Silicon Valley Smart Corridor: Final Evaluation Report

Submitted by:

Science Applications International Corporation

September 24, 2003

U.S. Department of Transportation

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Comments on this report should be provided to SAIC by email, fax or mail, addressed to:

Mark Carter
Science Applications International Corporation
c/o FHWA
400 7th St SW, Room 3416
Washington, DC 20590
202-366-2196 (phone)
202-493-2027 (fax)
mark.r.carter@saic.com

1. Report No.
FHWA-OP-03-XXX

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle

Silicon Valley Smart Corridor: Final Evaluation Report

5. Report Date
August 2003

6. Performing Organization Code

7. Authors

M. Carter (SAIC), A. Chandra (CSI), T. Luttrell (SAIC), D. Sallman (CSI),

8. Performing Organization Report No.

9. Performing Organization Name and Address

Science Applications International Corporation (SAIC)
8301 Greensboro Drive, MS E76
McLean, VA 22101

Cambridge Systematics Incorporated (CSI)
1300 Clay Street, Suite 1010
Oakland, CA 94612

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
DTFH61-96-C-00098; Task 9809 / 9829

12. Sponsoring Agency Name and Address

United States Department of Transportation
ITS Joint Program Office, HOIT-1
400 7th Street SW
Washington, DC 20590

13. Type of Report and Period Covered

14. Sponsoring Agency Code
HOIT-1

15. Supplementary Notes
Dr. Joseph I. Peters (COTR)

16. Abstract

This document summarizes the findings from the evaluation of the integrated freeway, arterial, and incident management system known as the Silicon Valley Smart Corridor (SVSC). Centered along the Highway 17/Interstate 880 corridor in San Jose, California, the SVSC was one of approximately 65 deployments occurring nationally under the direction and partial funding of the FY 1999 National ITS Integration Earmark Program, and one of eight sites selected for targeted, independent national evaluation.

The SVSC system was designed to demonstrate measurable safety and mobility benefits in a critical commuter corridor in the Silicon Valley Region. Unfortunately, the implementation was plagued by a series of delays, including continual cuts to the system's fiber network. In addition, baseline data collection and analysis revealed that even when the system did become operational, it was unlikely to deliver significant benefits within a reasonable period of time. A crumbling regional economy and inadequate project planning both contributed to this situation.

This document summarizes the results of the evaluation of the SVSC and presents the status of the deployment as of December 31, 2002.

Key Words
Freeway Management, Arterial Management, Intelligent Transportation Systems, ITS, Evaluation, Deployment Program

18. Distribution Statement
No restrictions. This document is available to the public from: The National Technical Information Service,
Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21.No of Pages	22. Price
Unclassified	Unclassified	50	N/A

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EXECUTIVE SUMMARY

This document presents the evaluation of the integrated freeway, arterial, and incident management system known as the Silicon Valley Smart Corridor (SVSC). Centered along the Highway 17/Interstate 880 corridor in San Jose, California, the SVSC was one of approximately 65 deployments occurring nationally under the direction and partial funding of the FY 1999 National ITS Integration Earmark Program, and one of eight sites selected for targeted, independent national evaluation.

Unfortunately, the implementation was plagued by a series of delays, including continual cuts to the system's fiber network. In addition, baseline data collection and analysis revealed that even when the system did become operational, it was unlikely to demonstrate significant impacts under current conditions. Specifically, the parallel arterial that the project was intended to relieve was found to have substantial capacity even during incidents. Traffic congestion that was anticipated at the outset of the project design never did materialize. This appears to have been a consequence of imprecise planning and a dramatic decrease in the economy of the Silicon Valley region.

Consequently, a planned 'after' data collection and analysis of the system was cancelled prior to the full culmination of the deployment. During the course of the initial phases of the evaluation, however, much valuable information was gathered related to the baseline conditions and lessons learned during the implementation phase of the deployment. This document summarizes these findings.

Evaluation Summary

The SVSC deployment represented an integration of numerous components, across jurisdictional boundaries, to provide an integrated approach to freeway and arterial corridor management during incident conditions. The evaluation team began an effort in 1999 to evaluate the system impacts of the deployment, including mobility, safety, customer satisfaction, and institutional coordination. An evaluation plan was developed and baseline data related to these impacts were collected using various techniques including: travel time runs, video capture of intersection performance, speed detectors, internet-based traveler surveys, and personal interviews. The goal of this effort was to provide a suitable assessment of the baseline conditions for comparison with data collection following the system deployment. The findings from this baseline assessment are included in this report.

Mobility Study

The findings of the mobility study describe statistics related to travel time and speed during incident and non-incident conditions in the corridor. The average travel time was 17 minutes and zero seconds, and was seven seconds longer for incident than for non-incident travel time runs. The average speed was 22.5 miles per hour, 0.4 miles per hour faster for non-incident travel time runs. These differences were not significant given the overall variation in the travel times (standard deviation of one minute and 59 seconds) and speed (standard deviation of 2.6 miles per hour). After correcting for day-by-day and hour-by-hour variations in the travel times, non-incident travel times appeared to be about three seconds slower than incident travel times, an insignificant difference. This analysis indicates that, for the incidents that occurred during the study period, there is little difference between the travel time and other mobility statistics resulting from those incidents.

Safety Study

During the initial data collection period, current and historical crash data were collected for the corridor. The random and infrequent nature of crashes in the corridor, combined with data collection constraints, caused the evaluation team to conclude that the analysis of the number of crashes in the before and after periods was unlikely to generate any meaningful findings. Therefore, methods of supplementing this safety analysis were explored, and the analysis of speed variability data was ultimately selected as the best surrogate for crashes in the safety analysis.

Speed variability detectors were deployed at key locations along the corridor and used to collect data. The data were then analyzed and separated into different data sets representing incident and non-incident conditions. The mean speeds in the two scenarios were analyzed and were not observed to have any appreciable difference between incident and non-incident conditions. The speed variability was analyzed by comparing the distribution of speeds from individual vehicles in the two different scenarios. This analysis also was unable to identify a statistically significant difference between the incident and non-incident conditions. Since no meaningful deterioration in speed variability was observed during incident conditions observed during the data collection, no conclusions can be reached regarding increased crash risks on the corridor during these conditions.

Customer Satisfaction Study

The purpose of the *Customer Satisfaction Study* was to assess motorist perception of and satisfaction with traffic operations along the corridor, both before and after system implementation. Data collection and analysis for this study was primarily focused on the post-deployment (Phase III) scenario; however, the data collection methodology was established in the baseline phase and captured some preliminary results. An innovative Internet based panel survey was used to identify and question corridor travelers on their travel patterns. The findings from this effort revealed that corridor travelers frequently encounter incident related congestion (more than twice a month) and that nearly half of the respondents divert from the freeway when congestion is encountered.

Institutional Study

The progress made to date on improving interagency coordination has been significant, yet many obstacles remain. The project partners with the most direct day-to-day role in the project have reported improved coordination and understanding among their agencies. However, improvement in interagency coordination with some of the more peripheral partners has fallen short of many of the partners' expectations.

In implementing the Smart Corridor technologies, the most significant difficulty faced by the project partners involved the deployment and maintenance of the system's fiber-optic communications infrastructure. Various project partners identified the fiber-optic deployment as the most problematic component of the integration.

Several project partners reported that institutional issues, specifically the inability to reach an agreement specifying the operational policies in a timely matter, served as greater impediments throughout the deployment process.

Summary of the Evaluation Opportunity

Several factors that limited the opportunity for conducting a meaningful evaluation of system performance are presented in this report. These factors include:

- The inability to identify any statistically significant traffic deterioration on Bascom Avenue during incident conditions on Highway 17;
- The lack of reliable automated data sources to monitor conditions over a longer term;
- The rapidly changing traffic patterns in the region due to economic boom/bust cycles; and
- Further delays in the deployment schedule.

Presented with these limiting factors, the evaluation team did not recommend the continuance of the Phase III system performance evaluation efforts. Since the evaluation team has not been able to identify any worsening of congestion during incident conditions in the baseline data collection, it is unlikely that any meaningful before/after performance impacts will be able to be identified.

FHWA agreed with this assessment of evaluation opportunity, following a briefing presented in June 2002, and approved the cancellation of the 'after' data collection and analysis. Although the evaluation and the system did not reveal any meaningful performance impacts, several important lessons were learned from the effort that may be useful to agencies considering these types of deployments, as well as evaluators looking to assess these deployments. Therefore, FHWA authorized the evaluation team to develop this Final Evaluation Report summarizing the evaluation approach, the baseline findings, and the lessons learned to conclude the evaluation effort.

1.0 INTRODUCTION

1.1 Purpose

This document outlines the evaluation strategy and presents baseline findings from the evaluation of the integrated freeway, arterial, and incident management system known as the Silicon Valley Smart Corridor (SVSC). Centered in San Jose, California, the SVSC is one of approximately 65 deployments occurring nationally under the direction and partial funding of the FY 1999 National ITS Integration Earmark Program.

This national program, born under the auspices of the Transportation Equity Act for the 21st Century (TEA-21), is designed to accelerate the integration and interoperability of ITS across system, jurisdictional, and modal boundaries. Projects approved for funding under the program are intended to support increased transportation efficiency, promote safety, increase traffic flow, reduce emissions of air pollutants, improve traveler information, enhance alternative transportation modes, build on existing ITS projects, and/or promote tourism.

The Silicon Valley Smart Corridor project was initiated to address many of these goals. Using advanced technologies and real-time system management techniques, the project seeks to keep all transportation facilities within the region's critical State Highway Route 17 and Interstate 880 (SR 17/I-880) corridor operating at maximum efficiency, even when following a major disruptive incident. Based upon a partnership of several agencies, the system combines advanced freeway, arterial and incident management techniques and resources to reduce delays.

To investigate the success of the SVSC deployment in meeting these goals and to provide insights into the potential strengths and weaknesses of the overall national integration program, the SVSC was one of eight sites selected for targeted, independent national evaluation. For various reasons, discussed in Section 7 of this document, the evaluation of the SVSC was completed prior to the full culmination of the deployment. During the course of the initial phases of the evaluation, however, much valuable information was gathered related to the baseline conditions and lessons learned during the implementation phase of the deployment. This document summarizes these findings and is structured into the following sections:

- **Section 1 – Introduction –** Provides background information on the project, including project participants, planned deployment schedule, system components, and system objectives.
- **Section 2 – Evaluation Plan –** Discusses guidelines used for conducting the evaluation, identifies evaluation objectives and measures, and defines the evaluation approach.
- **Section 3 – Mobility Study –** Details the approach and baseline results related to traveler mobility.
- **Section 4 – Safety Study –** Details the approach and baseline results related to traveler safety.

- **Section 5 – Customer Satisfaction Study –** Presents the findings from the analysis of customer satisfaction.
- **Section 6 – Institutional Study –** Details findings related to interagency coordination and implementation issues.
- **Section 7 – Evaluation Risk Assessment –** Presents the opportunities and risks associated with continuing the evaluation activities in the post-deployment scenario and discusses the reasons for not continuing the evaluation.

1.2 Project Background

As the heart of Silicon Valley, the San Jose area experienced significant growth during the late 1990s. Between 1992 and 1999, over 250,000 new jobs were added to the area, and a further 200,000 jobs are expected by 2010. Not surprisingly, this economic growth was accompanied by a substantial increase in roadway congestion and traveler concerns.

Recognizing these concerns, local officials launched a multi-prong approach to deal with the problem. First, they began working towards providing additional capacity by taking advantage of a local sales tax initiative to obtain nearly $1.4 billion in new road, rail and bicycle improvements before 2006. Second, they began reducing demands through the promotion of integrated transportation and land use philosophies, such as offering transit incentives and ensuring a healthier job/housing balance. Finally, they set out to develop strategies that neither add significant capacity nor reduce demands, but rather better manage existing conditions. A significant element of this third prong is the SVSC.

The SVSC Project was initiated in 1994 with the development of a feasibility study. This feasibility study identified a program to implement ITS elements for the I-880/SR 17 corridor. The Smart Corridor defined in the feasibility study extends approximately 15 miles from the City of Milpitas in the north, to the Town of Los Gatos in the south. This evaluation focuses on one specific section of the corridor that is described in Section 1.3.

Different integrated sub-systems were identified and planned for deployment, including closed-circuit television traffic surveillance, message signs, coordinated signal timings, and communication infrastructure. Completion of the initial implementation was anticipated in August 2000; however, several project setbacks have delayed full deployment until 2003. Future phases of the project will expand the geographic coverage of the deployment and are anticipated to integrate additional systems with the project, such as traveler information and public transit systems. The goals of corridor improvements identified by the project participants include[1]:

- Minimum intrusion of freeway traffic onto local streets due to freeway congestion and freeway incidents;
- More rapid response to and clearing of incidents on both the freeway and surface streets;

[1] *I-880/SR 17 Smart Corridor Improvements: Project Information for Participation in the ITS Integration Component of the ITS Deployment Program*, Santa Clara Valley Transportation Authority, 1999.

- Active management of traffic diverted from the freeway to minimize its impacts on the arterial;
- Improved traffic signal coordination that is responsive to fluctuations in demand;
- Improved collection and dissemination of current travel condition information;
- Coordination of these activities between agencies; and
- Sharing resources among agencies.

When fully implemented, the system is intended to improve traffic management capabilities on freeways and arterials for selected routes in the corridor. It is anticipated that this initial implementation will facilitate the future integration with other systems and jurisdictions.

Twelve various local, regional, and state agencies involved in the integrated effort entered into a joint agreement in 1999. The Santa Clara Valley Transportation Authority (VTA) was designated as the program coordinator responsible for leading efforts related to funding, programming, grants, and county-wide planning.

The City of San Jose is the lead program manager, responsible for technical program management and design/engineering contract management.

The Silicon Valley ITS (SVITS) Program Steering Committee is made up of participants from the various agencies. Partner jurisdictions are shown in Table 1.1. The SVITS Committee meets monthly to discuss issues surrounding the project.

Table 1.1 Silicon Valley Smart Corridor Project Partners

• City of San Jose	• City of Milpitas
• City of Campbell	• City of Santa Clara
• Town of Los Gatos	• County of Santa Clara
• Santa Clara Valley Transportation Authority (VTA)	• Metropolitan Transportation Commission (MTC) and TravInfo
• California Department of Transportation (Caltrans)	• Alameda County Congestion Management Agency (AC/CMA)
• City of Fremont	• California Highway Patrol (CHP)

An oversight committee, the ITS Task Force, provides overall guidance for the ITS planning effort. The committee reports to the VTA's Technical Advisory Committee, composed of public works and planning directors from the County of Santa Clara and its 15 cities and towns. The ITS Task Force is composed of representatives from each of these agencies and the Valley Transportation Authority. The committee also includes ex-officio members from MTC, Caltrans, CHP, and the Federal Highway Administration.

1.2.2 Project Schedule

Original schedules estimated the initial deployment and integration of Smart Corridor components to be completed by 2000. Several delays have resulted in the extension of this schedule. While the deployment of components has generally proceeded according to schedule, the integration of previously deployed components with the new equipment has proven to be the more difficult task. This has required a greater amount of time than was first anticipated and has been complicated by the fragmented nature of each jurisdiction's previously deployed systems.

Progress has been made and the integrated system deployed on the northbound section of Bascom Avenue was fully operational in the summer of 2003. This section of the Smart Corridor was the focus of a large part of the evaluation effort.

The build-out of the next project phase will expand the communication infrastructure and data sharing capabilities to additional jurisdictions. Components will also be added to project corridors to provide additional coverage and data collection capabilities. Longer-term plans call for the geographic expansion of the system and the possible integration with other sub-systems, including public transit and traveler information systems. The Smart Corridor project is envisioned as a 10-year project. Following the implementation of the initial components, the project partners plan to continue adding management capabilities and integrate the system with additional jurisdictions to address other regional transportation needs.

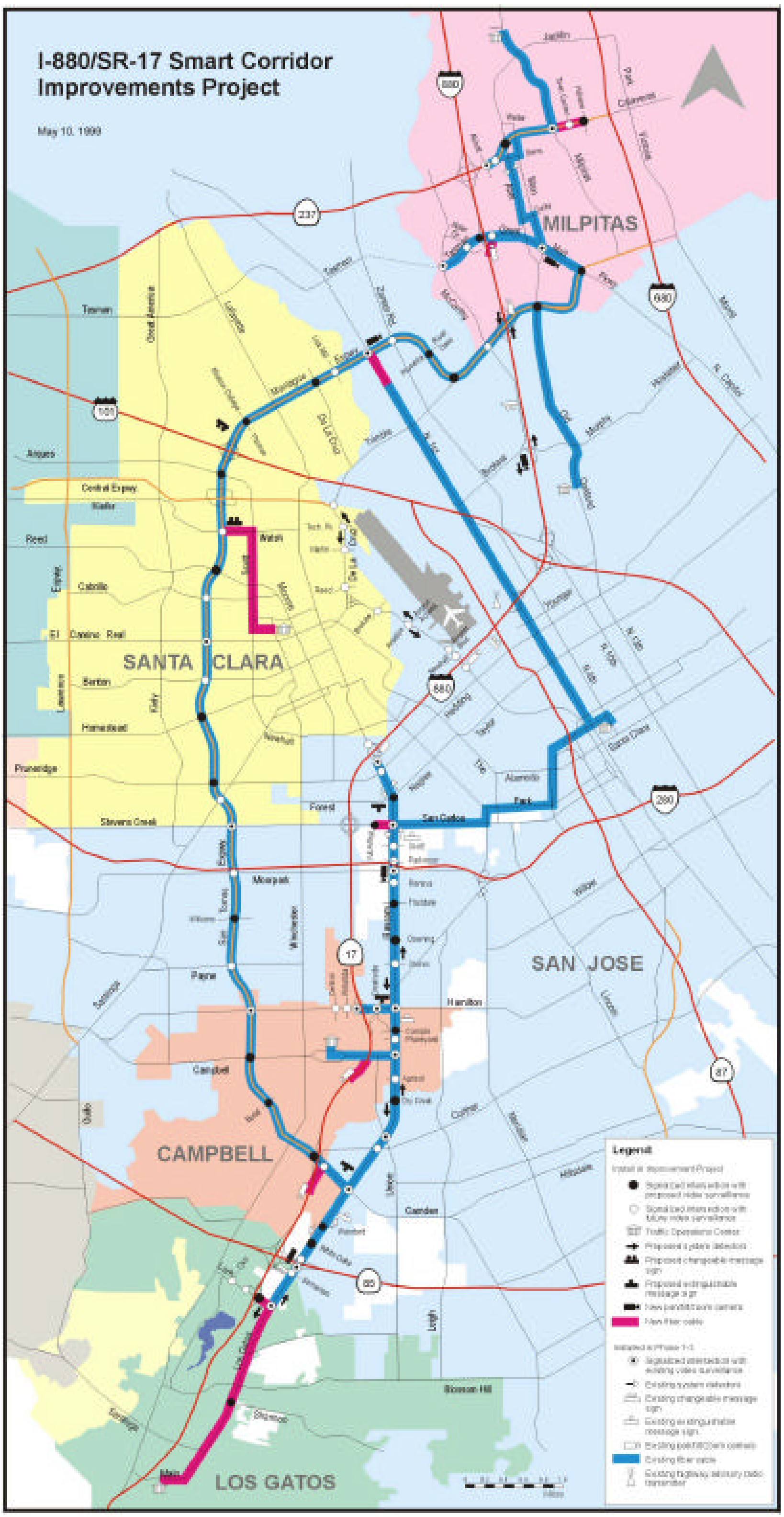
1.3 System Description

The Silicon Valley Smart Corridor Project involves the integration of arterial traffic management, freeway traffic management, and incident management capabilities along a 15-mile corridor traversing a number of Silicon Valley communities. The integration includes ITS components owned and operated by over 10 different transportation agencies. The section of the Smart Corridor under evaluation roughly parallels the SR 17/I-880 corridor. This corridor includes a major north/south freeway facility leading from Santa Cruz County and exurban areas in the south to downtown San Jose, the San Jose International Airport, and major Silicon Valley and East Bay employment centers to the north.

Besides the freeway itself, the corridor includes several additional north/south roadways, including the San Thomas and Montague Expressways and Bascom Avenue. These parallel roadways carry large volumes of through and local traffic, and serve as diversionary routes when the freeway is overly congested due to incidents.

The system consists of numerous components located along the Smart Corridor routes, as shown in Figure 1.1. These components include integrated freeway management, arterial management, and incident management components. Of primary interest to the evaluation were the system components deployed in the vicinity of Bascom Avenue as it parallels SR 17 near the southern portion of the project boundaries.

Figure 1.1 Overview of Smart Corridor Components



Source: DKS Associates.

Bascom Avenue is a four-lane arterial that closely parallels I-880/SR 17 and provides a potential diversionary route for travelers attempting to avoid incident backups on the freeway. The study corridor is bound on the south by Lark Avenue in the City of Los Gatos, and on the north at the I-880 interchange in San Jose. This four-mile arterial corridor crosses the jurisdictions of Los Gatos, Campbell, Santa Clara County, and San Jose. In addition, Caltrans maintains responsibility for the parallel sections of I-880 and SR 17. This subsection of the Silicon Valley Smart Corridor project was selected for evaluation as it represented the greatest concentration of integrated components and best opportunity to test the impact of this integration.

The following sections provide detail on the planned location and operation of ITS components deployed along the Bascom Avenue corridor. Details are also provided on the project participant's objectives for implementing and operating this integrated deployment.

1.3.1 System Components

When fully deployed, the SR 17 and Bascom Avenue corridors will contain integrated elements of freeway management, incident management and arterial management components. These components include:

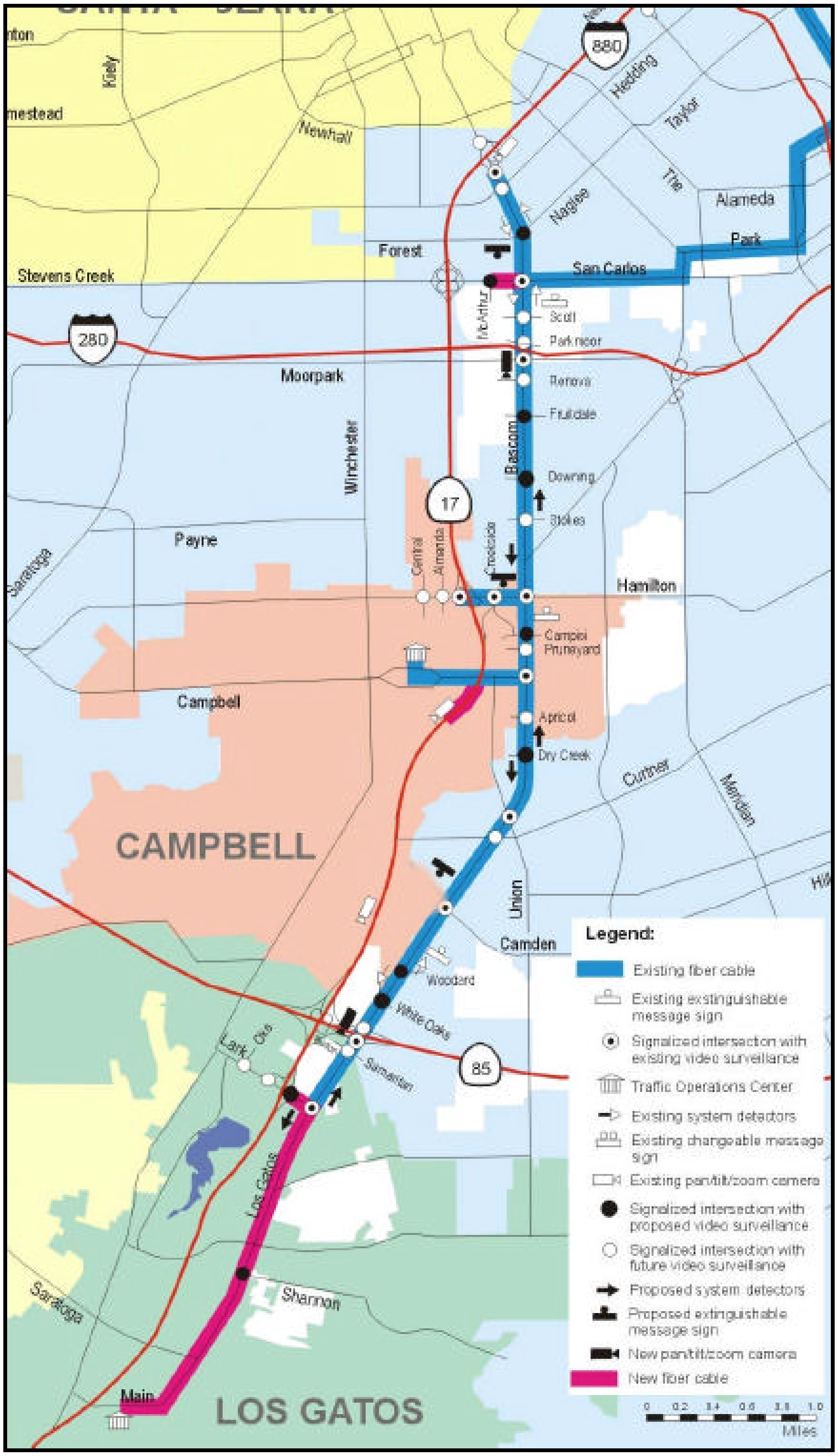
- Communications infrastructure;
- CCTV traffic surveillance;
- Freeway variable message signs;
- Arterial "trailblazer" signs (extinguishable message signs);
- Pavement traffic detectors;
- Coordinated traffic signal timing; and
- Traffic management centers.

Separate traffic management centers are operated by Caltrans, the City of San Jose, Santa Clara County, the City of Campbell, and the City of Los Gatos. In the past, each traffic management center functioned independently in the operation of signals and other ITS components along the Bascom Avenue or SR 17/I-880 rights-of-way. A fiber-optic communications infrastructure has been deployed as part of the Smart Corridor project to link the various TMCs with each other and the various components along the corridor. A detailed view of the corridor components is presented as Figure 1.2.

Traffic surveillance and incident detection capabilities along SR 17 are provided by the deployment of surveillance cameras. Freeway management capabilities are supported by the deployment of two variable message signs. Ramp metering is deployed along the freeway corridor, but is not integrated as part of the Smart Corridor system.

Arterial traffic management capabilities are provided by the integration of 26 individual signalized intersections (operated by five separate jurisdictions) with the communication infrastructure. Camera traffic surveillance (Figure 1.3) is currently available at eight

Figure 1.2 Detail of the Bascom Avenue Corridor



Source: DKS Associates.

Figure 1.3 View from CCTV at Bascom Avenue and SR 85

Bascom Avenue intersections, with seven more intersections to be equipped in the next phase of the project. Additional surveillance is provided by in-pavement loop detection systems capable of collecting volume and speed data at five mid-block locations. Six additional loop detection locations are planned along Bascom Avenue during the next phase of the project.

Trailblazer signs are currently installed at three locations along Bascom Avenue – just south of the intersections of Camden, Hamilton, and San Carlos Avenues. These signs are targeted at the northbound traffic and are located immediately prior to strategic decision points. Specifically, the signs are placed at locations where northbound travelers could take a left turn onto cross streets to access on-ramps to SR 17. As Figure 1.4 indicates, the trailblazer signs are relatively simple in design and are intended to provide direction for those drivers wanting to access SR 17. The signs either indicate the SR 17 logo with a left arrow, or with a forward arrow indicating that the driver should stay on Bascom and access SR 17 at a point further upstream. The default message is blank. Although installed, these signs have not yet been used during incident conditions.

In the initial phase of the Smart Corridor project, most components have been deployed to aid in the management and control of traffic traveling northbound along the corridor. This is the prevalent direction of travel in the morning peak period. Additional components are planned in future phases to provide the same capabilities for the southbound direction.

Figure 1.4 Trailblazer Arterial Message Sign

1.3.2 System Operation

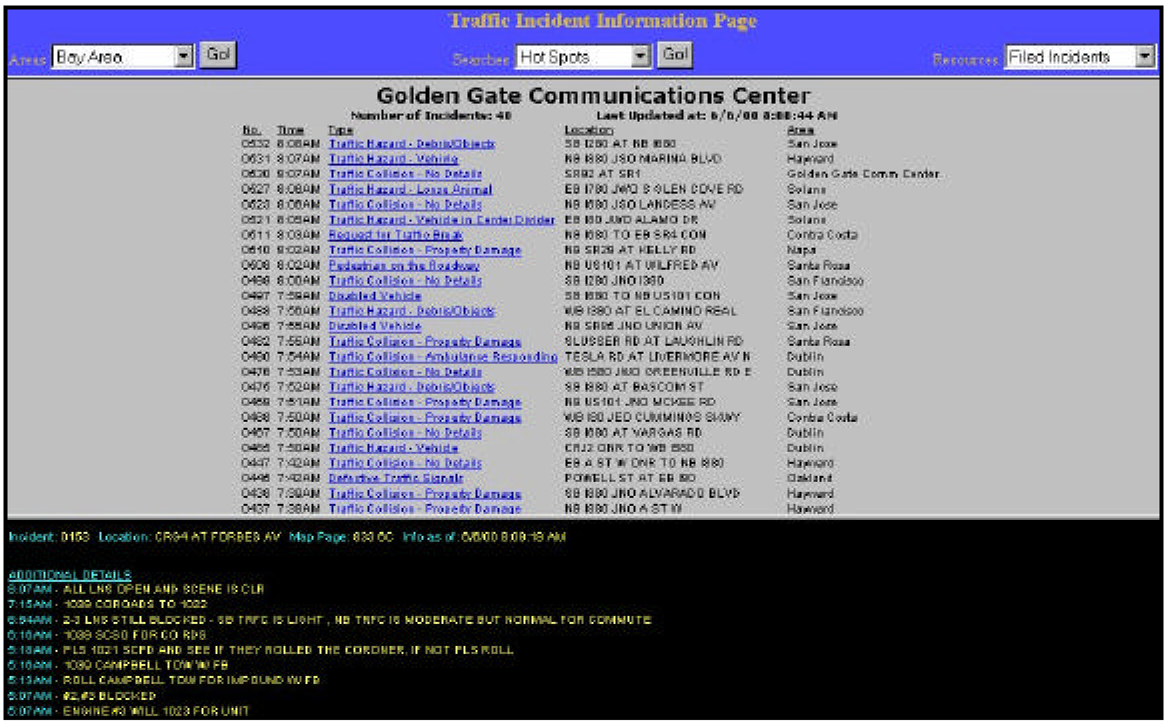
In the past, each jurisdiction operated their own signals and components independent of the other jurisdictions. In the event of an incident on SR 17, travelers will divert from the freeway as a result of information received from the variable message signs, radio traffic reports, or the traveler's own knowledge of corridor characteristics. This diverted traffic is thought to add to the local and through traffic on Bascom Avenue, negatively impacting corridor operations.

Prior to the deployment, each jurisdiction attempted to mitigate the impact of the diverted traffic by modifying their signal timing plans to adapt to the additional diverted traffic. Coordination between jurisdictions was limited, often consisting of a telephone call between traffic operations personnel. The various jurisdictions also did not have access to the traffic surveillance capabilities of the neighboring jurisdictions, so operational adjustments were based on localized information.

The Smart Corridor project is intended to link all the traffic management centers and to allow greatly improved sharing of information among the various jurisdictions. The communications infrastructure will be integrated with all the components along Bascom Avenue to allow joint operation and control when necessary. During typical conditions, jurisdictions providing operational control of components along Bascom will operate the system according to current plans. Existing time-of-day signal timing strategies will be employed by the various jurisdictions according to historical traffic patterns.

In the event of an incident on I-880/SR 17, the Smart Corridor components may be activated and operated as an integrated system to lessen the impact of the non-recurring congestion. Caltrans operates 24-hour incident detection capabilities via CCTV surveillance through its TMC located in Oakland (approximately 40 miles north of the corridor). Caltrans also monitors the CAD incident reporting site maintained by the California Highway Patrol, which provides summaries of all incoming distress and 911 emergency calls. Figure 1.5 presents a view of the CHP CAD incident data. If an incident is detected along the freeway, Caltrans attempts to verify the location and severity of the incident using the video cameras. Caltrans also has several incident response vehicles available, which may be dispatched to verify and clear the incident.

Figure 1.5 View of the CHP CAD Incident Data



Based on an analysis of the incident severity and anticipated duration, Caltrans may use the variable message signs located on the corridor to warn drivers of the upstream congestion. The VMS messages will be informational only and will not offer route guidance or divert travelers to surface streets.

If the incident is determined to be significant (roughly judged as blocking one or more lanes of traffic for more than one-half hour), Caltrans will contact the City of San Jose traffic management center. Personnel at the San Jose TMC will have access to the Caltrans cameras, as well as cameras located at Bascom Avenue intersections in Los Gatos and Campbell. The San Jose TMC will use this information to judge the severity of the situation and determine the amount of traffic diverting from the freeway.

If the traffic diverting onto Bascom Avenue is deemed significant, the San Jose TMC may implement several different strategies. The most significant is the integrated operation of all signals along the corridor from a coordinated plan designed to "flush" the added arterial traffic, which diverts from the freeway, by borrowing green phase time from the cross streets. The plans were developed to favor movements that divert traffic off and back on to the freeway. The arterial has been divided into feasible segments for the purpose of signal timing, with each segment sharing a common cycle length (each signal is set to the highest cycle length currently used in each segment). The plans add capacity to the priority direction and provide for smooth progression through each segment along Bascom Avenue.

The San Jose TMC can implement this plan and acquire control over signals in all jurisdictions based on the judgment of personnel. Although permission from the other jurisdictions is not a requirement of implementing the system, personnel at the San Jose TMC will contact the other agencies' TMCs to inform them of the flush plan implementation.

The second management strategy available to the TMC personnel is the guidance provided by the trailblazer signs. These signs, located at key decision points along the corridor, can be used to guide diverted traffic to the easiest freeway access point. If the freeway incident is downstream from the decision point, the trailblazer sign will direct traffic off of Bascom and back onto the freeway. If the incident is upstream from the decision point, the trailblazer signs will direct travelers to stay on Bascom until they have passed the incident location.

Once the incident backup has cleared from the freeway and diverted traffic has cleared the Bascom corridor, the San Jose TMC will relinquish the integrated control of the traffic signals to the respective jurisdictions and extinguish the trailblazer sign message. Caltrans will likewise extinguish the message displayed on the freeway VMS.

1.2.3 System Objective

The Smart Corridor project brings together agencies and organizations in the Silicon Valley area and promotes regional coordination and cooperation. The impetus for this integrated approach to traffic operations was the desire among project participants to minimize the negative impacts caused by freeway incidents and the resulting diversion of traffic onto surface streets.

Participating project agencies report that many of the current corridor travelers maintain a high degree of knowledge of alternative routes along the SR 17 corridor and often do not hesitate to divert when they encounter unusual congestion levels. Once diverted, however, these drivers add to congestion levels on already heavily traveled major arterials, negatively impacting existing local and through travelers on these facilities. The added congestion also greatly increases the crash risk along the arterial corridors.

The Smart Corridor system was implemented to reduce the delay experienced by existing and diverted travelers along Bascom Avenue during incident conditions on I-880/SR 17. Project participants indicated the improvement of mobility as their primary objective in implementing the integrated system. The smoothing of the traffic flow and the reduction in the number of crashes occurring in the corridor was another major objective. The sharing of information and improvement of coordination among the corridor jurisdictions was also cited as an important objective.

Although the Smart Corridor project incorporates freeway management capabilities in the design of the system, it should be noted that the improvement of freeway travel conditions was not a primary goal of the deployment. Following the implementation of the system, the operating procedures on SR 17 are anticipated to remain largely unchanged. There was not an expressed goal of increasing the amount of traffic diverted from the freeway. Instead, the objective expressed by project participants was to minimize the diversion of freeway traffic onto local streets and to mitigate the traffic that already diverts to improve arterial operations. Consistent with this objective, the Bascom Avenue improvements were not heavily publicized by the implementing agencies. While some improvement in freeway conditions may result as an indirect impact of the system, the focus of the integrated implementation is to improve surface street conditions.

2.0 EVALUATION APPROACH

2.1 Purpose

The Silicon Valley Smart Corridor project was selected by the FHWA for evaluation in 1999 as a *System Impact Study*. The Smart Corridor project was selected because it was perceived as an opportunity to collect quality system impact data in areas, such as safety performance, system operational performance, and customer satisfaction, along with qualitative documentation of lessons learned.

The overall goals of the Silicon Valley Smart Corridor Evaluation were to provide a quantitative analysis of the system impacts for the integration of freeway management with arterial and incident management, and identify qualitative lessons learned. These impacts and issues were carefully explored and documented to help provide guidance for other regions considering similar integration projects. The findings of this evaluation may be used by other agencies to assess the appropriateness of ITS integration as a potential solution to locally identified needs.

The evaluation guidelines for the ITS Integration Program specifies that system impact evaluations are conducted in a series of distinct phases, including:

- **Phase I –** The preliminary identification of anticipated impacts of ITS Integration Program projects and the screening of projects that provide favorable opportunities to collect meaningful evaluation data, the selection of a few representative projects to serve as *Case Study/Lessons Learned* qualitative studies, and the selection of a subset of this group to serve as more quantitatively detailed *System Impact Studies*.

- **Phase II –** This evaluation phase is intended to develop and implement the preliminary evaluation approach resulting in the collection and analysis of baseline data. This phase also provides a formal opportunity to assess whether or not a project evaluation will be completed in a reasonable timeframe and to ensure that reliable and usable data will be collected to enable the testing of hypothesis.

- **Phase III –** This future phase was to be conducted if the were indications that the evaluation would provide a favorable opportunity to offer reliable and usable data for the testing of hypothesis during the implementation of Phase II. If warranted, data would have been collected following system implementation to determine the change from the baseline and provide measurement of the incremental system impact.

Following the conduct of Phase II, the evaluation team concluded that the SVSC deployment was unlikely to provide the quality evaluation opportunity originally envisioned for the project. Section 7 discusses the reasons that led the evaluation team to recommend the discontinuation of the system impact evaluation. FHWA concurred with this recommendation and the planned evaluation of the post-deployment conditions was discontinued. Despite the discontinuation of the post-deployment evaluation, many valuable lessons were learned from the conduct of the initial phases of the evaluation. This section provides details on the objectives of the evaluation and presents the approach that was used in evaluating the project.

2.2 Evaluation Objectives and Measures

The evaluation of the Silicon Valley Smart Corridor focused on identifying impacts and issues related to four primary objectives, including:

- Safety;
- Mobility;
- Customer Satisfaction; and
- Institutional Issues.

The Silicon Valley Smart Corridor evaluation structure is based on standard evaluation practices. For each evaluation objective, a hypothesis was formulated identifying the anticipated system impact. One or more Measures of Effectiveness (MOEs) was then associated with each hypothesis to assess the accuracy of the hypothesis. Required data and data sources were then identified for each MOE.

Table 2.1 presents the hypothesis to be tested and the measures of effectiveness related to each evaluation objective. The specific data collected during the baseline data collection period is also indicated for each MOE.

2.3 Evaluation Challenges

In order to test the system's impact on traffic mobility in the corridor, an understanding of the baseline traffic conditions was first required. These baseline conditions were analyzed to provide a basis for comparison with data that was anticipated to be collected during the post-deployment scenario.

Complicating the data collection and assessment of the baseline traffic data were two challenges. First, many of the Smart Corridor components are primarily designed to be operational only during incident or non-recurring congestion conditions. Therefore, it was necessary to collect traffic data on these non-normal conditions, as well as the normal baseline corridor conditions. Traffic data collected during these incident conditions was intended to form the baseline for any future comparison with traffic data collected in the post-deployment scenario under system operating conditions.

To address this challenge, an innovative methodology was used to identify and document incidents occurring in the corridor, leveraging the real-time incident data available on the California Highway Patrol's (CHP) Computer Aided Dispatch (CAD) internet site. The time, location, and severity of each incident occurring on the freeway corridor were automatically logged, allowing the later assessment of the incident and the identification of incident vs. non-incident days.

Table 2.1 Evaluation Objectives and Measures

Evaluation Objective	Hypothesis	MOEs	Required Data
Mobility – Reduce travel time in the corridor.	The Smart Corridor will reduce travel time through the corridor during incident conditions.	Change in travel time in the primary direction during incident conditions.	Observed corridor travel time during incident conditions.
		Change in the overall corridor travel time reliability.	Observed travel time variability.
		Change in signal queue lengths during incident conditions.	Observed queue lengths during incident conditions.
Safety – Improve traveler safety in the corridor	The Smart Corridor implementation will reduce accident risks during incident conditions	Changes in the number of crashes or crash severity occurring in the corridor.	Historical crash data. Real-time crash data.
		Changes in speed variability along the corridor during incident conditions.	Observed speed variability during incident conditions.
		Change in the number of conflicts that occur in the corridor during incident conditions.	Observed number of conflict situations occurring during incident conditions
Customer Satisfaction – Improve travel satisfaction for corridor users.	The Smart Corridor will result in improved satisfaction among corridor users.	Corridor traveler perceptions.	Traveler survey responses.
		Corridor traveler behavioral response to system components.	
Institutional – Improve coordination among implementing agencies.	The Smart Corridor will result in improved coordination among implementing agencies	Documented institutional issues.	Documented institutional issues.

The second major challenge facing the evaluation team was related to the Silicon Valley region's dynamic economic and development environment. These changing economic and employment conditions presented the possibility that traffic patterns might change between the "before" and "after" data collection periods. During the evaluation period, the evaluation team was challenged by the effects of both economic expansion and contraction in the region. These rapidly changing economic conditions made it difficult to compare traffic conditions occurring on different dates.

2.4 Evaluation Approach

Several study areas were established for the evaluation to assess the potential for providing reasonable evaluation results. The four study areas centered on the evaluation objectives included:

- **Mobility Study –** Evaluating the system's ability to reduce corridor travel time during incidents and reduce travel time variability;
- **Safety Study –** Evaluating the system's ability to improve traveler safety in the corridor;
- **Customer Satisfaction Study –** Evaluating the system's ability to improve customer (traveler) satisfaction; and
- **Institutional Study –** Documenting qualitative lessons learned during implementation and operation of the integrated system.

Individual test plans were developed for each of the study areas to define the data collection and analysis procedures to be followed. These plans were implemented beginning in August 2000. Sections 3 through 6 detail the data collection plans and findings from each of these study areas.

2.4.1 Baseline Data Collection and Analysis

The baseline data collection was initiated in August 2000. This data collection effort was focused on gathering data related baseline, "pre-deployment" traffic conditions. The data gathered in this initial effort was primarily meant to assess the mobility and safety baseline conditions; however, some additional data related to customer satisfaction and institutional issues was also captured. This initial baseline data collection effort focused on the northbound direction of Bascom Avenue in the morning peak period commute direction, and involved:

- Documentation of all incidents occurring on the SR17/I-880 corridor to isolate "incident" from "non-incident" conditions.
- Floating car travel time runs used to estimate the travel time, travel time reliability, number of stops, delay, travel speed, travel speed reliability, and speed variability conducted over a two week period.
- Intersection approach videotaping used to estimate the intersection volume, and queue length.
- Gathering archived accident and roadway volume data from the project participants.
- Conduct of an Internet-based panel survey to gather perceptions from corridor travelers.

In the initial baseline study, 45 travel time runs and analysis of more than a month of video data for a 6.3-mile section of Bascom Avenue were used to generate baseline estimates of eight mobility statistics, travel time, travel time reliability, number of stops, delay, travel speed, travel speed reliability, speed variability, and queue length. These statistics were evaluated and compared for days on which incidents did and did not occur on the parallel Highway 17/I-880 freeway, so that incident and non-incident values of these baseline statistics could be estimated.

The analysis performed on this data formed the basis for the *Phase II Evaluation Report* submitted in February 2001. This report documented the baseline conditions and noted that travel conditions were observed to deteriorate slightly during incident conditions. Corridor travel times and speeds, and intersection volumes and queue lengths were all observed to worsen during incident conditions; however, the deterioration of these measures was not statistically significant in most instances due to:

- The small degree of variance observed from the "incident" to "non-incident" conditions; and
- The limited number of incident days occurring during the data collection.

The assessment of the evaluation opportunity at that time noted that, although the impact identified was small, the evaluation was not able to capture the impacts of a major incident event (causing the significant restriction or complete closure of the freeway), where the impact was likely to be more significant. Combined with the nearly feverish development pace (and deteriorating traffic conditions) in the Silicon Valley region at the time, the evaluation team felt the deployment remained a strong potential opportunity for evaluation. Recognizing the limitations of the initial baseline assessment, however, additional baseline data collection was proposed to more carefully assess the opportunity and control for the passage of time that had elapsed since the initial data collection.

At the time of the initial baseline assessment, several threats that could impact the evaluation opportunity were identified. The ability of the project partners to maintain their planned deployment schedule was one of the threats identified. Given the rapidly occurring development in the region, it was felt that a significant delay in the deployment could invalidate the initial baseline data. Unfortunately, deployment delays did occur, further increasing the importance of collecting additional data.

Additional baseline data collection was completed in October 2001 using enhanced data collection methodology. Travel time runs were completed using GPS-based locational recorders, and spot speed variability was collected and analyzed at several key locations along the corridor. These enhanced data collection methods were applied to provide more robust data sets in which to draw conclusions regarding the level of diversion and related negative traffic conditions on Bascom Avenue during incident conditions.

Analysis of the collected data showed that the conditions from both data collection periods were generally comparable. Using the enhanced data sets, however, the evaluation team was unable to find any significant deterioration in traffic conditions on Bascom Avenue resulting from incidents occurring on the Highway 17/I-880 corridor. While several multi-vehicle crashes were observed during both the initial and enhanced data collection period, the evaluation team was unable to evaluate travel conditions during a major incident that resulted in a closure of several lanes of the freeway for an extended period time (greater than one hour). Under these circumstances, there may be greatly increased diversion to the parallel arterial roadways, but the evaluation team was unable to gather evidence that supports this possibility. These major incident events do not appear to occur with sufficient frequency to lend themselves to reliable evaluation. Fully automated sources of data would need to be obtained for long periods of time to capture these impacts and reliable sources for these types of data have not been found.

Difficulties in assessing the traffic conditions during impact conditions were greatly exacerbated by a dramatic decrease in travel demand. This decrease was largely a result of a significant slowing of the economy and a decrease in computer technology employment in the region. This reduction in congestion had the effect of reducing the overall number of incidents occurring on Highway 17, as well as likely reducing the incentive for travelers to divert to surface streets to avoid any incident-related congestion.

For these reasons, among others summarized in Section 7, the evaluation of the Silicon Valley Smart Corridor was discontinued and the planned collection of post-deployment data was not completed.

2.4.2 Evaluation Deliverables

Several important deliverables were generated in conducting the evaluation of the Silicon Valley Smart Corridor. The deliverables and the date they were submitted are presented in Table 2.2.

Table 2.2 Evaluation Deliverables

Deliverable	Date Submitted
Evaluation Plan	June 2000
Phase II Evaluation Report	February 2001
Addendum to the Phase II Evaluation Report	April 2002
Final Evaluation Report	August 2003

3.0 MOBILITY STUDY

3.1 Purpose

The purpose of the mobility study was to collect and analyze data related to a change in mobility resulting from the Smart Corridor deployment. Specifically, four measures of effectiveness were selected to test the impact on traveler mobility resulting from deployment, including:

- Change in travel time in the primary direction during incident conditions;
- Change in the overall corridor travel time reliability;
- Change in travel time on cross-links during incident conditions; and
- Change in signal queue lengths during incident conditions.

Although the evaluation was not conducted during post-deployment conditions to allow the identification of system impacts, a large amount of baseline data were collected and analyzed. The following sections document the data analysis methodologies and findings related to mobility.

3.2 Data Collection and Analysis Plan

During the period of August 21, 2000 through August 31, 2000, a probe vehicle was used to make 45 travel time runs used to estimate the mobility statistics travel time, travel time reliability, number of stops, delay, travel speed, travel speed reliability, and speed variability. In addition, video data were used to estimate queue lengths at several intersections on the study route. One of the results of this analysis was the observation that the day-to-day and hour-to-hour variability in the travel times and other mobility statistics made it difficult to differentiate between differences in mobility caused by incidents and those related to day-to-day or hour-to-hour variations on those statistics.

Additional mobility data were collected in October 2001 to provide a more robust baseline data set and to control for the passage of time that had occurred since the initial data collection. The primary data collection method for baseline data collection effort were "floating car" travel time runs along the northbound direction of Bascom Avenue. The data collection occurring in 2000 utilized manually collected travel times, while the data collection in 2001 utilized automated GPS data collection devices to provide more accurate corridor travel time profiles.

The information from the travel time runs was supplemented with incident records obtained from the California Highway Patrol's Computer Aided Dispatch (CHP CAD) system used to identify those dates, times, and locations when incidents occurred on or near Highway 17/I-880 close to the study corridor. The CHP CAD system publishes real-time incident information on the Internet at http://cad.chp.ca.gov/. The project team used software to monitor this web site and archive information about any incidents that occurred in San Jose during the study period. This archived information was later reviewed manually to identify those incidents of interest in this study.

3.3 Findings

The first step in analyzing the data gathered for this study was evaluating the incidents that occurred. Table 3.1 lists all of the incidents that occurred near the study corridor during the study period, and Figure 3.1 shows the locations of those incidents.

The team then studied each of the incidents to assess the likely impact on the corridor and identify those incident days when the impacts of diversion could likely be observed. This assessment was based on the time, location and severity of the incident. Table 3.2 lists the incidents identified as having a likely impact on the corridor. The date and time of each incident is presented in the first column and a more detailed description of the type of impact expected is presented in the second column.

Table 3.1 Incidents That Occurred Near the Study Corridor During the Study Period

Date and Time	Incident Type	Description
8/21/2000 9:56:00 a.m.	Hazard in the road	NB SR17 JNO Hamilton Av – A muffler in the road on SR-17 in the middle of the study route
8/24/2000 7:51:00 a.m.	Traffic collision	NB I880 JSO NB US101 – Two-car collision several miles north of study route
8/25/2000 7:43:00 a.m.	Disabled vehicle	NB I880 JSO Dixon Landing Rd – Occurred several miles north of study route
8/29/2000 8:54:00 a.m.	Disabled vehicle	NB SR17 JSO Hamilton Av – Vehicle on shoulder of SR-17 in the middle of the study route
8/30/2000 8:24:00 a.m.	Disabled vehicle	NB I880 JNO SR237 – A disabled vehicle waiting for help well north of the study area
8/30/2000 10:21:00 a.m.	Disabled vehicle	NB I880 JSO Bascom Av – A disabled vehicle in center divide at the northern edge of the study area
8/31/2000 8:21:00 a.m.	Traffic collision	NB SR17 JSO Lark Av – A rear-end collision at the southern edge of the study area
10/9/2001 10:37:00 a.m.	Traffic collision	NB I880 At The Great Mall – A two-car collision blocking the off-ramp well north of the study area
10/11/2001 7:07:00 a.m.	Traffic collision	NB I280 At Bascom Av – A two-car collision blocking a lane at a cross-street in the study area
10/11/2001 7:18:00 a.m.	Traffic collision	NB I280 JSO NB I880 – A two-car collision at a cross-street in the study area
10/11/2001 8:40:00 a.m.	Traffic collision	NB I880 JNO Coleman Av – A two- or three-car collision (blocking 1 lane) just north of the study area
10/11/2001 9:33:00 a.m.	Disabled vehicle	NB SR17 At The Cats – A disabled vehicle (blocking 1 lane) a little south of the study area
10/16/2001 7:12:00 a.m.	Disabled vehicle	NB SR17 At Camden Av – A disabled vehicle within the study area
10/16/2001 8:47:00 a.m.	Traffic hazard	WB Coleman Av OnR To NB I880 – A sign with a large pole obstructing entrance north of study area
10/17/2001 6:40:00 a.m.	Traffic collision	NB SR17 JNO Camden Av – A collision (vehicle on shoulder) within study area
10/17/2001 9:06:00 a.m.	Traffic collision	NB I880 JNO Dixon Landing Rd – A collision with small spill (lanes blocked) well north of the study area
10/17/2001 9:19:00 a.m.	Traffic collision	NB I880 JNO Dixon Landing Rd – A collision well north of the study area
10/17/2001 9:22:00 a.m.	Traffic collision	NB I880 JNO Stevens Creek Blvd – A collision (blocking one lane) within the study area

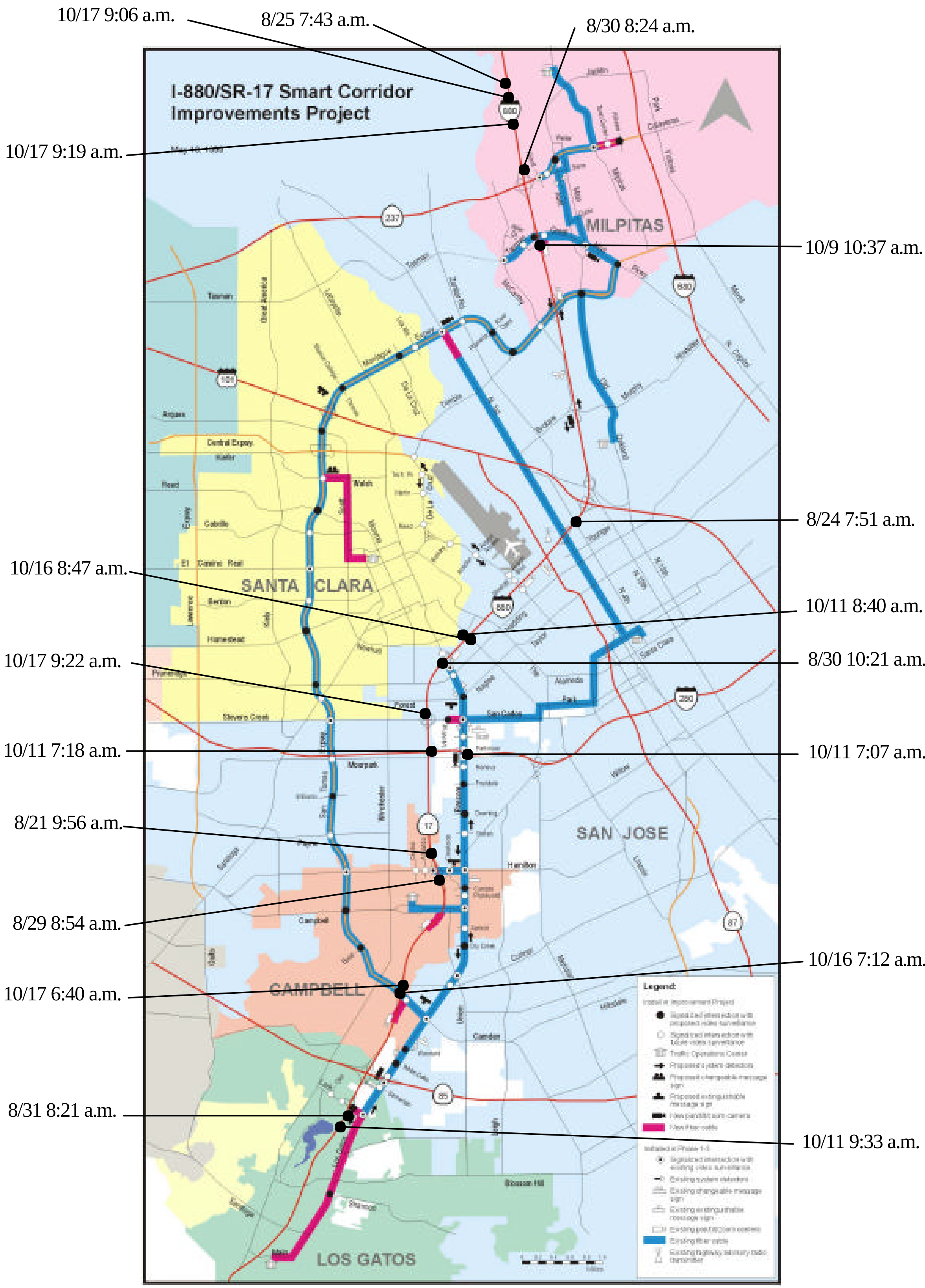


Figure 3.1 The Locations of Incidents During the Study Period

Table 3.2 Incidents with a Likely Corridor Impact

Date and Time	Expected Impact
August 29, 2000 8:54:00 a.m.	Small impact throughout study corridor
August 31, 2000 8:21:00 a.m.	Significant impact, but only affects southern portion of study corridor
October 11, 2001 8:40:00 a.m.	Significant impact, but only affects northern portion of study corridor where Bascom is not a preferred bypass
October 11, 2001 9:33:00 a.m.	Small impact only affecting southern portion of study corridor
October 16, 2001 7:12:00 a.m.	Small impact only affecting southern portion of study corridor
October 17, 2001 6:40:00 a.m.	A mild impact affecting the southern portion of the study corridor
October 17, 2001 9:22:00 a.m.	A significant impact affecting most of the study corridor

After the evaluation team characterized the incidents, analysis of the mobility statistics began with a general review of the statistics intended to serve two purposes. First, this general review allowed for some early and simple observations that help guide the later analysis and allowed an evaluation of whether sufficient data were collected on days that incidents occurred. Second, this review discounted one of the concerns cited in the initial evaluation report, the concern that the dynamic nature of the Silicon Valley region could result in markedly different traffic patterns if the delay between the baseline measurements and the Smart Corridor deployment were large. Figure 3.2 depicts the travel time measurements resulting from the two sets (August 2000 and October 2001) of travel time runs for this evaluation.

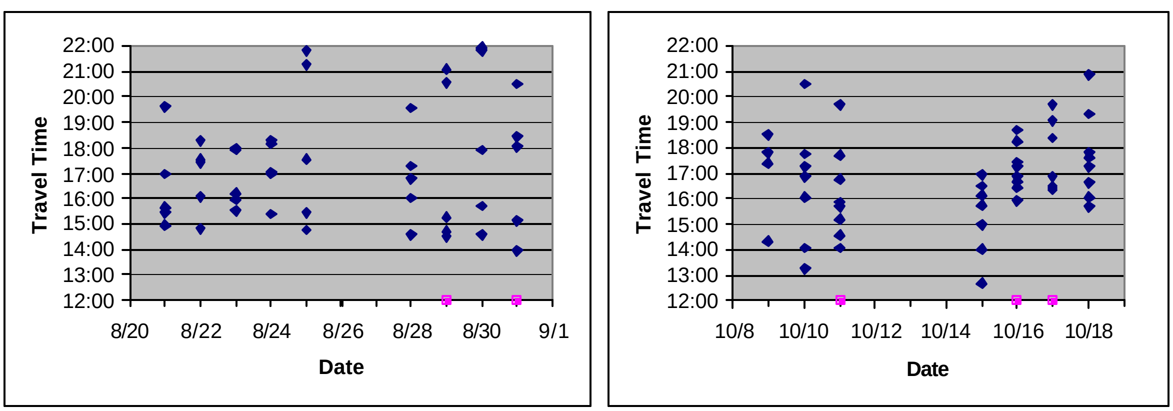


Figure 3.2 Travel Time Measurements by Day

In this figure, each diamond represents a travel time measurement with the travel times listed in a "minutes:seconds" format. The squares on the bottom axes represent the days on which incidents occurred. These two charts:

- Help confirm the day-by-day variations observed during the initial travel time runs;
- Imply that incident days result in longer travel times when compared to travel times on the same day of the week; and,
- Indicate compatibility between the travel time observations made in August 2000 and October 2001.

The results in Table 3.3 confirm that there is little systematic difference between the August 2000 and October 2001 observations. The two sets of measurements were combined for most of the remainder of this analysis.

Table 3.3 Summary of Mobility Statistics

Mobility Statistic		Travel Time Run Observations		
		August 2000	**October 2001**	**Total**
Count		45	51	96
Travel Time	Minimum (min:sec)	13:58	12:42	12:42
	Average (min:sec)	17:14	16:49	17:00
	Maximum (min:sec)	21:55	20:51	21:55
	Stnd Dev (min:sec)	2:14	1:45	1:59
Stops[a]	Count	8.6	8.4	8.4
	Time Stopped (min:sec)	4:29	4:07	4:17
Speed[b]	Average (mph)	22.5	22.6	22.5
	Stnd Dev (mph)	2.8	2.5	2.6

[a] The number and duration of stops were record manually in August 2000, while the values in October 2000 were computed based on the number of times that the vehicle was traveling at or below 8 kph (5 mph) and the length of time the vehicle was stopped.

[b] The speeds computed in August 2000 was based on the travel time run and estimates of intersection lengths derived from GIS data, while the values computed in October 2000 were based on time-weighted averages of the speed measurements of the GeoLog device. This difference in methodology accounts for the fact that the travel time values differ by about two percent, while the average speeds are the same.

To further explore the relationship between the occurrence of incidents and travel time, each travel time run was assigned an incident severity value equal to the highest incident severity that occurred in the two hours preceding the travel time run.[1] (See Table 3.2 for a list of the incidents and their severities.) Then, the mobility statistics for travel time runs affected by incidents were computed and compared to those runs not affected by incidents. The results of this comparison are listed in Table 3.4.

The results in this table seem to indicate that there is a marginal decrease, at most, in mobility associated with incidents. However, these results do not account for:

- The day of the week on which the incidents occurred; and,

[1] In the initial evaluation report, travel time runs were labeled incident runs if they occurred on the same day as the incident. In this analysis, travel time runs that occur on the same day as, but before, an incident are considered non-incident runs.

- The time of day at which the incidents occurred.

During the initial evaluation study, the travel time depended strongly on the day of the week (with variations of up to one and one-half minutes between days) and the time of day (with variations of over seven minutes within a single day). Figure 3.3 depicts the variation in travel time observations that were observed both by day of week and by time of day.

Table 3.4 Summary of Mobility Statistics for Incident and Non-Incident Travel Time Runs

Mobility Statistic		Travel Time Run Observations		
		Non-Incident	Incident	Total
Count		77	19	96
Travel Time	Minimum (min:sec)	12:42	14:32	12:42
	Average (min:sec)	16:59	17:06	17:00
	Maximum (min:sec)	21:55	19:40	21:55
	Stnd Dev (min:sec)	2:06	1:33	1:59
Stops[a]	Count	8.4	8.8	8.4
	Time Stopped (min:sec)	4:17	4:20	4:17
Speed[b]	Average (mph)	22.6	22.2	22.5
	Stnd Dev (mph)	2.7	2.1	2.6

[a] The number and duration of stops were record manually in August 2000, while the values in October 2000 were computed based on the number of times that the vehicle was traveling at or below 8 kph (5 mph) and the length of time the vehicle was stopped.

[b] The speeds computed in August 2000 was based on the travel time run and estimates of intersection lengths derived from GIS data, while the values computed in October 2000 were based on time-weighted averages of the speed measurements of the GeoLog device. This difference in methodology accounts for the fact that the travel time values differ by about two percent, while the average speeds are the same.

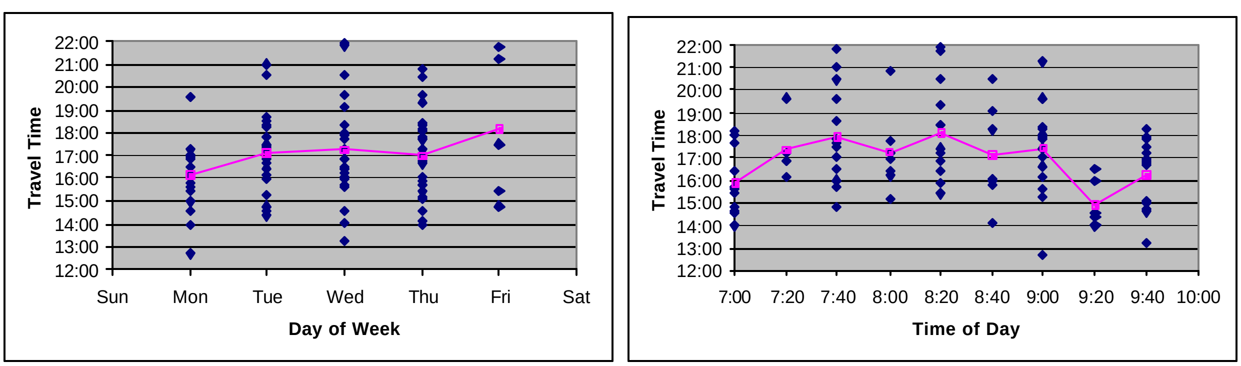


Figure 3.3 Travel Time Measurements by Day and Time of Day

In these charts, the diamonds represent individual travel time measurements, and the squares connected by line segments represent the average of all travel times that occurred at the indicated day or time. As noted in the initial study, the observed travel times show considerable variation with respect to these two variables relative to the expected size of the variation caused by the relatively minor incidents that occurred during the study periods. Because of the potential for the effect of these other factors to wash out the effect of the incidents on travel time, a multi-variable analysis of variance calculation was used to estimate the impact of each of the following factors (taken together) on the travel time: the day of the week, the time of day, the study period (i.e., August 2000 or October 2001), and the presence of an incident. The results of this analysis are presented in Table 3.5.

Table 3.5 Effect of Factors on Travel Time

Factor	Value	Effect on Travel Time
Day of Week	Monday	-62.5 seconds
	Tuesday	4.5 seconds
	Wednesday	13.1 seconds
	Thursday	-3.5 seconds
	Friday	49.0 seconds
Time of Day	7:00 a.m.	-70.3 seconds
	7:20 a.m.	35.2 seconds
	7:40 a.m.	56.4 seconds
	8:00 a.m.	21.7 seconds
	8:20 a.m.	64.4 seconds
	8:40 a.m.	19.4 seconds
	9:00 a.m.	29.3 seconds
	9:20 a.m.	-112.4 seconds
	9:40 a.m.	-43.1 seconds
Analysis Period	August 2000	10.8 seconds
	October 2001	-10.2 seconds
Incident Occurrence	Non-Incident	1.7 seconds
	Incident	-1.2 seconds

The two calendar-based factors have the expected effect on the observed travel times: travel times are faster on Monday and slower on Friday and faster before and after rush hour, supporting the basic validity of the analysis. This analysis confirms the results already indicated in Table 3.4, that there is not a significant difference in travel time between those travel time runs characterized as occurring during incidents and those characterized as occurring without incidents.

Another measure used to assess the baseline mobility was intersection queue length. In the initial baseline data collection, video archives from traffic surveillance cameras were studied to compare the queue lengths occurring on incident vs. non-incident days. Similar to the initial travel time findings, the queue lengths on incident days observed to be longer; however, the difference was often not statistically significant.

During the additional data collection in October 2001, the GPS equipped travel time vehicles were used to more accurately assess the queue lengths encountered, measured as the point furthest upstream of the intersection (but after the preceding intersection) at which the vehicle stopped. Figure 3.4 depicts the results of these measurements.

In this figure, queue measurements that were made during non-incident runs are pictured as diamonds and those made during incident runs pictured as squares. This figure depicts little systematic difference between the queue lengths measured for non-incident (average for all segments is 183 feet) and incident days (average for all segments is 198 feet).

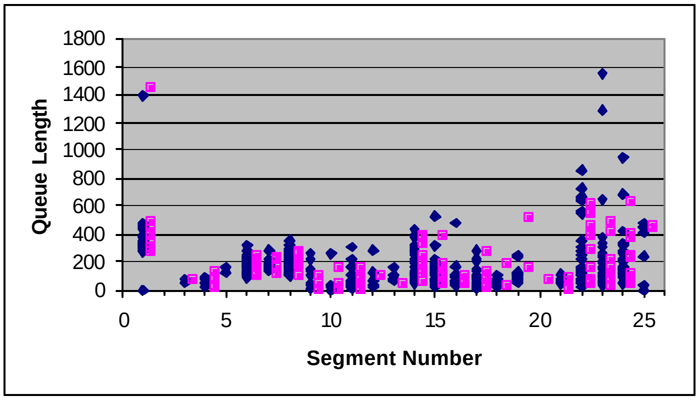


Figure 3.4 Measured Queue Lengths

4.0 SAFETY STUDY

4.1 Purpose

The purpose of the safety study was to collect data for analysis of potential changes in safety resulting from the Smart Corridor deployment. Specifically, four potential measures of effectiveness were selected to test the impact on traffic safety resulting from deployment. These measures include:

- Historical crash data,
- Real-time crash data,
- Observed speed variability during incident conditions, and
- Observed number of conflict situations occurring during incident conditions.

4.2 Data Collection Plan

The CHP CAD web site was monitored in real time to isolate incident periods for analysis. Consequently, a specialized computer program was developed by the evaluators to capture the information presented about each incident, separate each field, and write the data to a database. Each field generated by the program can be queried and sorted to show only incidents that occur on northbound SR-17/I-880 during the morning peak period. The database also stores detailed information on each incident, such as lane blockages and number of vehicles involved in a crash. The real-time data from the CHP CAD web site is used only to isolate incident days for the purposes of the evaluation, and is not used as an historical record of crash frequency. The team was able to determine the magnitude of each incident from the data captured by the program, along with the timeframe in which it occurred. A screen capture of the program can be seen in Figure 4.1.

The fully completed safety evaluation was anticipated to include a comparison of two phases, including the comparison of traffic safety aspects during the pre-implementation phase (Phase II), with similar data from the post-implementation phase (Phase III). The evaluation was discontinued prior to the completion of the deployment; therefore, no “before” and “after” comparison was possible. This section outlines the strategies and methods used in the Phase II safety study, along with the findings from an analysis of pre-implementation (baseline) data.

Historical Freeway Data

In order to obtain historical crash records for the section of Highway 17/I-880 between Los Gatos and San Jose, the evaluation team contacted the California Department of Transportation’s (Caltrans’) Traffic and Vehicle Data Systems Unit. Caltrans provided electronic logs of all reported crashes for 1997, 1998, 1999, and most of 2000 by querying the Traffic Accident Surveillance and Analysis System's (TASAS) Selective Accident Retrieval Database. The team analyzed the data and calculated historical crash rates for the section of freeway in question, and made a determination of the historical frequency of crashes in the northbound direction of travel.

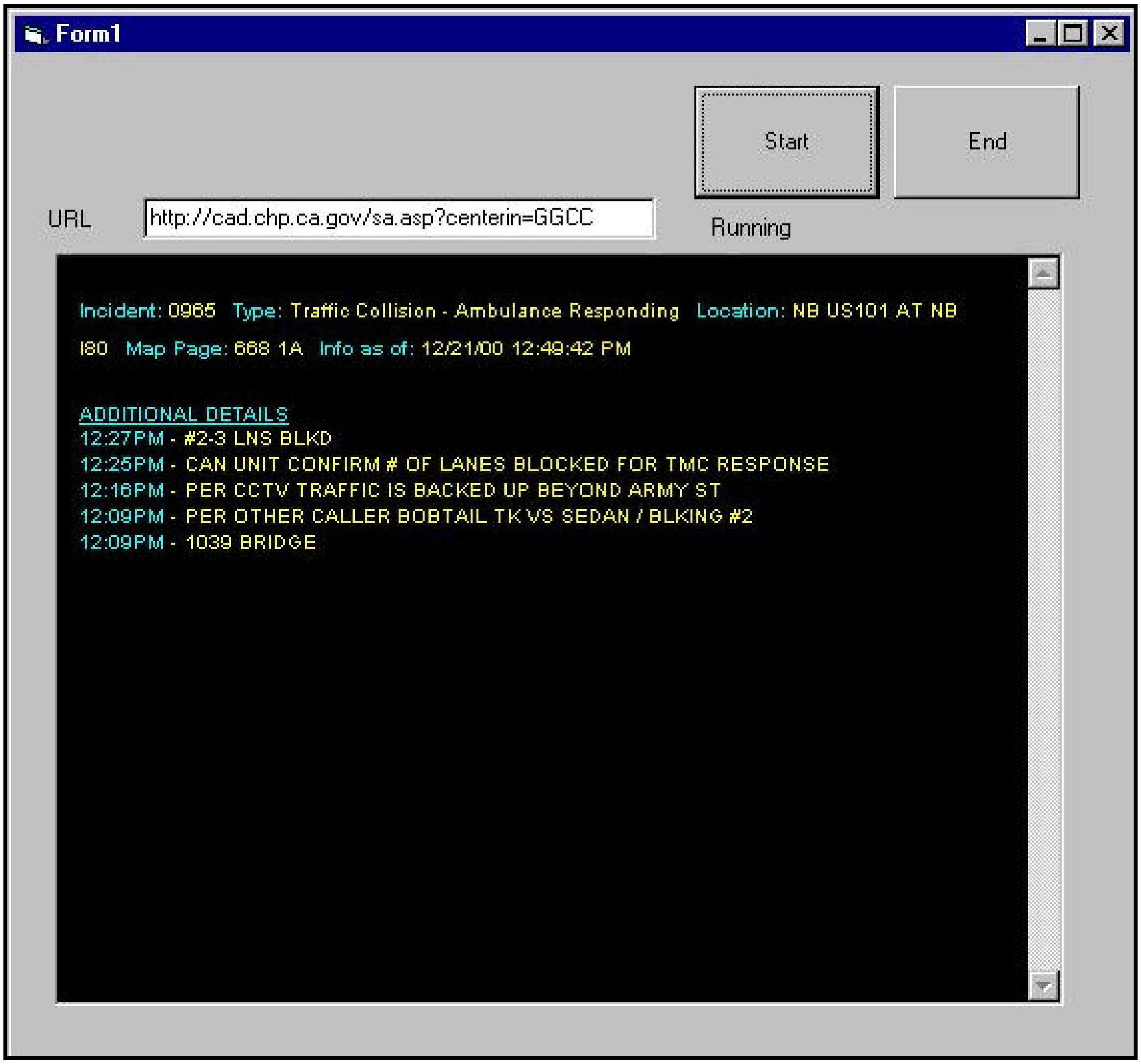


Figure 4.1 Screen Capture of the Incident Web Program

Crash rates were also compared with statewide average crash rates in an effort to determine the relative level of safety of Highway 17/I-880 as compared with other similar transportation facilities in California.

This information allowed the team to delineate the length of the "before" data collection period based on the frequency of northbound freeway incidents, thereby allowing for an adequate opportunity to capture the effects of at least one freeway incident during data collection. It was important that incidents were captured during baseline conditions in order to have enough data for comparison with the post-implementation scenario.

Historical Arterial Data

Arterial crash records were obtained from several local jurisdictions in Silicon Valley, including the City of San Jose, Santa Clara County, the City of Campbell, and the Town of Los Gatos. Crash data were provided for 21 intersections along Bascom Avenue for 1997, 1998, and 1999. An analysis of the total number of crashes was performed for each intersection, along with an analysis of the number of crashes involving at least one northbound traveling vehicle during the peak period from 7:00 a.m. until 11:00 a.m. This morning peak period coincides with the overall time period used for data collection.

Graphs were included in the Phase II report that displayed the total number of crashes for each intersection along Bascom Avenue; however, reliable estimates of traffic volumes could not be collected to determine the actual crash rates. Unsuccessful efforts were made in the supplemental data collection period to obtain traffic volume counts at each approach to the intersections for use in calculating crash rates. Additional follow up was also conducted with each agency to ensure all available volume data were obtained. A thorough search concluded that several manually collected traffic counts were available for sporadic years from 1990 through 1998 for several intersections along Bascom Avenue. These counts varied significantly in their format (e.g., peak hour, peak period, daily) and the time of year in which they were collected. Additionally, these data often represented a single data collection day, providing a large opportunity to introduce evaluation bias. The evaluation team made attempts to use the incomplete volume data to interpolate meaningful volume metrics; however, the efforts were unsuccessful in obtaining figures that the team could be sufficiently confident in to conduct crash rate analysis.

Speed Variability Data

Travel speed variability was selected as a safety performance measure for the Bascom Avenue arterial, based on the high correlation between this measure and crash rates. Further, given the small likelihood of a statistically significant number of vehicle crashes to occur in the constrained data collection window (crashes would need to be observed during non-recurring and unpredictable incident conditions), this measure was selected to provide a more readily observable, surrogate measure for crash risk exposure.

Data related to speed variability were collected using parallel-hose traffic counters that were deployed at five strategic corridor locations for the period from October 9 to October 24, 2001. The locations were selected based on their proximity to major decision locations (intersections providing access back to Highway 17/I-880) throughout the length of the corridor. All locations were for the northbound direction of travel and included:

- South of Lark Avenue (capturing traffic entering the study corridor at the southern limit);
- South of Camden Avenue (capturing traffic immediately prior to the first major decision location);
- North of Camden Avenue (capturing traffic immediately following the first major decision location);

- South of Hamilton Avenue (capturing traffic immediately prior to the second major decision location); and
- North of Stevens Creek/San Carlos (capturing traffic immediately following the last major decision location.

The data collection devices were deployed to sample the individual vehicle speeds from one lane of travel. The left lane was used in two locations that offered a suitable traffic island for locating the equipment. The right travel lane was used in the remaining three locations. The detectors were located at mid-block locations, beyond the normal range of the queues backing up from the signalized intersections. Data were collected 24 hours a day, seven days a week, but the data analysis focused on an extended morning peak period from 6:00 a.m. to 11:00 a.m. for weekdays only.

The data collectors measured the speed of each vehicle crossing the tubes and archived the data every 15 minutes into a format documenting the number of vehicles observed traveling a particular speed (segmented into five mph speed bins) during the previous 15-minute period. This format provided an average speed and speed distribution for 20 distinct periods everyday.

Equipment problems limited the usefulness of the data at two locations. An equipment malfunction at the location south of Lark Avenue (the southernmost detector) caused the data to be unreliable throughout the data collection period. Equipment vandalism at another location, immediately north of the Stevens Creek intersection (the northernmost detector) limited the data to speeds collected from October 9 through October 17.

The remaining data were then analyzed to remove anomalies and identify the variation due to day-of-week and time-of-day differences.[1] Using the CHP incident information, the data were segmented into incident and non-incident bins to identify the significance of travel speed variability due to those factors.

Conflict Analysis

Before commencing the analysis of traffic conflicts at Bascom Avenue intersections, the team consulted with an expert in the area of traffic safety analysis. The primary focus of the discussion was to develop a set of standard procedures for such analysis. Traffic conflict analysis is normally performed in the field; however, due to limited resources and the random nature of incident conditions, such field observations were not feasible for this analysis.

4.3 Findings

Due to difficulties in obtaining reliable data to perform meaningful crash rate and conflict analysis, the measurement of travel speed variability was selected as the most appropriate surrogate for analyzing the crash risk exposure during incident conditions in the corridor. The speed variability data collected from the four operational detector locations were analyzed to identify the average speed and the distribution of speed under various travel conditions,

[1] Weather conditions were also considered in this analysis; however, no inclement weather days were observed during the data collection period.

including day-of-week, time-of-day, and incident conditions versus non-incident conditions. This section presents the findings from this analysis.

The speed variability data collection was performed simultaneously during the travel time data collection period to allow the cross validation of results. The automated nature of the speed variability data collection, however, provided the opportunity to evaluate a broader range of data, including an expansion of both the temporal period and number of data collection days. Data were analyzed for a period from October 9 to October 24 for each weekday from 6:00 a.m. to 11:00 a.m. This expanded the data collection period by approximately one week and by one hour each day, when compared with the travel time data collection.

The speed data from the various locations were first analyzed to identify the mean, range, and standard deviation of speed. Table 4.1 presents the combined results (all observations) of the data from each location. Locations are listed from the south traveling north. The standard deviation and range are based on the mean speed observed during each distinct 15-minute period.

Table 4.1 Speed Metrics Based on All Observations

	Mean	Std. Deviation.	Minimum	Maximum
South of Camden	40.8	1.9	30.83	46.00
North of Camden	36.5	1.4	32.50	40.18
South of Hamilton	36.6	1.9	31.23	41.59
North of Stevens Creek	33.7	3.2	23.12	42.12

These summary performance measures are generally comparable with the findings from the travel time studies and show relatively little speed variation when all observations are included. The detector location north of the Stevens Creek Road intersection shows the greatest variability and greatest range of speeds. These findings are generally consistent with expectations for this location as this is most geometrically constrained location – the detector is located north of the intersection where three travel lanes are constrained into two, and the land-use characteristics of the corridor change from a commercial corridor to a primarily residential corridor. All other detector locations were characterized by three travel lanes or two travel lanes, plus a middle turning lane. The findings from the Stevens Creek location are also based on the smallest number of observations (days) of any location, due to an equipment malfunction.

Speed Data by Day-of-Week

The speed data were then analyzed to identify the impact of day-of-week and time-of-day factors. These factors were both shown to have a significant impact in the travel time data analysis. The analysis of the speed data obtained from spot locations along the corridor showed these factors impact the speed and speed variability at selected locations, but generally to a less significant degree than they impact overall corridor travel time.

Figure 4.2 presents the mean speed observed on the various days of the week for the various locations. This analysis shows that for most locations, the day-of-week factor has little impact on the observed speed. The exception to this finding is that the Friday observance of speed at the north of Stevens Creek location is much higher than that observed in the other days (37.58 for Friday versus an average of 33.9 for all other days). This observation is counter to the finding from the travel time analysis, which found the longest average travel times on Fridays. The figure for this particular location is based on a single day's observance. However, due to data collection equipment malfunctions this data point was removed from subsequent analysis.

The standard deviation was also calculated and analyzed for each day of the week. However, this analysis found no discernable differences or patterns identified between the various observation days.

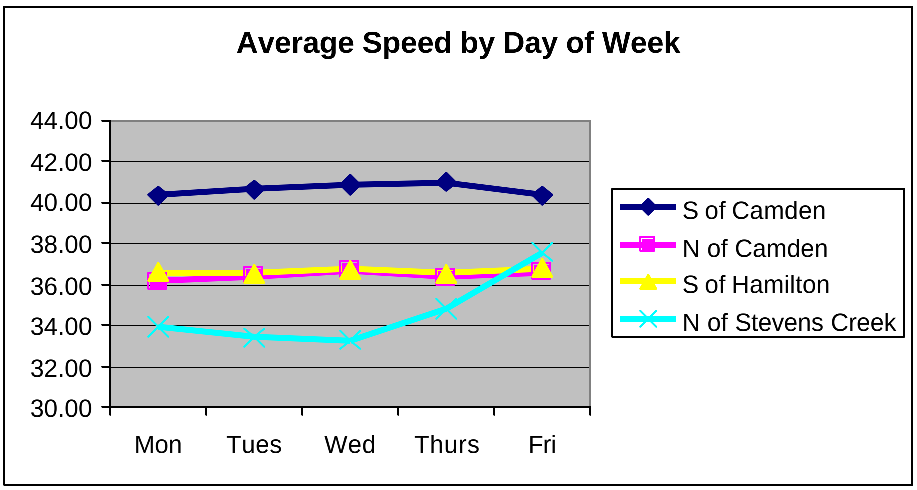


Figure 4.2 Average Speed by Day of Week

Speed Data by Time-of-Day

The time-of-day factor was then analyzed and was shown to have a more significant impact on observed speeds for particular locations (south of Hamilton and north of Stevens Creek). Consistent with the travel time data analysis, the time-of-day was shown to result in a decrease in speeds at these locations during the height of the morning peak (approximately 7:45 a.m. to 8:45 a.m.). The two detector locations to the north and south of the Camden Avenue intersection did not display any significant change in speed by time-of-day, as shown in Figure 4.3.

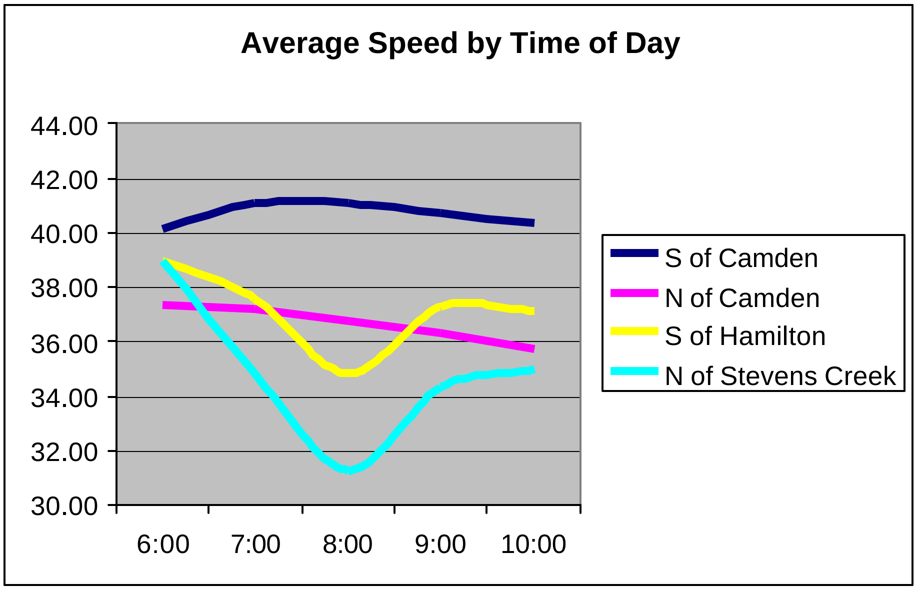


Figure 4.3 Average Speed by Time of Day

The standard deviation of speed was also shown to experience greater variation by time-of-day than by day-of-week. The pattern of variation among three of the locations was nearly identical to that displayed for the south of Camden location displayed in Figure 4.4 – the greatest variation observed early in the morning, when the lowest volumes are observed, and gradually tightens around the mean over time. The red line in this figure shows the mean speed, while the Y-error bars display the standard deviation.

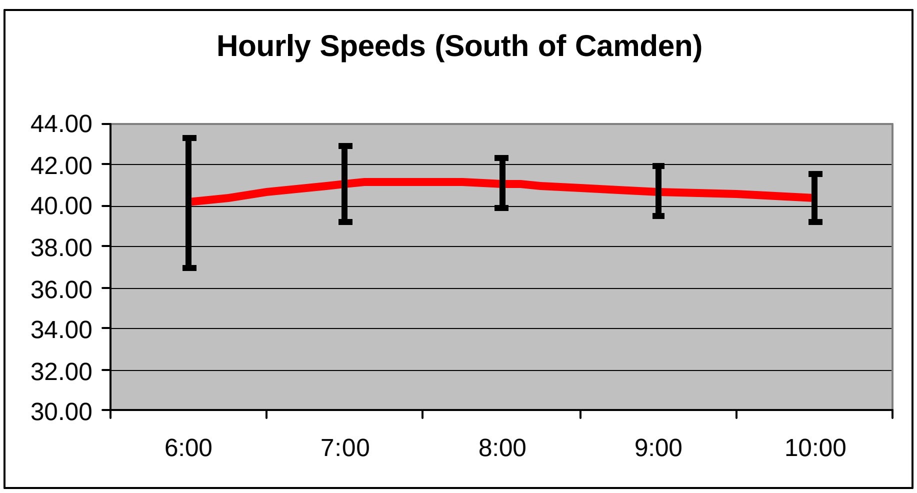


Figure 4.4 Average Speed and Standard Deviation (South of Camden)

The detector located north of the Stevens Creek intersection again displayed a different pattern than the other detectors, as shown in Figure 4.5. The Stevens Creek location was observed to experience the largest variability in travel speed near the peak volume period, in parallel with the lowest travel speeds.

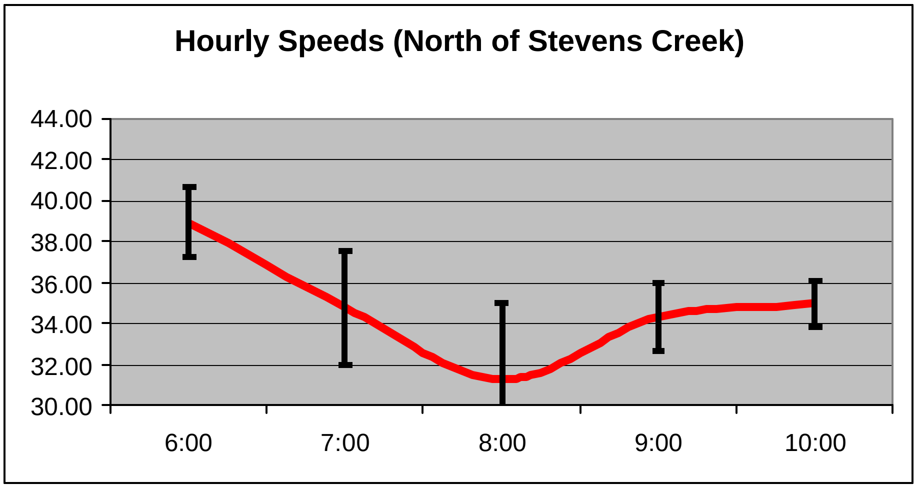


Figure 4.5 Average Speed and Standard Deviation (North of Stevens Creek)

Analysis of Incident Versus Non-Incident Conditions

The impact of the occurrence of incidents on Highway 17/I-880 was then analyzed to identify any difference in travel speeds and speed variability due to this factor. The data sets were separated into incident and non-incident bins consistent with the travel time data analysis. (See Table 3.2 for an identification of the incident dates and times used in this analysis.)

Once the data were separated into incident and non-incident sets, the average speed and standard deviation were calculated to identify if there was a significant variation in the mean speed between these two data sets. Table 4.2 shows the results of this analysis for each data collection location. These findings are presented graphically in Figure 4.6 (with 1= South of Camden, 2= North of Camden, 3 = South of Hamilton, and 4 = North of Stevens Creek).

Table 4.2 Comparison of Incident Versus Non-Incident Conditions

		Non-Incident	Incident	Difference	% Difference
South of Camden	Speed	40.8	40.8	0.04	0.1%
	Std Deviation	*2.0*	*1.6*	*-0.42*	*-21.0%*
North of Camden	Speed	36.5	36.4	-0.14	-0.4%
	Std Deviation	*1.3*	*1.4*	*0.11*	*7.9%*
South of Hamilton	Speed	36.6	36.7	0.02	0.0%
	Std Deviation	*1.8*	*1.6*	*-0.23*	*-12.8%*
North of Stevens Creek	Speed	33.9	33.4	-0.53	-1.6%
	Std Deviation	*2.7*	*3.6*	*0.90*	*32.7%*

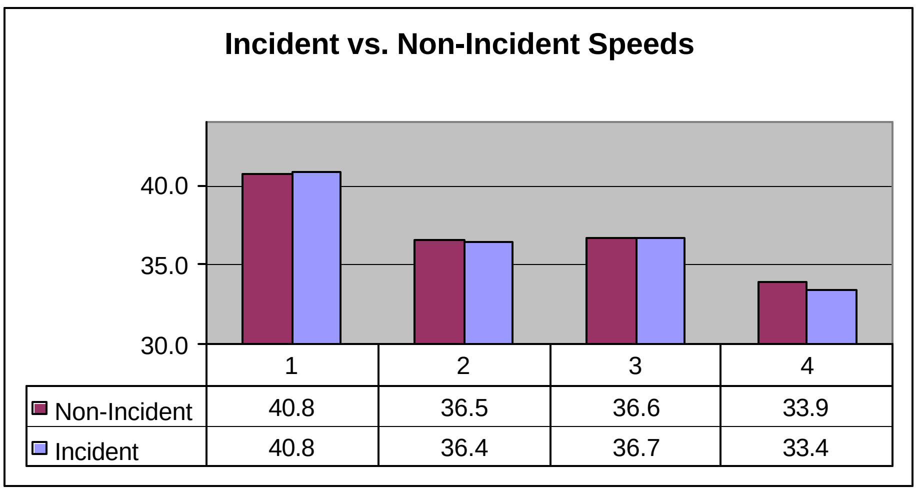


Figure 4.6 Comparison of Incident vs. Non-Incident Speeds

The preliminary results of this analysis showed little variation in the mean speed observed or in the standard deviation of travel speed. Statistical tests were also performed to determine the likelihood that the observed incident data set was significantly different than the non-incident set. For all locations, the data could not be proven to be drawn from different sample populations. Thus, no statistically significant difference exists between the speed means for the two data sets.

Analysis of Speed Variability

To this point in the analysis, the average or mean speed was evaluated and was not shown to vary between the incident and non-incident conditions. The next step in the analysis focused on evaluating the distribution or variability of travel speed between the incident and non-incident conditions.

The detectors utilized in this study archived a distribution of observed speeds for each 15-minute interval during the data collection period (segmented into five mile-per-hour groupings). This data format was used to identify the distribution and variability of travel speeds. The separation of data into incident and non-incident data sets allowed the comparison of the distribution of travel speeds in order to prove the hypothesis that speeds on incidents days would display greater variability than non-incident days. The distribution of speed variability for the different data sets was analyzed to identify differences in the distribution.

Figure 4.7 through 4.10 display the comparison of the speed distributions for incident conditions versus non-incident conditions. These speed distributions are nearly identical and show little variation in the speed variability observed during the two conditions. Further analysis found that the speed distribution curves for the two data sets were not statistically different. Thus, the analysis was not able to identify any significant speed variability differences between incident and non-incident conditions.

Speed variability was analyzed in this study as a surrogate for crash risk exposure. Increased speed variability observed in previous studies has demonstrated a strong correlation with increased crash risk. Since the data analysis in this study was unable to reveal a statistically significant increase in speed variability during incident conditions, no conclusions can be drawn from this analysis regarding increased accident risk exposure during incident conditions.

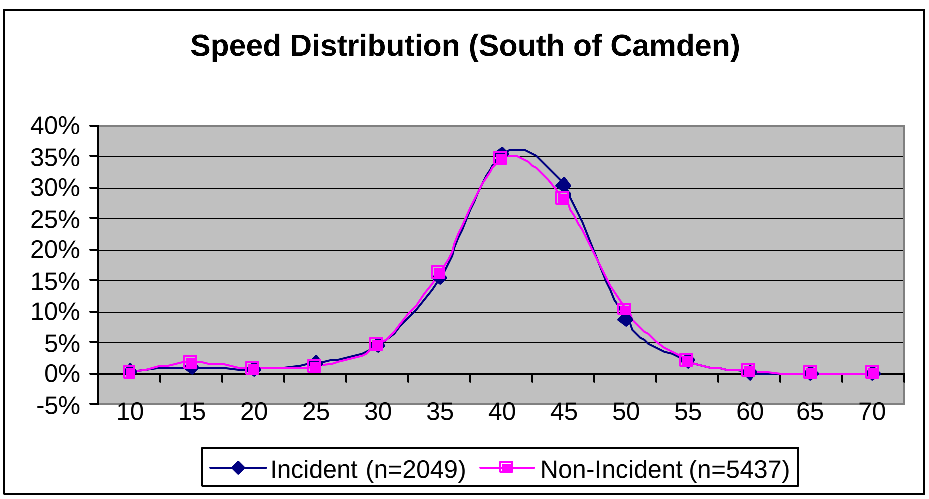


Figure 4.7 Comparison of Speed Distribution (South of Camden)

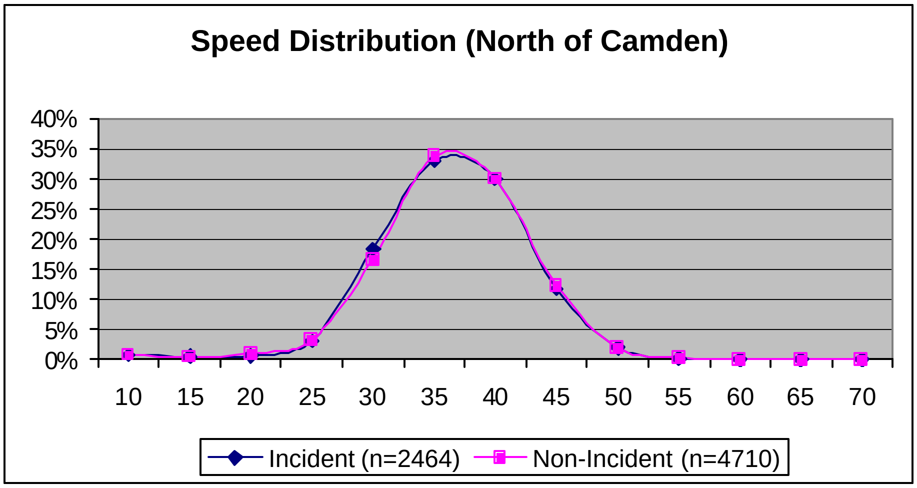


Figure 4.8 Comparison of Speed Distribution (North of Camden)

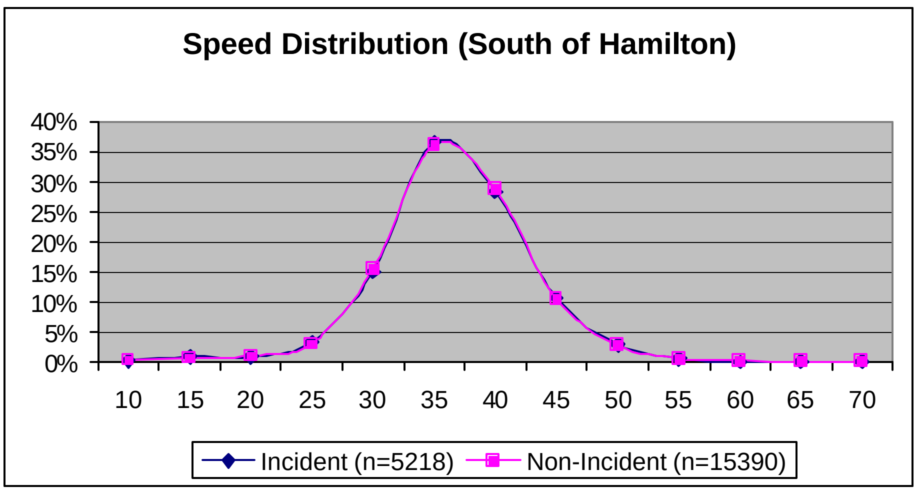


Figure 4.9 Comparison of Speed Distribution (South of Hamilton)

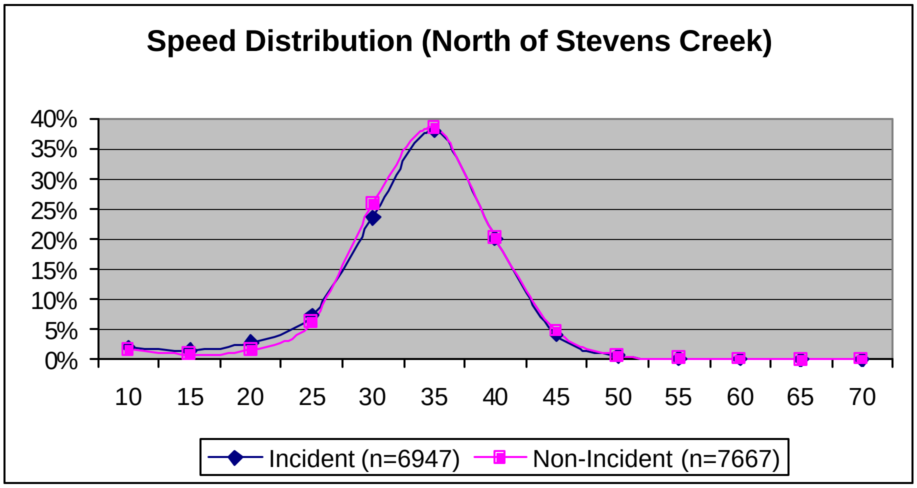


Figure 4.10 Comparison of Speed Distribution (North of Stevens Creek)

Analysis of Arterial Volumes

A final analysis was performed to assess the possible increased accident risk on Bascom Avenue during incident conditions. This analysis focused on the volumes of vehicles captured by the speed detectors deployed along the corridor. The observed volumes were evaluated to assess the possibility that there was a diversion of vehicles to Bascom Avenue during incidents on the freeway, but that the available capacity on the arterial was generally sufficient to handle the diversion (i.e., increased volumes could be handled with little or no change to travel times or speeds).

The analysis of observed volumes during incident and non-incident conditions revealed an increase in average volumes during incident conditions in all but one location (North of Stevens Creek), which showed no change in volume. The increases in volume ranged from 2 to 13 percent, with the location South of Camden showing the largest increase. In numerical values, however, none of the volume increases represents more than 20 vehicles per hour per lane.[2]

This analysis seems to support the hypothesis that a moderate amount of travelers are diverting to Bascom Avenue during incident conditions on the freeway, but the available capacity is sufficient to handle the diversion with little impact to the existing travelers.

[2] The speed detectors were deployed over a single travel lane. The volumes captured from this single lane were used as a surrogate for the total roadway volume. It is assumed that these values are comparable.

5.0 CUSTOMER SATISFACTION STUDY

5.1 Purpose

The purpose of the *Customer Satisfaction Study* was to assess motorist perception of and satisfaction with traffic operations along the SR 17/I-880 corridor, both before and after system implementation. In particular, the study was intended to determine the level of commuter satisfaction with traveler information and traffic management.

Data collection and analysis for this study was primarily focused on the post-deployment (Phase III) scenario; however, the data collection methodology was established in the baseline phase and captured some preliminary results.

5.2 Data Collection Plan

The perceived benefits of the Smart Corridor implementation were to be measured through an innovative Internet-based panel survey consisting of commuters in the Silicon Valley area. The City of San Jose, in coordination with the Silicon Valley Manufacturing Group (SVMG), assisted the team in securing an adequate survey panel. The SVMG is an organization that involves principal officers and senior managers of member companies in a cooperative effort with local, regional, state, and federal government officials to address major public policy issues affecting Silicon Valley. The SVMG forwarded a distribution letter to several companies in the group asking employees to participate in the survey.

Two surveys were administered as part of the pre-implementation data collection: a screening survey and an incident survey. In order to assess whether the driving patterns of commuters were consistent with the needs of the study, interested participants were asked to complete the screening survey. The survey included questions about commuter driving routes, including whether motorists normally travel northbound on SR 17, I-880, or Bascom Avenue during the morning peak period. Driving patterns of interested commuters had to match the corridor routes of interest in order for them to participate. Once the necessary driving pattern was confirmed, participants were asked to provide their email address so they can be notified to return to a web site and complete the incident survey. A copy of this incident survey is provided in the appendix to this document.

The incident-specific survey includes questions on baseline traffic operations during incident conditions. The team monitored the CHP CAD web site in real-time, and asked participants via email to complete the incident survey on days when significant incidents are reported. These questions allowed the team to determine the effects of the incident on travel through the corridor. During the post-implementation scenario, it was expected that the incident survey would be modified to collect data on motorist reaction to the Smart Corridor System components and features during significant incidents.

5.3 Findings

Data have been queried from specific responses to the screening survey to assess the driving patterns of motorists and their overall satisfaction with several aspects of traffic operations along the corridor. Responses were recorded from the initial group of 139 participants to several informational questions, including the hour during which they typically travel through the corridor, their approximate commute time, and their approximate length of commute. Tables 5.1 through 5.3 outline the results from these specific questions.

Table 5.1 Typical Commute Hour During the Morning Peak Period

	Participants That Typically Commute Between The Hours of:				
	6:00 a.m. to 7:00 a.m.	**7:00 a.m. to 8:00 a.m.**	**8:00 a.m. to 9:00 a.m.**	**9:00 a.m. to 10:00 a.m.**	**Other**
Percentage of Participants	29%	35%	23%	9%	4%

Table 5.2 Approximate Commute Times During the Morning Peak Period

	Approximate Commute Time					
	Less Than 15 Minutes	**15 to 30 Minutes**	**31 to 45 Minutes**	**46 to 60 Minutes**	**61 to 75 Minutes**	**Greater Than 75 Minutes**
Percentage of Participants	0%	22%	34%	26%	7%	12%

Table 5.3 Approximate Commute Distances During the Morning Peak Period

	Approximate Commute Distance:				
	Less Than 10 Miles	**10 to 20 Miles**	**20 to 30 Miles**	**30 to 40 Miles**	**Greater Than 40 Miles**
Percentage of Participants	14%	45%	16%	14%	12%

With respect to traffic condition information, almost 85 percent of participants reported that they use radio reports while in their vehicle to assess traffic conditions. Slightly more than 25 percent rely on variable message signs on the freeway, while very few report using the Internet or

Highway Advisory Radio for traffic condition information. Table 5.4 illustrates participant responses on the usefulness, timeliness, and accuracy of traveler information in Silicon Valley.

Table 5.4 Usefulness, Timeliness, and Accuracy of Traveler Information

	Not Useful	Somewhat Useful	Useful	Very Useful	Extremely Useful	No Response
Percentage of Respondents	21%	55%	15%	7%	1%	1%

	Not Timely	Somewhat Timely	Timely	Very Timely	Extremely Timely	No Response
Percentage of Respondents	30%	53%	12%	1%	1%	3%

	Not Accurate	Somewhat Accurate	Accurate	Very Accurate	Extremely Accurate	No Response
Percentage of Respondents	14%	62%	22%	0%	1%	1%

The remainder of the screening survey was designed to find out what motorists typically do in response to an incident. Of the 139 participants, almost 60 percent reported that they typically encounter greater than normal delays on the freeway more than four times per month. When encountering such delays, 48 percent of participants reported that they typically exit the freeway and use another route, while 42 percent reported that they normally do not divert from the freeway. For those who choose an alternate route, 27 percent and 21 percent use Bascom Avenue and Winchester Avenue, respectively. Almost 50 percent of respondents did not provide a response to this question. The percentage of participants was fairly evenly split on how often they divert in a typical month, from more than six times per month (23 percent) to less than once a month (16 percent). Almost 85 percent of respondents reported that they are not made aware of incident-related delays until they encounter the problem area.

6.0 INSTITUTIONAL STUDY

6.1 Purpose

The purpose of the *Institutional Study* was to provide an evaluation of the degree to which the integration project served to increase or enhance interagency cooperation and coordination. The institutional study also investigated implementation issues that were encountered and documented lessons learned to help other future implementers identify potential opportunities and pitfalls in deploying these types of integrated components. While there were no predetermined evaluation measures for this study, the evaluation team worked closely with the project participants to identify and document interagency and implementation issues as they arose.

The type of technologies being integrated and the geographic scope of the project required the close coordination of many agencies. While many of these agencies had a history of successful collaboration, the degree of coordination required of this integration project was unprecedented in the region. Furthermore, the use and integration of new technologies resulted in significant challenges. The lessons learned by the project participants have been significant. The following sections detail some of the issues encountered and lessons learned to date.

6.2 Data Collection Plan

The nature of this project and the data collection plan established for other efforts required close coordination between the evaluation team and the project partners. The use of the system capabilities to collect a large portion of the evaluation data (e.g., video data, system detector data, etc.) resulted in numerous opportunities to interact with project personnel. A member of the evaluation team was staffed in Oakland, California, and was available to attend many of the monthly project partner meetings and closely observe project progress.

In addition to directly observing the interaction and coordination of project partners at the group meetings, the evaluation team was able to interview a wide range of technical and managerial representatives from the partner agencies to obtain additional opinions and information. During the initiation of the evaluation, structured interviews were conducted with representatives from four different project partner agencies to document individual goals, perceived challenges to deployment, expected benefits, and opinions regarding the likelihood of a successful deployment. Follow-up interviews were conducted with these personnel as the project neared full deployment.

Additionally, the evaluation team participated in periodic conference calls where the institutional issues encountered by different evaluation personnel were discussed. These discussions allowed the comparison of different viewpoints encountered during discussions with the many project partner representatives.

6.3 Findings

Preliminary findings from the Institutional Study include both interagency coordination issues and implementation issues, as detailed in the sections below.

6.3.1 Interagency Coordination Issues

The progress made to date on improving interagency coordination has been significant, yet many obstacles still remain. The project provided an excellent test bed for evaluating interagency issues given the large number of partners who are actively involved in and directly impacted by the deployment. The project also includes a number of periphery partners due to the wide geographic scope and technical complexities of the Smart Corridor integrated systems.

Many of the Smart Corridor partners had an established, if limited, history of working successfully together. Other partners, however, have historically avoided direct coordination in the past and pursued their individual goals with little communication with other agencies/organizations in the region. This previous lack of coordination was cited several times as the source of past conflict between these agencies resulting in stagnant and often acrimonious relationships between several agencies.

To date, the project is reported to have mixed results in improving these relationships. The project partners having the most direct day-to-day role in the project – primarily those partners involved in arterial operations – have reported improved coordination and understanding among their agencies. Improvement in interagency coordination with some of the more periphery partners has; however, fallen short of the partner's original expectations.

The improvements in coordination can be traced to several characteristics of the deployment process and of the project itself. First, the inter-agency coordination required of the deployment planning process has improved interagency relationships. The deployment process has required the establishment and continuation of regular dialog between the partners. Communication links have been strengthened between the organizations and project partners reported having a better understanding of the activities of the other agencies. Interagency coordination has provided for the more rapid dissemination of data and ideas, and in several cases has resulted in agencies adopting the useful procedures and policies developed by partner agencies. For example, implementation difficulties in maintaining the stability of the fiber-optic communication infrastructure has resulted in agencies experimenting with and implementing policies from other jurisdictions that better define responsibilities and damage mitigation related to the fiber-optic system in their own jurisdictions.

Secondly, the deployment has resulted in the integration of data sharing technologies and has provided the partners with direct access to information on traffic conditions and the operational status of traffic management systems in neighboring jurisdictions. Personnel at the partner agencies reported that the inability to access this type of information in the past had resulted in a great deal of frustration and inefficiency. Improvements deployed as part of the Smart Corridor project have provided the agencies with access to critical information from other partners' traffic management centers, including the ability to view other agencies' live camera feeds and identify the signal timing plans being implemented on a number of regional arterials. These capabilities have greatly enhanced and facilitated the exchange of information between the agencies.

While interagency coordination has been enhanced among a core group of partners, coordination between other more periphery partners has not met expectations. The lack of improvement in the coordination between the partners responsible for arterial operations and freeway operations was cited as a major impediment in the development of a truly integrated deployment.

Different agencies have placed a lower-priority on the project, and have often followed their own independent deployment schedule for Smart Corridor-related components in their own jurisdictions. These deployment schedule inconsistencies have required the active project partners to alter the scope of the project to account for the unavailability of supporting components to be provided by these other agencies. These scope changes have not significantly impacted the primary capabilities of the Smart Corridor system. In several situations, however, these changes have created bottlenecks in the real-time exchange of data between agencies that could ultimately impact the success of the deployment.

The final deployment tasks that are currently underway should serve to further strengthen interagency coordination among the direct partners. The development and testing of operational strategies should result in a better definition of roles and responsibilities for various agencies. The formalization and adoption of these policies and procedures by the Smart Corridor partner agencies should further institutionalize coordination activities and help ensure the long-term survivability of the interagency communication links. Further efforts to facilitate improved coordination between the agencies responsible for arterial and freeway operations are required to remove barriers to the full integration of the deployment.

6.3.2 Implementation Issues

The Smart Corridor project involved the complex integration of a number of previously unrelated systems. To accomplish this integration, many new technologies and techniques were developed and implemented. As with any new technology deployment, numerous difficulties were encountered in implementing and integrating the various components. These difficulties encountered provide valuable lessons learned to help guide future deployment.

In implementing the Smart Corridor technologies, the most significant difficulty faced by the project partners involved the deployment and maintenance of the system's fiber-optic communications infrastructure. Various project partners identified the fiber-optic deployment as the most problematic component of the integration.

The most frequently cited problem was that rapid and ongoing development in the corridor environs often resulted in the fiber-optic cable being cut or damaged by construction crews. The fiber infrastructure breaks occurred numerous times during the deployment process and often resulted in delays, as the availability of the fiber-optic communications infrastructure was a prerequisite for many additional deployment and system integration activities. Complicating this situation was the limited familiarity among project partners of deploying and maintaining fiber-optic infrastructure. For many agencies, the Smart Corridor deployment represented the first exposure to this type of infrastructure. Significant lessons were learned by the agencies during the deployment, including the following:

- The original implementation did not include sufficient safeguards (e.g., signage, system maps, etc.) to ensure the integrity of the system after installation. Construction crews often unknowingly dug up the infrastructure when they had no prior knowledge of the fiber-optic line placement. The partner agencies implemented policies to better inform the public of the location of fiber-optic lines and included language into the scopes of work for later fiber-optic installation that better defined line signage and markings.

- The initial fiber-optic infrastructure did not include a sufficiently robust monitoring system that could identify system breaks and notify system personnel when they occurred. Therefore, many fiber cuts occurred without the immediate knowledge of agency personnel. This occasionally resulted in difficulties in identifying the parties responsible for the infrastructure damage due to the long time lag before the fiber cut was discovered. A more robust monitoring system was implemented to lessen the potential duration and impact of infrastructure damage.

- When fiber cuts occurred, several agencies reported having inadequate policies in place to assess responsibility and designate appropriate mitigation of the damage done. This resulted in significant delays in properly repairing the cut. The agency partners have been testing and sharing various policies to help address these policy deficiencies.

- Various agencies discovered that their own internal personnel lacked the technical training to address many of the more complex issues arising from the fiber implementation. Several technical problems required the consultation of outside contractors and the additional contracting effort resulted in deployment delays. To address this issue, the partner agencies have sought additional training for some of their maintenance personnel and have developed alternative contracting mechanisms to more quickly and effectively repair or replace infrastructure damage.

Significant progress has been achieved by the Smart Corridor partners in better ensuring the integrity and availability of the fiber-optic infrastructure for use by other components of the system. Newly adopted policies and procedures have resulted in greater system stability. Additionally, successful policies and procedures have been disseminated and shared amongst the partners, resulting in greater standardization across the various jurisdictions. Many of the project partners have reported that maintaining the integrity of the fiber-optic system is their highest priority as they have realized that system instability poses the greatest threat to the success of the deployment.

An additional lesson learned by the project partners was related to the procurement of the trailblazer signs. The purchase of the sign equipment was completed through the standard equipment bid process where cost constituted the primary selection criteria. The procurement contract was won by a small local firm with relatively little experience in producing this type of equipment. Although the equipment provided has met the minimum operating qualifications specified in the contract, other performance qualities have limited the usefulness of the signs.

The decision was eventually made to replace the signs with products from a more established contractor. The replacement of these trailblazer signs has yet to be completed.

The project manager reported that the procurement process that was used to purchase standardized "commodity" type equipment was often inadequate for the purchase of highly complex integrated ITS components. Changes were made to the procurement process as a result of the difficulties with the trailblazer sign purchase.

While the technical implementation barriers were significant, several project partners reported that institutional issues served as greater impediments throughout the deployment process. Key among the institutional impediments cited was the inability to approve an agreement specifying the operational procedures in a timely matter.

During the initial phase of the deployment, a memorandum of understanding (MOU) was approved by the direct partners. This MOU established the project committees and provided a basic understanding of the operational concept. This original MOU was not intended to detail the specific operational strategies of the deployment; however, and efforts were initiated soon after the project inception to draft agreements specifying these policies.

Many difficulties were encountered in reaching agreement on these policies among the various agencies and their legal council. A sample of the concerns that caused difficulty in achieving consensus included:

- Policies that enabled one jurisdiction to assume control over equipment located in a neighboring jurisdiction;
- The use of maintenance staff from a jurisdiction to repair equipment in another jurisdiction;
- The rights of individual jurisdictions to use the deployed equipment for other purposes than defined by the group;
- The assignment of operational and maintenance responsibilities and funding;
- Liability concerns; and,
- Policies specifying the hierarchy of control over particular components.

These issues, among others, resulted in significant delays in approving an overall MOU defining system operations. The MOU was finally agreed upon by all direct partners in late 2002.

7.0 SUMMARY OF EVALUATION OPPORTUNITY

The evaluation of the Silicon Smart Corridor deployment began in late 1999. The initial baseline data collection was completed in August/September 2000. The results from this preliminary baseline data assessment showed a noticeable, but not always significant impact on travel times, roadway volumes, and signal queue lengths occurring on Bascom Avenue when incidents occurred on the parallel Highway 17/ I-880 corridor.

The assessment of the evaluation opportunity at that time noted that, although the impact identified was small, the evaluation was not able to capture the impacts of a major incident event (causing the significant restriction or complete closure of the freeway), where the impact was likely to be more significant. Combined with the nearly feverish development pace (and deteriorating traffic conditions) in the Silicon Valley region at the time, the evaluation team felt the deployment remained a strong potential opportunity for evaluation. Recognizing the limitations of the initial baseline assessment, however, additional baseline data collection was proposed to more carefully assess the opportunity and control for the passage of time that had elapsed since the initial data collection.

Additional baseline data collection was completed in October of 2001 using enhanced data collection methodology. Travel time runs were completed using GPS-based locational recorders, and spot speed variability was collected and analyzed at several key locations along the corridor. These enhanced data collection methods were applied to provide more robust data sets in which to draw conclusions regarding the level of diversion and related negative traffic conditions on Bascom Avenue during incident conditions.

Analysis of the collected data showed that the conditions from both data collection periods were generally comparable. Using the enhanced data sets, however, the evaluation team was unable to find any significant deterioration in traffic conditions on Bascom Avenue resulting from incidents occurring on the Highway 17/I-880 corridor. While several multi-vehicle crashes were observed during both the initial and enhanced data collection period, the evaluation team was unable to evaluate travel conditions during a major incident that resulted in a closure of several lanes of the freeway for an extended period time (greater than one hour). Under these circumstances, there may be greatly increased diversion to the parallel arterial roadways, but the evaluation team was unable to gather evidence that supports this possibility. These major incident events do not appear to occur with sufficient frequency to lend themselves to reliable evaluation. Fully automated sources of data would need to be obtained for long period of time to capture these impacts and reliable sources for these types of data have not been found.

Difficulties in assessing the traffic conditions during impact conditions have been greatly exacerbated by a dramatic decrease in travel demand that is largely a result of a significant slowing of the economy and a decrease in computer technology employment in the region. An annual congestion monitoring report from the Santa Clara Valley Transportation Authority (VTA) indicated a significant decrease in traffic congestion in the Silicon Valley region as a result of the decrease in high-tech employment. The report specifically identified the Highway 17 corridor as one of the most significant examples of traffic congestion easing following the dot.com industry crash. The VTA reported that travel on Highway 17 was congested 82 percent of the time in 2000, but was congested only 25 percent of the time one year later. The report also cited a reduction in average morning commute times in the Silicon Valley region of 29 percent from 2000 to 2001. This reduction in congestion has the effect of reducing the overall number of incidents occurring on Highway 17, as well as reducing the incentive for travelers to divert to surface streets to avoid any incident-related congestion. This wide fluctuation in travel conditions presents significant challenges to the comparison and normalization of traffic data collected at different times.

Additionally, at the time of the initial baseline assessment, several threats were identified that could impact the evaluation opportunity. The ability of the project partners to maintain their planned deployment schedule was one of the threats identified. Given the rapidly occurring development in the region, it was felt that a significant delay in the deployment could invalidate the initial baseline data. A second threat included the instability of the fiber optic communications infrastructure. It was noted that the project partners had experienced difficulty in maintaining the integrity of the systems communication backbone, and this was creating delays in the full deployment and testing of system components.

Although steps have been taken to better maintain and ensure the integrity of the fiber optic network, including the recent addition of ten certified fiber-optic technicians, the system has not yet been made reliable on a day-to-day basis. The failure to maintain the integrity of this critical communications infrastructure has resulted in further delays in the deployment and testing of components that depend on this technology. The full availability of the system is predicted to be delayed until 2003.

7.1 Recommendations

Many of the factors presented in the section above limit the opportunity for conducting a meaningful evaluation of system performance, primarily:

- The inability to identify any statistically significant traffic deterioration on Bascom Avenue during incident conditions on Highway 17;
- The lack of reliable automated data sources to monitor conditions over a long term;
- The rapidly changing traffic patterns in the region due to economic boom/bust cycles; and
- Further delays in the deployment schedule.

Based on these limiting factors, the evaluation team did not recommend the continuance of the post-deployment (Phase III) system performance evaluation efforts. Since the evaluation team has not been able to identify any worsening of conditions during incident conditions in the baseline data collection, it is unlikely that any meaningful before/after performance impacts will be able to be identified. Further, since the system was not intended to actively promote diversion onto the arterial during incidents, the evaluation team felt there was little opportunity to measure these impacts in the post-deployment scenario. Therefore, the continuance of the system performance evaluation was not perceived by the evaluation team as a prudent use of the FHWA's evaluation resources.

FHWA agreed with this assessment of evaluation opportunity, following a briefing presented in June 2002, and approved the discontinuation of the evaluation effort. Although the evaluation was not successful in capturing the performance impacts of the system, several important lessons were learned from the effort that may be useful to agencies considering these types of deployments. Therefore, FHWA authorized the evaluation team to produce this Final Evaluation Report summarizing the evaluation approach, the baseline findings, and the lessons learned to conclude the evaluation effort.

In addition to the valuable lessons learned by project participants documented in this report, it is hoped that this evaluation effort will also provide evaluators with guidance on conducting evaluations and assessing evaluation opportunities. The SVSC evaluation presented several unique challenges to evaluators, and in response, many innovative assessment techniques were explored and implemented. The lessons learned regarding these innovative evaluation methodologies are documented in this and the previous evaluation reports to assist future evaluators in implementing these techniques.

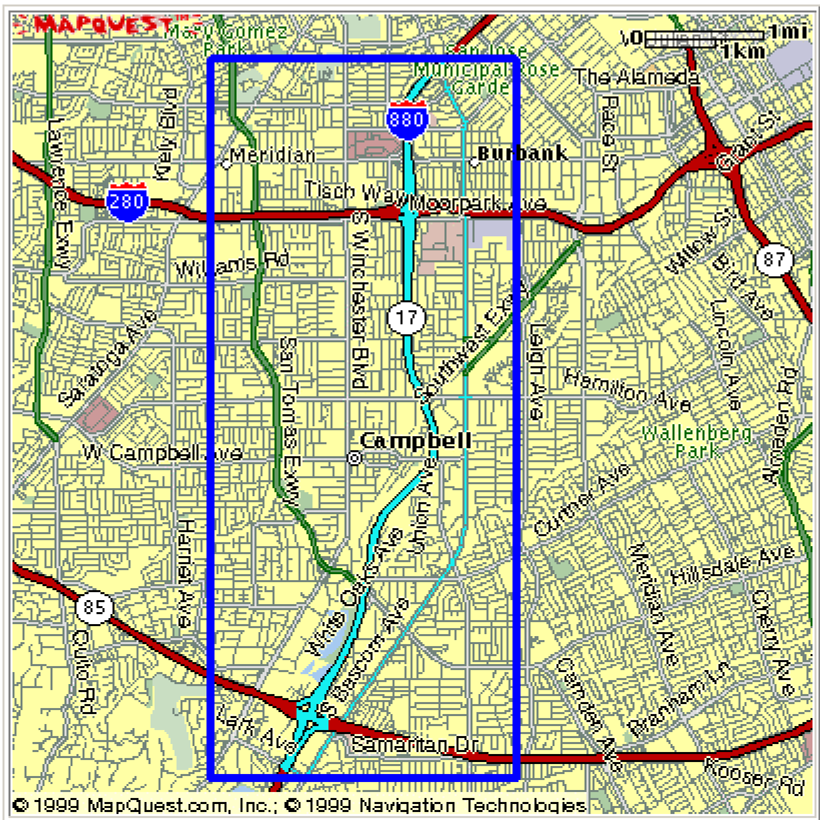
APPENDIX

Web Based Panel Survey Instrument

WELCOME

Silicon Valley Smart Corridor Incident Study

As part of an ongoing commitment to relieve traffic congestion in our region, a team of state and local agencies will implement the **Silicon Valley Smart Corridor System** along Highway 17/I-880 and several parallel surface streets this winter. This system will make use of a variety of technologies in an effort to resolve traffic flow problems resulting from incidents (*e.g. a crash, stalled vehicle, etc.*) occurring on the freeway thereby relieving overflow congestion on local streets. The area affected by the Smart Corridor System is shown on the highlighted area of the following map:



We would like to ask for your assistance in helping us analyze the system. Please complete the screening survey by clicking on the "screening survey" link below. If your travel patterns fit the needs of this study, you will be notified by e-mail, and asked to complete an incident survey. Your input is critical and your participation will assist local transportation professionals in calibrating the system to meet your needs and identify areas for improvements. Thank you for participating in this study.

This site prepared by SAIC under the sponsorship of the U.S. Department of Transportation Federal Highway Administration.

Questions or comments to: Tim Luttrell

This study will focus on travel along Highway 17 / I –880 corridor, generally between Los Gatos and downtown San Jose (refer to the blue area on this map).

1.1. Do you commute through the corridor in a private automobile (including carpools and vanpools) on a regular basis (at least three days in the average week)?

- Yes
- No

1.2. Do you typically travel **NORTH** on portions of either of the following roads within the corridor during the AM peak?

- SR 17/I-880
- Bascom Avenue
- Both
- Neither

Continue

You said that you commute through the study corridor in a private automobile on a regular basis,and that you travel NORTH on SR 17/I880 and/or Bascom Avenue during the AM peak time. Based on this response, please provide the following information:

2.1. What hour during the AM peak period you typically travel through the corridor?

- 6:00 a.m. to 7:00 a.m.
- 7:00 a.m. to 8:00 a.m.
- 8:00 a.m. to 9:00 a.m.
- 9:00 a.m. to 10:00 a.m.

2.1A. Other, please specify:

2.2. What is your approximate commute time (from begining of trip to end of trip) each morning?

(Minutes)

2.3. How far do you drive during your morning commute?

(Miles)

2.4. What sources of traffic condition information do you use before and/or during your morning commute? (please check all that apply)

- Television coverage
- Radio reports before leaving home
- Radio reports while in my vehicle
- Internet
- Variable or Electronic Message Signs on the Freeway (SR17 or I-880)
- Highway Advisory Radio

2.4A. Other, please specify:

2.5A. How would you rank the **usefulness** of traveler information in Silicon Valley?

- Not useful
- Somewhat useful
- Useful
- Very useful
- Extremely useful

2.5B. How would you rank the **timeliness** of traveler information in Silicon Valley?

- Not timely
- Somewhat timely
- Timely
- Very timely
- Extremely timely

2.5C. How would you rank the **accuracy** of traveler information in Silicon Valley?

- Not accurate
- Somewhat accurate
- Accurate
- Very accurate
- Extremely accurate

2.6. On average in a typical month, how often do you encounter delays on the freeway that are significantly greater than you anticipated?

- Once a month
- Twice a month
- Three times a month
- Four times a month
- More than four times a month
- Never

2.7A. During your commute, when you encounter significantly greater than normal delays from an incident (*e.g. crash, stalled vehicle, etc.*) on the freeway, what do you typically do?

- use another freeway
- exit the freeway and use another route
- stay on the freeway
- I normally travel on a parallel roadway instead of SR-17/I880

2.7B. If you divert from the freeway and use a surface street, which one do you use?

- Winchester Blvd.
- Leigh Ave.
- Meridian Ave.
- Bascom Ave.

Other, please specify:

2.7C. On average, how often do you divert to this alternate route to avoid heavy congestion?

- More than six times per month
- Four to six times per month
- One to three times per month
- Less than once a month
- Never divert from the freeway
- Never, always use a parallel roadway instead of the freeway

2.8. Are you made aware of significantly greater delays from incidents (*e.g. crash, stalled vehicle, etc.*) on SR-17/I880 before you encounter them?

- Yes, I am made aware of delays from most incidents before I encounter them
- No, I am not made aware of delays from most incidents until I encounter the problem area

2.9A. Please type in your zip code.(All responses will be kept confidential, and will not be shared with anyone.)

Your Zip Code:

2.9B. Please type in your employer's zip code.

Employer's Zip Code:

2.10. Please provide your e-mail address so that we may contact you with further information.
Your email address along with your survey responses will be kept confidential, and will not be shared with anyone.

Your e-mail address:

Select continue to verify your responses before they are submited.

Continue Reset