FINAL REPORT

I-90 Gate Operations Project
Mn/DOT District 7B in
Jackson, MN & Windom, MN

Prepared for:
Minnesota Department of Transportation

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Figure 1: I-90 Mainline Gate Deployed
EXECUTIVE SUMMARY

A. Purpose. The I-90 Gate Operations project is a successful public/private partnership between Minnesota Department of Transportation (Mn/DOT) and ThomTech Design, Inc. The project provides a web enabled remotely controlled freeway gate closure system that can automatically raise and lower the existing FHWA approved gates and activate the advanced warning signs to control traffic at the intersection of Interstate 90 (I-90) and United States Highway 71 (US 71) in Jackson, MN.

The installed I-90 Gate System provides Mn/DOT personnel the option of closing the freeway (I-90) from either or both directions (east/west) during a severe snow storm, hazardous waste spill, or other event where traffic needs to be controlled and monitored.

B. System Description. The I-90 Gate System consists of four subsystems identified as follows; (1) monitor and control, (2) communications, (3) detection and sensor, and (4) traffic management. Figure ES-1 provides a conceptual diagram of the system configuration.

The monitor and control subsystem provides a system operator with the ability raise and lower the gates, activate the advanced warning signs, and monitor the on ramps and mainline roadways from a secure web site. The communications subsystem consists of the signaling and connectivity between the system components and uses a variety of wireless and terrestrial communications links to control the traffic devices and monitor the video. The detection and sensor subsystem provides a means to record and monitor violations of the traffic control process by motorists. The traffic management subsystem consists of the gates arm control kits and other hardware necessary to remotely control the gates and signs.

Figure ES-1: Conceptual Diagram of I-90 Gate Closure System
C. System Operation. The I-90 Gate Closure System was installed in late January and early February and was operational during the latter half of the 2002 winter season. The system passed acceptance test during April 2002. The system can be operated from the Mn/DOT truck station in Jackson or the Mn/DOT District 7 B office in Windom. The system has a manual backup if the intersection loses electrical power. The system operator accesses the system by using a high speed Internet connection and opening a browser (Internet Explorer) from a Desktop PC using Windows 2000 as an operating system. See Figure ES-2. Entering the proper user ID and password allows the operator to control four gates (westbound on ramp, eastbound on ramp, and both mainlines) to control the traffic attempting to access I-90.

The gates are controlled via a web based software application residing on a web server located at the Jackson truck station. The web server controls the gates/signs and monitors the video using wireless spread spectrum communications between the intersection and the truck station. The violations are recorded in a database for later playback and are date and time stamped as well as providing a snapshot of what triggered the alarm system.

D. Results. The system has proven the concept of remotely closing the gates using real-time video, system security, and wireless communications. It is anticipated that this will improve safety of Mn/DOT personnel and significantly reduce the time to gain control of the interstate traffic when necessary. The system employs an open architecture philosophy and uses existing FHWA approved gate arms and communications protocols. The data is stored in common text files for use by other Mn/DOT software applications.

Several lessons learned issues will be incorporated in the follow-on production phase or phase II of this project such as improved video frame rate and resolution, wireless Internet, handheld and push button control from the intersection, and simpler solid state control box. The web based software application has proven to be remarkably capable and can be used as a rural traffic operations control center having the ability to control and monitor several types of traffic control devices.
I. INTRODUCTION

A. Purpose. The purpose of this document is to provide a final report on the results of the I-90 Gate Operations Project. This document includes a comprehensive description of the project and describes the tasks, implementation procedures, and integration aspects of the project. As well as including a chronological listing of the events comprising the completion of the project.

B. Task Description. The final report task description is based on the results of Task 6. The objective of the final report is to provide a comprehensive analysis of the results of the installation and implementation of the I-90 Gate Operations solution for the US71 and I-90 intersection near Jackson, Minnesota.

This document was prepared using Microsoft Word and does not exceed 20 pages. The following documents (published earlier in the project under separate cover) are attachments to this final report.

- Research Report; August 2001 – Attachment A
- Work Plan; October 2001 – Attachment B
- Training Documentation; 2002 – Attachment C
- Equipment Manuals; April 2002 – Attachment D

The final report consists of a compiled summary of the research report (task 2), the work plan (task 3), the project implementation (task 4), as well as procedures, results, lessons learned and recommendations for future development of automatic gate closure operations.

This deliverable includes one camera-ready, 5 bound copies, and one electronic copy of Final report with executive summary and attachments containing the I-90 Gate Operations project results and recommendations.

II. BACKGROUND

A. General. Recent events have shaped the world’s approach to transportation safety and the marshalling of resources to respond to several potentially damaging scenarios. Paramount to successfully managing these situations is the rapid movement of emergency personnel and vehicles, the control of vital transportation arteries, and the ability to react in real-time over a wide geographic area using a variety of communications means and host of emergency and environmental services.

Accomplishment of this crucial task is fundamental to saving lives and national interests. Although a worldwide challenge, the local government agencies are the first line of defense. Through the foresight of several state and county government transportation agencies and visionary commercial entities, selected portions of rapid response
engineering development models are presently in the evaluation stage to leverage the latest technology and lessons learned policies into our emergency procedures.

B. Challenge. The challenge for evaluating these types of system centers on the integration of a diverse set of technologies that employ a standard set of information and communication tools. This set of tools provides the services and resources necessary to collect information, enhance decision making, and control emergency personnel and resources. Thus, solving the problem involves the integration of sensors (gather data), information presentation graphics for the display of vital information (decision support systems), and communication (physical, visual, audio, and data for controlling resources).

C. Research Report. The purpose of the research report was to document the results and recommendations of research conducted by ThomTech Design in developing a freeway management system at the I-90 and US 71 interchange at Jackson, Minnesota. Previously, there was a manually operated gate system in place at the interchange and it was 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.”

Figure 2: Previous Manual Gate
D. Research. 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 several states. The results of the research portion of this project are contained in the research report, see Attachment A. In summary, it was determined that an automated gate closure system would greatly improve safety and efficiency. There wasn’t an automatic gate closure system presently fielded, yet several ideas were offered by traffic professionals. There was a keen interest amongst the states for developing this type of system and several states asked for copies of the project documentation as it was published.

III. I-90 GATE OPERATIONS SYSTEM

A. System and Subsystems. The I-90 Gate Operations solution is comprised of four subsystems. Figure 3 provides a block diagram illustration of the four subsystems and their components. Detailed descriptions of each of the subsystems is provided in the Work Plan, see Attachment B. Figure 4 provides a system overview of at the intersection of I-90 and US 71.
B. Traffic Management Subsystem. The traffic management subsystem consists of automatic gate closure devices that are designed to operate in all climes, are remotely controlled, and provide ample advanced warning to the motorist. See Figure 5. In addition, each device needs to be FHWA approved for crash worthiness, safety, and operability. Research was completed on the best type of gates considering inflatables, laser, barricades, breakaways, and others. The research report explored the most promising candidates.
Another key area of design is the advanced warning signs and means to maintain traffic safety in the wake of environmental, weather, terrorist, and hazardous waste incidents. See Figure 6. This project included the signaling of the signs but not the implementation. The advanced warning signs will be deployed under a separate project.

![Figure 6: Entrance Ramp Advanced Warning Signs; three different phases (left) – sign closed, (top right) – sign opening, (bottom right) – sign open](image)

The I-90 gate project selected to use the existing gate arm mechanism and automate the gate raise and lower operation using an electric linear actuator. An appropriate steel frame was designed and implemented to attach the actuator to the gate. Figure 7 illustrates the completed installation for the gate.

![Figure 7: Automated Gate Photo with Gate Lowered](image)
C. Communications Subsystem. The Gate Operations system is designed to be installed at existing intersections without extensive cable trenching and landline connectivity. Thus, maximum use of wireless communications is employed. Each of the frequency bands have been chosen to ensure adequate bandwidth, throughput, and range is employed to meet the various communications requirements. Other communications subsystem mediums were considered, specifically fiber-optic and microwave. Figure 8 provides a block diagram of the communications system selected for the I-90 Gate Operations project. Figure 9 illustrates the communications subsystem requirements.

![Communications Subsystem for One Gate](image)

**Figure 8: Communications Subsystem for One Gate**

- Traffic Cabinet
- Broadband Radio
- 900 MHz Radio
- Digital Video, Control, & Data
- Video & sensor & pan,tilt,zoom platform

Communications are needed to provide the following connections. Each connection provides a control or detection function between the intersection in Jackson and the district office in Windom.

- Gates (turn "gate" on/off from the district office in Windom)
- Advanced signs (turn "warning signs" on/off from district office)
- Detect violators (signal an alarm that vehicle has entered/remained on freeway)
- Provide image capture of violation (series of snapshots from the autoscope)
- View near real-time video from the four autoscopes directed at the gates
- Connection to the Internet from the intersection and from the District 7B office

**Figure 9: Communications Subsystem Requirements**

Figure 11 provides an overall aerial view block diagram of the intersection and component locations. Figure 13 illustrates the gate and sign-signaling portion of the communications subsystem. Figure 15 shows the entire communications subsystem in block diagram format.
D. Control and Monitor Subsystem. A web site with controlled access is used to control and monitor the Gate Operations system resides on the web server at each intersection or group of intersections. Access to the web site is controlled by a user name and password. Once the system operator has successfully entered the web site, they will have access to control and monitor of gates and signs, data collection, access, video, violations, playback, and reports. See Figure 10.

The control and monitor subsystem consists of two ways to control the gate operation system. The first way is by manual control and is used if the intersection loses electrical power. The gate is returned to operation via the hand-cranked wench by disconnecting the electrical actuator, hooking up the wench cable and winding the gate down/up as needed. The automatic method is to use the web site control provided by the web server at the Jackson Truck Station. Figure 10 provides a screen shot of the web page used to control the gates and signs at the intersection.

An additional method of control is the emergency vehicle override. This method allows the gate to be raised if the emergency vehicle receiver “hears” the emergency traffic override signal, the lowered gate is raised until the receiver senses an absence of the emergency signal. The I-90 Gate Closure System is configured with the Tomar brand of emergency override. This portion of the system has not been tested because of the absence of a control transmitter in Jackson County.

The project team considered several methods of controlling the gates if the electric power was lost. The method selected for the follow-on intersections is to purchase the hand wheel option on the actuator that allows for manual operation if electrical power is lost.

Figure 10: Screen Display for Web Site Control
This figure illustrates an aerial view of I-90 Gate Operations system at the US 71 & I-90 interchange.

Figure 11: I-90 and US 71 Intersection Block Diagram
Figure 12: Final I-90 Gate Closure System Schedule
Signal subsystem:

Signal subsystem is part of the communications subsystem and consists of the wireless connections to signal the gates to close/open and the advanced warning signs to turn on/off.

The mainline signs are enclosed in an arrow pointing east and west to signify that the figure is not to scale.

Signalling is accomplished using a 900 MHz wireless radio system.

Figure 13: Gate and Sign Signaling Portion of the Communications Subsystem
**Figure 14: Detection and Sensor Subsystem Block Diagram**
Figure 15: Communications Subsystem Block Diagram
E. Detection and Sensor Subsystem. The purpose of the detection and sensor subsystem is to provide reliable means of visual, audio, and graphic interface to detect violations of the traffic management system, record, log, and playback these incidents. The Autoscope was used to provide the video and detection portion of this project. Two of the autoscopes were configured with pan/tilt platforms and were stationed on the mainline gates. Figure 14 provides a block diagram of the detection and sensor subsystem.

During this project the video detection subsystem experienced a change in approach by switching from using analog video to digital video. This was done to prepare for future use of digital video, to keep the project on the leading edge of technology, to simplify the communications infrastructure, and to provide quicker digital images for the violation and history files. The disadvantage is that the digital image processing software was not quite mature and several modifications were necessary to achieve the needed resolution, frame rate, and system integration properties. Figure 16 provides a photograph of the autoscope, pan/tilt platform, and broadband radio mounted at the top of a nearby luminaire at the intersection of I-90 and US 71 in Jackson, MN.

![Figure 16: Photo of Autoscope, Pan/Tilt Platform, and Broadband Radio Installed on Light Pole at the I-90 and US 71 Intersection in Jackson, MN](image)

F. Schedule. The final project schedule is provided in Figure 12.
IV. DISCUSSION

A. Assumptions. As part of the design solution for this project, the following assumptions were forwarded to assist in determining communications connectivity, information flow, and integration with other systems. The project team formed these assumptions based on the premise that these things will happen whether the gate project existed or not. Thus, the gate project could take advantage of advances in the areas of communications, information, security, and Internet access without devoting resources to developing those technologies.

- Internet access and features will become more available, easier to use, and familiar to the public.
- High speed and wideband (broadband) communications connections will be more evident, faster, equipment prices will decrease.
- People will look to receive the data they need from the Internet.
- Public will demand open architecture systems that connect directly to common infrastructure, thereby allowing several applications to share the same database.
- Data collection, device control, computer and Internet equipment and software will get faster, smaller, and cheaper.
- High speed communications infrastructure will become available along the interstate highway system.
- Web site control of remote devices will become commonplace.
- Security issues will continue to be more complex and sophisticated.

As a result, the gate project will be able to leverage new technologies as they become available, such as digital video, image processing, highspeed Internet access, broadband radios, faster processing power, larger databases, etc. The project’s use of open architecture, ITS NTCIP standards, and existing database conventions will assist in this effort.

A demonstration model, shown in Figure 17 (at left) illustrates some of the improvements and lessons learned from this project. The demonstration model provides the five methods of control listed below. It also employs the hand wheel option for operating the actuator when loss of electrical power occurs.

![Figure 17: Demo Model](image)
B. Lessons Learned. The following items are provided as lessons learned.

1. Control of the gates and signs must be provided for during several types of scenarios. This includes loss of electrical power, remote areas, and during different types of emergencies. This project demonstrated two types of control – web site and manual. The list below provides the recommended methods of control during the next phase. All of these methods aren’t required, but should be available if needed.

Five methods of gate and sign control are listed below:

1. Manual – loss of power
2. Push Button control at the Gate
3. Handheld for all gates and signs at the intersection
4. Web site control via browser and secure access
5. Emergency Vehicle Override

The new control box is only 8 x 10 inches. It provides push button control at the gate, can be programmed for other methods of control, and has an emergency power shutoff switch. See Figure 18.

Figures 19 and 20 illustrate a proposed handheld control system for opening and closing the gates from the intersection when the web site control is not needed or unavailable.

2. Video – resolution and frame rate. The debate over whether to use digital versus analog real time video was part of the design portion of this project. The digital video provides for several advantages and once the technology matures, the challenges
experienced during this project should be eliminated. The digital video provides for many more communications options, is easier to store violation snapshots, and in the case of the autoscope allows data, control, and video to be transmitted over one communications link.

![Figure 21: Pictures of Installation at the Jackson Interchange](image)

3. Pan/tilt – options, use, and accuracy. The pan/tilt platforms that are on the market today that meet the ruggedized standards and also provide a return to home accuracy of 0.1 degree are expensive. There is a latency (time lag) between using the web site controls and movement of the pan/tilt unit. There are a couple of options to improve the use of pan/tilt, one is to have preset points that the video camera can be moved to, the other is to discuss this with the system operators during training. The present system requires quite a bit of patience. This is one of the reasons that another camera and pan/tilt platform is being recommended for production and phase II.

4. History and Playback – series of photos. Originally, the design desired that a series of photos be available in storage to view when a violation occurred. Because of the many versions of software necessary to integrate with the digital camera (video compression) and the slower than anticipated frame rate, the software application is capturing only one snapshot, each time a violation occurs.

5. Control box – priority for EV, handheld, web site, manual. It quickly became apparent during the testing and evaluation phase that it was desirable to have more ways to open and close the gates. Thus, for the production phase of this project, two additional means of control have been added. The handheld option for controlling the gates and signs via a “garage door opener” style of device is presented. See Figures 19 and 20. Another issue to determine is the sequence for closing an intersection. The system is configured, presently, to operate each device (gate or sign) one at a time. Initially the system was configured to operate given two choices – close the eastbound lanes and/or
close the westbound lanes. This will be an issue that can be discussed after some data is collected during the next winter season. The gates and signs can be set up as a gang switch where one button push can activate a series of device activations based on a predetermined timing scheme.

6. Communications options. This project has highlighted several communications options and challenges. Attachment A and Attachment B provide insight into the decision process for using wireless connectivity for the communications subsystem. The ideas behind this decision was to attempt wireless to provide a testbed vehicle for wireless connectivity in rural areas, to measure the frame rate and resolution of video over a variety of connections, and to anticipate the improvement of wireless Ethernet, spread spectrum radio, and wireless Internet within the communications industry. The following means of communications were explored as part of this project – wireless DSL, 900 MHz spread spectrum, 5.8 GHz broadband, 450 MHz spread spectrum, landline DSL, line of sight (LOS), microwave relay, and omni directional and dish antennas.

7. Web site – internet access. The issues surrounding web site security will need to be addressed in the future. Determination of access to the web site from Mn/DOT infrastructure (inside the firewall) and from external sources (outside the firewall) will play an important role into how the system interfaces with other Mn/DOT software applications and databases.

8. Traffic Operations Control Center. The software application has proved to be very capable and can be used in the future to control a variety of other devices from the Windom District 7B offices. This could include other traffic cameras, changeable message signs, traffic counters, speed detectors, RWIS stations, and other traffic monitoring cameras.

9. Open Architecture. This project promoted and delivered an open architecture system. Using internet protocol (IP) addressed radios, cameras, and devices, as well as, storing data in an ASCII comma delimited text format provides the system with many more options for integrating with other Mn/DOT software applications.

V. SUMMARY

A. Research Continues. As with camouflage and harassment, research is continuous. There are three main topics that are presently undergoing research and development and may prove to be added to this project.

- Video and violation detection using another video/pan/tilt platform.
- Communications using wireless links and fiber-optics.
- Advanced warning signs that meet highway safety standards and provide messaging options to the traffic operations control center.
B. Features. The following items briefly describe the features of the automated gate
closure system as installed at the intersection of I-90 and US 71 in Jackson, MN.

- Closure and opening of freeway gates
- Activation of advance warning signs
- View and record real-time video surveillance
- Wireless technology for remote areas
- Open architecture design and integration
- Violation detection with snapshot history file
- Report generator of gate activations, violations, diagnostics
- Five methods of control for agency use

Attachment A – Research Report; published under separate cover August 2001
Attachment B – Work Plan; published under separate cover October 2001
Attachment C – Training Documentation; published May 2002
Attachment D – Equipment Manuals; distributed under separate cover April 2002