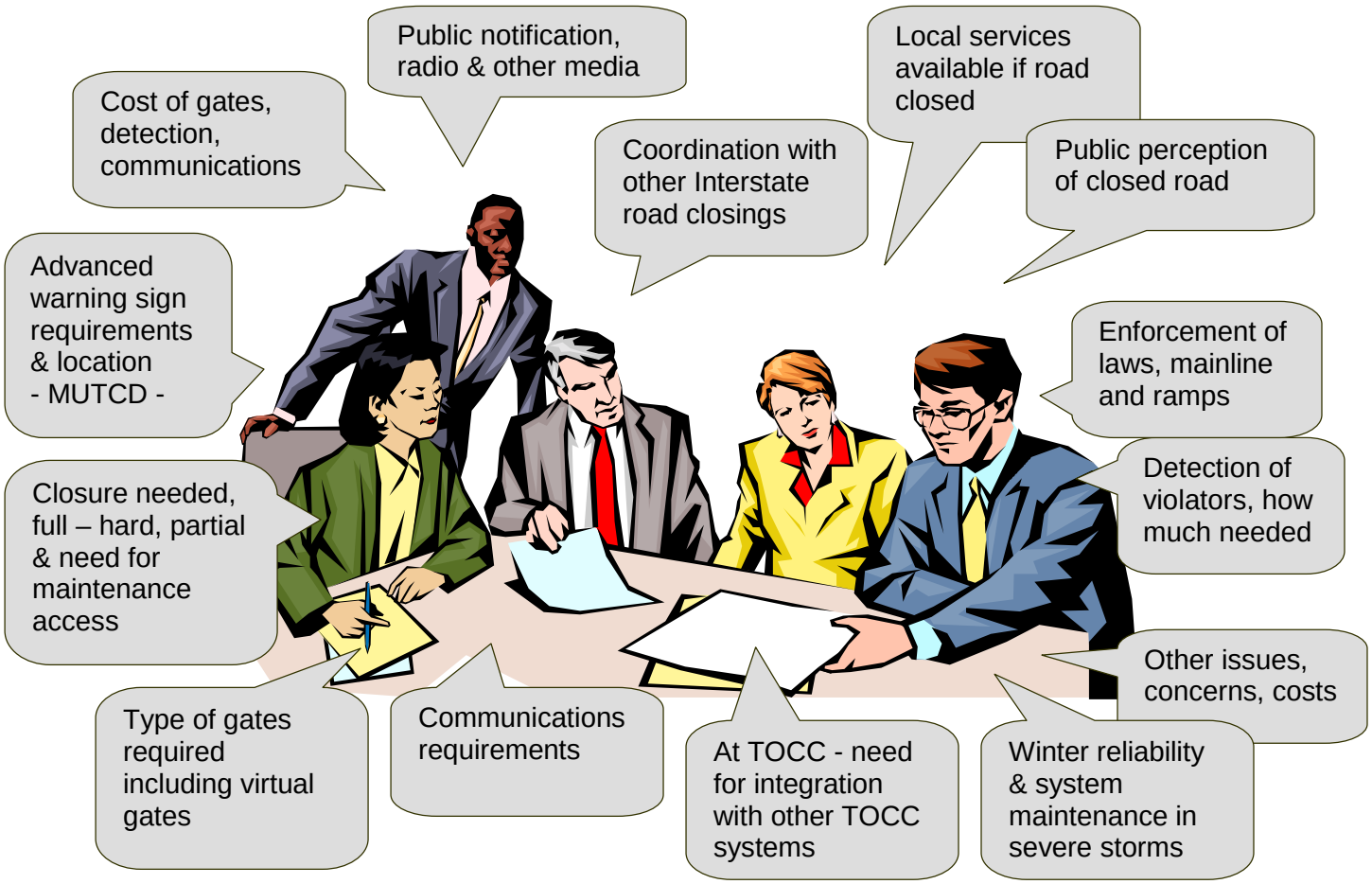
5. RECOMMENDED METHOD AND ALTERNATIVE METHOD FOR DEPLOYMENT

In preparing it's recommendations ThomTech Design Inc. has tried to follow the terms of its contract with the State which requires "*seeking new and innovative partnership arrangements between State and the private sector to meet the needs of controlling traffic through the use of gates. It is the goal of this project to test different technologies, communications, and public/private operational and maintenance partnering scenarios to develop the optimal freeway management system for I-90….*"

Task 2.5 requires a recommended method and at least one alternative method for the I-90 Gate Operations solution compatible and cost effective for deployment on multiple intersections with control functions remotely managed from Transportation Operations Communications Centers (TOCC's) using VTOC software.

While conducting a study on road closing systems and methods it doesn't take long to realize there can be a number of valid opinions in how to manage road closures during severe storms. The graphic below was created to show some of the many different issues that influence and determine each person's opinion.

Issues Influencing Interstate I-90 Mainline and Ramp Closing Systems



In viewing the graphic, the comments to the lower left generally are hardware-oriented issues, while those to the upper right are more people and political oriented issues.

In preparing our recommendations the first major issue, and the issue that influence all others, is whether to develop a full-hard closure gates system or a more limited system with virtual gates (soft closures). Those issues are discussed below for both the I-90 mainline and I-90 entrance ramps.

Hard closure or soft closure?

During the research phase of this project a number of conflicting needs and opinions have been expressed about full and limited closure of Interstate mainlines. It appears this is an issue where there is no absolute right/wrong answer. Full closure of the I-90 mainline is a clear choice for both public safety and some maintenance operations. Balancing that option is the need of State Patrol, maintenance and other emergency vehicles to enter I-90 and respond as needed.

Currently when I-90 is closed there is a law enforcement vehicle at the gate and it can be assumed that violations of the closure will be minimal. However, if law enforcement persons can be relieved from gate enforcement duty they could be available for other emergencies. When discussing this subject with snowplow operators, they indicated that they drive around the gates or enter the freeway going the wrong way on the opposite ramp in order to deploy their snowplow onto the freeway. This can be dangerous and also provides a pathway for motorists to avoid the gates.

The issue of full closure or partial closure will remain long after the project is constructed. However, the operational characteristics of the gate systems and other systems installed on this project can assist in answering this issue for the future. This project will have detection subsystems for vehicles that violate the gates or other road closing systems. Through the use of video or still motion cameras, it is possible to detect the number and type of violations of whatever road closure system chosen. As a result, a comparison study is feasible (See the system study recommendation below for more details).

Another issue for this project is the subject of FHWA approved equipment. Is the project limited to using equipment that has passed FHWA testing and evaluation? When speaking with the FHWA personnel from the Saint Paul, MN office, they indicated that only FHWA equipment could be installed on active roadways. This creates a dilemma in that because there isn't an automatic gate closure system approved by FHWA, it is difficult to deploy a system. However, the recommendations below include subsystems that have gained FHWA approval and are only unique in that they become a working subsystem of a innovative total solution. For example, the gate arm used in Wyoming is FHWA approved, the new feature is the automatic deployment mechanism to raise and lower the gate from a remote location.

The following recommendations do not include design or technical details. Specifications for the installation and implementation of the I-90 gate operations will be developed in TASK 3 of the project, Prepare Work Plan. Finally further development of any of the recommendations will need to be coordinated with the designs to be developed by the District 7 ITS Work Team.

Recommendations for feasible solutions to meet the objectives of this project are summarized into two alternatives – (1) Hard Closure and (2) Soft Closure. For the purposes of discussion, the hard closure alternative uses west bound I-90 traffic as an example and the soft closure alternative uses east bound I-90 traffic. There are three subsystems listed (1) hard/soft closure subsystem, (2) violation detection subsystem, and (3) communication subsystem.

Other issues not addressed in this section are: back-up power supplies, placement of emergency telephones, and issues surrounding the conditions for freeway closure. The two tables below describe a hard closure and soft closure alternative.

NOTES FOR THE TABLES
Specific engineering details of devices, placement, and messages are to be developed in the next phase of this project. These are general recommendations.

* - This device was not included in the current Jackson gate project budget, however, some devices may replace gates that were in the project budget.

- Messages shown are for conceptual purposes only, not final messages to be used.

Recommendations Table for a Hard Closure subsystem (example - West Bound I-90)

Location - Westbound Mainline approaching the Jackson Exit	Device	# Typical Message
On the WB mainline 2000 ft before the Jackson exit, each side of the roadway	Dynamic Message Sign *	ROAD CLOSED AHEAD
On the WB mainline 1000 ft before the Jackson exit, each side of the roadway	Dynamic Message Sign *	EXIT AT JACKSON
Gate I - placed on the left mainline shoulder at the Jackson exit. To force vehicles to exit.	Automated gate mounted on a luminaire closing the left lane of I-90	3 Flashing lights on the arm
Static information sign attached to the gate luminaire	Use existing STATE LAW - $700 fine sign	STATE LAW up to $700 fine for driving past this point when gate arm is down.
Gate 2 - placed on the right mainline shoulder 60 ft beyond the left shoulder gate 1, The two gates force vehicles to exit but, emergency-maintenance could use the 60 ft spacing to enter I-90	Automated gate mounted on a luminaire closing the right lane of I-90 To a driver the two gates overlap and look like a solid closure	3 Flashing lights on the arm
Static information sign attached to the gate luminaire	Use existing STATE LAW - $700 fine sign	STATE LAW up to $700 fine for driving past this point when

		gate arm is down.
On shoulder or bridge on WB I-90 at US 71	Autoscope Solo Pro with pan tilt	Notification at the Windom Workstation
Location – US 71 at the Jackson interchange.		
SB 71 - Route marker guide sign for WB I-90 Entrance ramp. To notify drivers the ramp is closed before they turn onto the ramp.	14” x 50” Blank out sign mounted on route marker guide sign below the route message	CLOSED
NB 71 - Route marker guide sign for WB I-90 Entrance ramp. To notify drivers the ramp is closed before they turn onto the ramp.	14” x 50” Blank out sign mounted on route marker guide sign below the route message	CLOSED
Location – Entrance ramp from US 71 to Westbound I-90		
Gate to be placed on the left shoulder of the entrance ramp at it’s intersection with US 71.	Automated gate mounted on a lumnaire closing ramp entrance to WB I-90. Must have an ability for emergency-maintenance vehicles to enter without leaving their vehicle	3 Flashing lights on the arm
Blank out sign to be placed on the right shoulder of the entrance ramp at it’s intersection with US 71, across from the gate	36” x 36” Blank out sign *	ROAD CLOSED
Static information sign attached to the gate luminaire	Use existing STATE LAW - $700 fine sign	STATE LAW up to $700 fine for driving past this point when gate arm is down.
On entrance ramp at WB I-90 and US 71	Autoscope Solo Pro without pan tilt	Notification at the Windom Workstation

Recommendations Table for Soft Closure subsystem (example - Eastbound I-90)

Location - Eastbound Mainline approaching the Jackson Exit	Device	# Typical Message
On the EB mainline 2000 ft before the Jackson exit, each side of the roadway	Dynamic Message Sign *	ROAD CLOSED AHEAD
On the EB mainline 1000 ft before the Jackson exit, each side of the	Dynamic Message Sign *	EXIT AT JACKSON

roadway		
On the left mainline shoulder at the Jackson exit.	4’ x 4’ Blank out sign, could be flashing *	ROAD CLOSED
Static information sign attached below the 4’ x 4’ Blank out sign	Use existing STATE LAW - $700 fine sign	STATE LAW up to $700 fine for driving past this point when road is closed.
On the right mainline shoulder at the Jackson exit.	4’ x 4’ Blank out sign, could be flashing *	ROAD CLOSED
Static information sign attached below the 4’ x 4’ Blank out sign	Use existing STATE LAW - $700 fine sign	STATE LAW up to $700 fine for driving past this point when road is closed
On shoulder or bridge on EB I-90 at US 71	Autoscope Solo Pro with pan tilt	No message – for violations detection
Location – US 71 at the Jackson interchange.		
SB 71 - Route marker guide sign for EB I-90 Entrance ramp. To notify drivers the ramp is closed before they turn onto the ramp.	14” x 50” Blank out sign mounted on route marker guide sign below the route message *	CLOSED
NB 71 - Route marker guide sign for EB I-90 Entrance ramp. To notify drivers the ramp is closed before they turn onto the ramp.	14” x 50” Blank out sign mounted on route marker guide sign below the route message *	CLOSED
Location – Entrance ramp from US 71 to Eastbound I-90		
On the left shoulder of the entrance ramp at it’s intersection with US 71 a 36” x 36” blank out sign closing the I-90 entrance ramp. No gate would be used	36” x 36” blank out sign mounted on a pedestal mount. *	ROAD CLOSED
Placed on the right shoulder of the entrance ramp at it’s intersection with US 71, directly opposite the 36” x 36” blank out sign	36” x 36” Blank out sign *	ROAD CLOSED
Static information sign attached to the each blank out sign	Use existing STATE LAW - $700 fine sign	STATE LAW up to $700 fine for driving past this point when road is closed
On entrance ramp at EB I-90 and US 71	Autoscope Solo Pro without pan tilt	No message – for violations detection

Detection Subsystem

The ThomTech Design proposal for this project includes two Autoscope Solo Pro units, one looking east of US 71 and one looking West of US 71. The Autoscope Solo Pro units contain a lot of capabilities for detection of vehicles that violate the road closure.

The autoscope solo pro detection subsystem is recommended for the following reasons:
It provides a sensor and video feed in one piece of equipment. This allows one interface for communication subsystem to process, signal, and display.
With the addition of a pan/tilt platform, the autoscope provides the most flexible solution for detecting visibility problems and violation areas (around gates, on shoulders, areas before and after the closure points).
The autoscope has proven to be reliable, is FHWA approved, and has track record of success within Mn/DOT.

Detection subsystems recommendations are that the Autoscope Solo Pro units are capable of providing visible detection and warnings when a motorist has bypassed the gates and is on the closed roadway. Alternatives should and will be considered, if they can be shown to meet all the capabilities of the Autoscope Solo Pro systems.

Communication Subsystem

A. Considerations. The alternatives for a communication subsystem must meet the following considerations.

1. The gate closure system will be controlled from the District 7B office in Windom.
2. The operator at Windom needs to have remote control (i.e. buttons to raise & lower gates) and visibility (video/still photo) of the gates for safety reasons and confirmation of closure.
3. The communication subsystem will need to be deployed at all types of intersections along the freeway system and the signals terminate at the Windom office. Thus the subsystem, like the other subsystems, must be replicatable in order to reap the cost benefits of quantity purchases.
4. The communication path must be able to handle video (the number of frames per second is flexible), data, and control signals.
5. The gates (hard or soft), message signs, violations, pan/tilt/zoom controls, visibility assessment, confirmation of closure, and options for access to the information and control.
6. Communication throughput options, security issues, and levels of access need to remain flexible to be consistent with the “pilot & innovative nature” of this project.
7. There exists two portions to the communications subsystem – from the gates to the host end and from the host end to the control point (Windom).

B. Options. Several options have been considered for meeting the communications requirements of this project. They can be grouped into the following categories:

- Fiberoptic cable
- Landline (telephone, frame relay, or T1)

- Wireless (spread spectrum (900MHz, 2.4 GHz, 5.8 GHz)
- Long haul microwave (one link (18mi), one repeater, or several repeaters)

A fifth and sixth option can be created if a combination of the above options is considered and whether a combination of wireless or trenching is used.

C. Discussion. Clearly fiber optic is the communications path of choice for this project. The communications nodes and terminals are all at static locations (there are no mobile (vehicles) considerations). However, fiber is not available. There is commercial fiber available at the intersection, but it does not extend to the areas needed. When fiber does become available in the future, and Mn/DOT can be provided a cost effective access, this meets all of the requirements and provides the highest performance in the area of reliability. Landline is another alternative and for this intersection (I90/US71) it may prove to be valuable. However, this option or solution is not available at every intersection or even at most intersections. Wireless using spread spectrum (does not require Mn/DOT to go through an FCC frequency licensing process) is feasible. This option is available at all intersections and provides access to the internet from a control box at each intersection, independent of trenching capabilities, landline, or other considerations. Long haul microwave or spread spectrum wireless is a distinct option for this intersection (I90/US71). However, it requires line of sight from the intersection to the Windom office (approx 18 miles). This option becomes unfeasible when considering several intersections. Another option is the use of the Internet, let each intersection, in particular (I90/US71) have access to the internet (wireless or landline). Each intersection has its own web address and access, throughput, and control is dictated by the speed of the connection. An advantage to this option, is that this technology continues to improve throughout the state by commercial and public demand. Frame per second, color or monochrome, storage or archive decisions are made on the basis of the connection to the internet, not on line of sight, height of towers, repeaters, trenching, or cable availability.

D. Recommendation. Wireless connection to the internet at the intersection (I90/US71) and at Windom (District 7B) provides the most cost effective, flexible solution for this project. This allows the project to take advantage of the internet industry (higher speeds, larger throughput, more access points, and flexible control) as it continues to advance by public demand. It also allows for additional points of information access and control. Because all display & control features are on a web site, supervisors and other interested personnel can access the intersection's web site from remote locations (including home office) to "see" visibility conditions, gate closure, violations, etc. Also the issue of full motion video or some degraded (yet acceptable) option is dependent on the internet connection speed. Thus, it is recommended that the truck station at the northeast corner of the I90 & US71 be used as the host end and include a communications and web server providing the intersection with a web site. This web site is connected to the internet via a spread spectrum wireless connection, high speed. The Windom office also connected to the internet via a high speed connection (wireless at this time). The option of sending the video and control signals (wireless or landline) is an option but does not provide the replicatable requirements for expanding this to multiple intersections. It also creates a larger infrastructure for maintenance, increases life cycle costs, and does not take advantage of the internet access industry improvements.

System Study

Once all systems are in and operational the question still remains, can warning signs or virtual gates adequately close I-90 and prevent violations of the road closure. Only an appropriate study of the operational characteristics of the gated and non-gated system can answer that question. Therefore the following recommendation is made.

Recommend that once all systems are operational that a study of hours of operation, traffic flows, and number of violations/number of vehicles approaching the I-90 interchange with US 71 be implemented. The purpose will be to provide additional input, and an answer to the question of gates vs. no gates, for closing roads during severe winter storm.

Alternative Method Recommendations

Included below are several alternative recommendations. As always the need for funding will be an important element during consideration of any of the alternatives.

Alternative one is to develop the project using gates only and not to try and develop a non-gated option. Alternate two is to fully incorporate the non-gated, warning sign only option on both directions of I-90.

For study purposes install another non-intrusive sensor to detect violations of the closed gate system. Obviously this does not provide as much information about current conditions and emergencies at the interchange.

Consider alternate sign systems including blank out and other types of warning signs as part of the “virtual” gate portion of the project.

Consider use of an alternative back-up power supply to provide power to the complete system in case of loss of electricity at the interchange. The back-up power system could take the place of solar and battery systems at many of the system components.

Consider placement of emergency phones at the interchange, probably near the on-ramp gates for emergency communications by the public, or for requests by emergency vehicles to have the gate opened.

General recommendation: Gates should not be installed at many locations without sufficient review of local conditions. Important to consider is the effect of gate closures on local facilities and the ability of travelers to retrace their steps. Always a critical consideration are the capabilities of travelers to find refuge during severe weather conditions.

Cost Considerations

The following cost estimates are provided in the table below. The costs are the best estimates based on the information available at time of preparation. Additional information received from equipment manufacturers will be provided when available. Additional cost considerations include the use of the existing gate arms or the use of used or excess luminaries.

Item	Estimated Cost
Hard closure gate, barrier arm, hydraulic automatic mechanism	$12-16K
Hard closure, FHWA approved barrier arm, with automatic mechanism	$8K
48" x 48" blank out sign, with transformer mounting base	$6,200
80' antenna tower, with installation	$6,000
300' antenna tower, with installation	$45,000
rent space on existing antenna, City of Jackson	unknown
High speed wireless internet access from intersection	$60/month
Dynamic changeable message sign	$10-18K
5.8 GHz wireless radio subsystem gates to host	$28K
wireless link to Windom from intersection, not including tower	$10K
wireless link to Windom using one repeater, not including towers	$20K
Luminaire	$3000

6. MANUFACTURERS WARRANTY INFORMATION

Key to the selection of any technology or hardware for installation on I-90 is the testing and FHWA approval of roadside systems. Andy Halvorson, Mn/DOT Assistant Design Standards Engineer, (651) 296-3032 serves as the Mn/DOT technical advisor to the Midwest States Pooled Fund Study which conducts crash testing of roadside objects. Andy estimates that a crash test for a gate system would cost in the neighborhood of $25,000 to $30,000. This cost places crash tests of gate systems clearly outside the scope of this contract. As a result whatever system is selected must have received prior FHWA approval, or the manufacturer must be willing to pay the cost of obtaining FHWA approval. Also before conducting any crash testing the time required to conduct the test will need to be considered, so that the contract time line can be maintained. Therefore an FHWA approval column has been added to the manufacturers warranty chart to indicate whether the product has federal approval for use on the Interstate Highway system.

In reviewing manufacturers warranties we found that few of them provided warranty information in their litterateur. Instead one needed to call the company for information and sometimes it was only supplied as part of a formal proposal.

Manufacturer	**Product - System**	**FHWA approval**	**Warranty**	**Comments**
B & B (800) 367-0387	Gates	Model VT-6802	2 years	Model VT-6802 is a traffic barrier, not a typical gate
Roadway Manufacturing, (888) 560-2060	Gates	No	2 Years	
Wyoming DOT	Gates systems	Yes	None	Made by the DOT for use in Wyoming only
Eagle Traffic Control Sys. (512) 837-8371	Gates	No, but willing to try	?	Would need to order 30 gates for Eagle to develop the gate.
Safetran	Gates	Yes ?		Makes the gates currently in use on I-90
ADDCO	DMS	?		Will be used on District 7 ITS project.
3M	DMS +	?		
deMaco (219) 670-6774	Blank out signs	Yes		
Quantum Lite (305) 887-9526	Displays	?		Need to verify they show blank when not lit.
Millerbernd Mfg. Co.	Steel lighting	Yes		Steel light pole used in So. Dakota test.

Manufacturer	Product - System	FHWA approval	Warranty	Comments
(320) 485-2111	poles			
SmarTek Systems Inc. (651) 773-2103	Acoustic Sensors	Not required?	?	
Nu-metrics (724) 438-8750	Sensors, counters			
AMTECH (800) 755-0378	Smart-Pass System			Used on gates at Highway 61 & 36.
Clary Continuous power Co. (612) 521-2122	Back-up power supplies	Not required ?		Todd Foster
Hy Security Gate	Hydraulic mechanism	In process	5 years limited	Proposed as solution for other uses within Mn/DOT

Additional Manufacturers web sites:

- AMP/MSI Sensors http://www.msiusa.com/sensors.htm
- Computer Expertise http://www.computerexpertise.com/
- Computer Recognition Systems, Inc. http://www.crs-its.com/
- Diamond Traffic Products http://www.diamondtraffic.com
- Econolite Control Products, Inc. http://www.econolite.com/
- EIS Electronic Integrated Systems, Inc. http://www.rtms-by-eis.com/
- Image Sensing Systems http://www.imagesensing.com/
- Intersection Development Corporation http://www.idc-traffic.com
- International Road Dynamics http://www.irdinc.com>
- International Traffic Corp. http://www.internationaltraffic.com
- JAMAR Technologies, Inc. http://www.trafficcounter.com
- Microwave Sensors Inc. http://www.microwavesensors.com
- Mikros Pty., Ltd. http://www.mikros.co.za/
- Mitron Systems Corporation http://www.mitronsystems.com/
- Nu-Metrics http://www.nu-metrics.com/
- PEEK Traffic http://www.peek-traffic.com
- Smartek Systems Inc. http://www.smarteksys.com
- Sumitomo Electric Industries, Ltd. http://www.sei.co.jp/

This document should be considered a work in progress that will become more valuable and accurate as additional information begins to surface and an open dialogue continues to generate new ideas, configurations, and systems integration.

Note: This report does not represent the end of the research for this project. ThomTech Design Inc. and the State will stay vigilant and seek new or more appropriate technology for employment. If a better or more appropriate technology is found or becomes available it should be considered for use.