FREEWAY INCIDENT DETECTION AND ARTERIAL SYSTEMS MANAGEMENT FOR THE I-84 CORRIDOR

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Idaho Transportation Department, in collaboration with other transportation agencies in the Treasure Valley, has participated in an Intelligent Transportation Systems planning process over the past two years. As a result of this planning process, ITD and other agencies have submitted a grant to the Federal Highway Administration to integrate real time traffic information from the I-84 freeway corridor into a regional traffic management system. The project that would be funded by this FHWA ITS grant has one objective: to integrate the data needed to make real time decisions: (1) by transportation agencies in the Treasure Valley so that they can more effectively operate and manage the region's transportation system and (2) by travelers in the Treasure Valley so that they can make optimal use of the region's transportation system.

The integration of real time data that can be accessed by a variety of users each with different needs is a complex task. The integration will require deployment of new sensors and communication linkages, and a data base management system that is able to continuously accept a large number of transactions and queries. For example, data from loops on a twelve-mile section of I-84 will be transmitted to the center every 30 seconds; this information will be processed and made available to travelers on an Internet web site. And, these same data will be used to identify when an incident has occurred so that the appropriate agencies can be notified to deal with the problem as rapidly as possible.

For effective incident detection and freeway management, various automatic incident detection algorithms (AID's) are currently available. But most AID's need calibration before they can be applied to a particular area. Each system differs in terms of detection rates, false alarm rates, and times to detection. Off-line testing of the detection systems to detect incidents and false alarm rates will be required before they can be implemented online. If an adequate quantity of incident data is not available some off-line testing may need to be done using simulated data. There are simulation programs available to simulate the operation of freeways as well as arterial streets. Finally, after adequate testing of the available AID's are conducted with real and/or simulated data, ITD

personnel will need to be trained to apply these systems on a day-to-day basis and to continually update and improve them.

Another component of the freeway/arterial corridor is the effective operation of the signal systems on the parallel arterials. Serious operational problems result when signal systems cannot effectively move traffic due to long queues on the arterials. Effective signal control and management strategies can be devised to minimize congestion using the actuated controllers already in use in the I-84 corridor. Evaluation of various congestion management schemes, such as adding unused green time to the main street, measuring congestion control, and testing other queue detection/control strategies is needed for the Treasure Valley area. This project will develop alternative control strategies, test and evaluate the strategies, and validate strategies.

PROJECT SCOPE AND OBJECTIVES

The purpose of this project, *Freeway Incident Detection and Arterial Systems Management for the I-84 Corridor,* is to enhance and build upon the work that will be completed as part of the Treasure Valley ITS integration project to accomplish some additional, and important, objectives:

- Test and evaluate standard incident detection algorithms that are used in practice today and help to determine which ones may be suitable for use in the I-84 corridor.
- Develop and test signal control strategies for actuated coordinated traffic control systems in the I-84 corridor.
- Develop a set of materials that can be used to train practicing professionals and university engineering students to operate a freeway traffic management center.

URGENCY

This project has several important benefits to Idaho Transportation Department, as well as to other transportation agency personnel in the Treasure Valley and throughout the state of Idaho:

- A freeway incident detection algorithm that is appropriate for the Treasure Valley and other areas in the state of Idaho,
- A set of materials and facilities that can be used to train practicing professionals and university engineering students in advanced technology applications, and
- A signal control strategy that can be used in conjunction with the I-84 incident detection system to improve traffic flow on parallel arterials for the I-84 corridor.

PROJECT TASKS

1) The parameter values of the six algorithms presented in the Phase I Interim Report were further examined and a new set of values were developed and tested. After parameter adjustment to reflect site-specific characteristics, recommendations were made for the use of a particular algorithm or group of algorithms in the I-84 corridor.

2) In addition to the six algorithms presented and examined as part of phase-1 of the project. Phase II activities will include examining three additional algorithms: All Purpose Incident Detection (APID), McMaster, and Multiple Speed Thresholds Queue Detection (MSTQ). The three algorithms are likely to be used in the ACHD ATMS software. The three algorithms were tested and evaluated for potential use in the ACHD incident detection subsystem.

3) The simulation models developed for the project were used to evaluate diversion route plans proposed during incident situations. A methodology was developed to allow traffic operators to quantify the potential benefits of implementing diversion route plans. The methodology employs a statistical technique [Mote Carlo simulation analysis] to take into account the

uncertainty in incident duration and percent of motorists who comply with the diversion route signs.

4) Signal control plans were developed and tested for the actuated controllers located on the arterial system networks in the proposed diversion route plans.

5) An ATMS lab was established at the University of Idaho’s campus in Moscow, ID. The lab will be connected to the ACHD TMC through the state microwave/wireless network. [The lab configuration and layout are presented in Appendix C]. In addition to this lab, a Virtual Traffic Management Center (VTMC) has been established at Boise State University in Boise. The management center is connected to ACHD TMC through a fiber optic network. Using real-time freeway data and the simulation models developed for this project, the labs will be used to train TMC operators to manage incidents under a variety of freeway operational conditions.
6) A set of materials are developed to train practicing professionals and students in managing freeway incidents and TMC operations.

1. INTRODUCTION

1.1 Background

Freeway incident management has become an important issue in departments of transportation nationwide. With many of the nation's roadways operating very close to capacity under the best of conditions, the need to reduce the impact of incident-related congestion has become critical. Non-recurring congestion caused by random events such as accidents, spilled loads, disabled vehicles or any other special event, represents up to 60% of the overall congestion on urban freeways, which can result in significant costs. While incidents on freeways cannot be prevented entirely, the implementation of an effective incident detection and management system can mitigate the impacts of the resultant congestion.

1.2 The Process of Incident Management

The process of managing an incident has four distinct stages: detection, response, clearance, and, with full capacity restored, recovery. Figure 1-1 graphically represents incident-based delay with and without an incident management system.

In general, the impact of incidents on traffic flow can be minimized by implementing incident management programs that:

- Reduce the time to detect and verify the incident.
- Reduce the response time for personnel and equipment to arrive at the incident location.
- Effectively manage on-site personnel, equipment and traffic.
- Implement effective diversion route plans to reduce incident-based delay.
- Reduce the time to clear the incidents.
- Provide timely and accurate information to motorists, including possible diversion routes.

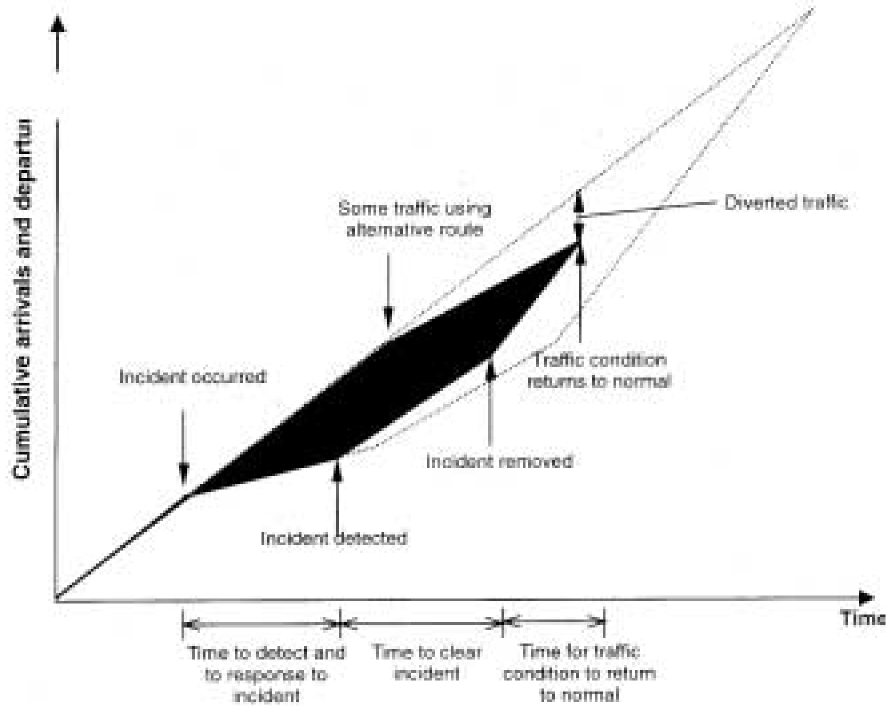


Figure 1-1. Incident-Based Delay With and Without an Incident Management System

1.3 Current Idaho Projects

In an effort to improve travel conditions in Idaho's Treasure Valley Corridor, the Idaho Transportation Department (ITD) has collaborated with other transportation agencies in the Treasure Valley area to plan a series of projects related to the application of Intelligent Transportation Systems (ITS). These projects are part of the ITS Integration Program funded by the Federal ITS Deployment Plan. Three such projects are the design, construction and implementation of a Traffic Management Center (TMC) for the Treasure Valley, the development of an Incident Management Plan (IMP) that encompasses the freeway and the arterial systems, and the design and implementation of ITS devices on I-84.

1.3.1 Treasure Valley Traffic Management Center (TMC)

The Treasure Valley includes the cities of Boise, Garden City, Meridian, Eagle, Kuna, Star, Middleton, Nampa, and Caldwell in Ada and Canyon counties (Figure 2). As part of the ITS deployment plan in the Treasure Valley area, the Ada County Highway District (ACHD) completed work on a state-of-the-art TMC in January of 2000.

The TMC controls 240 of ACHD's 328 traffic signals, along with managing the operation of most of the arterial streets and the freeways (I-84 and I-184) within the Treasure Valley that are under ITD's jurisdiction.

This unique joint operation between ACHD and ITD facilitates integrated freeway and arterial system management, and hence more efficient traffic operation is possible. This will be particularly valuable during incident situations, as some of the freeway traffic can be diverted onto the arterial system network. The TMC also operates strategically located Changeable Message Signs (CMS) when necessary, and uses closed circuit TV camera (CCTV) systems to provide surveillance. Figure 1-2 illustrates the locations of the ITS components within the Treasure Valley area.

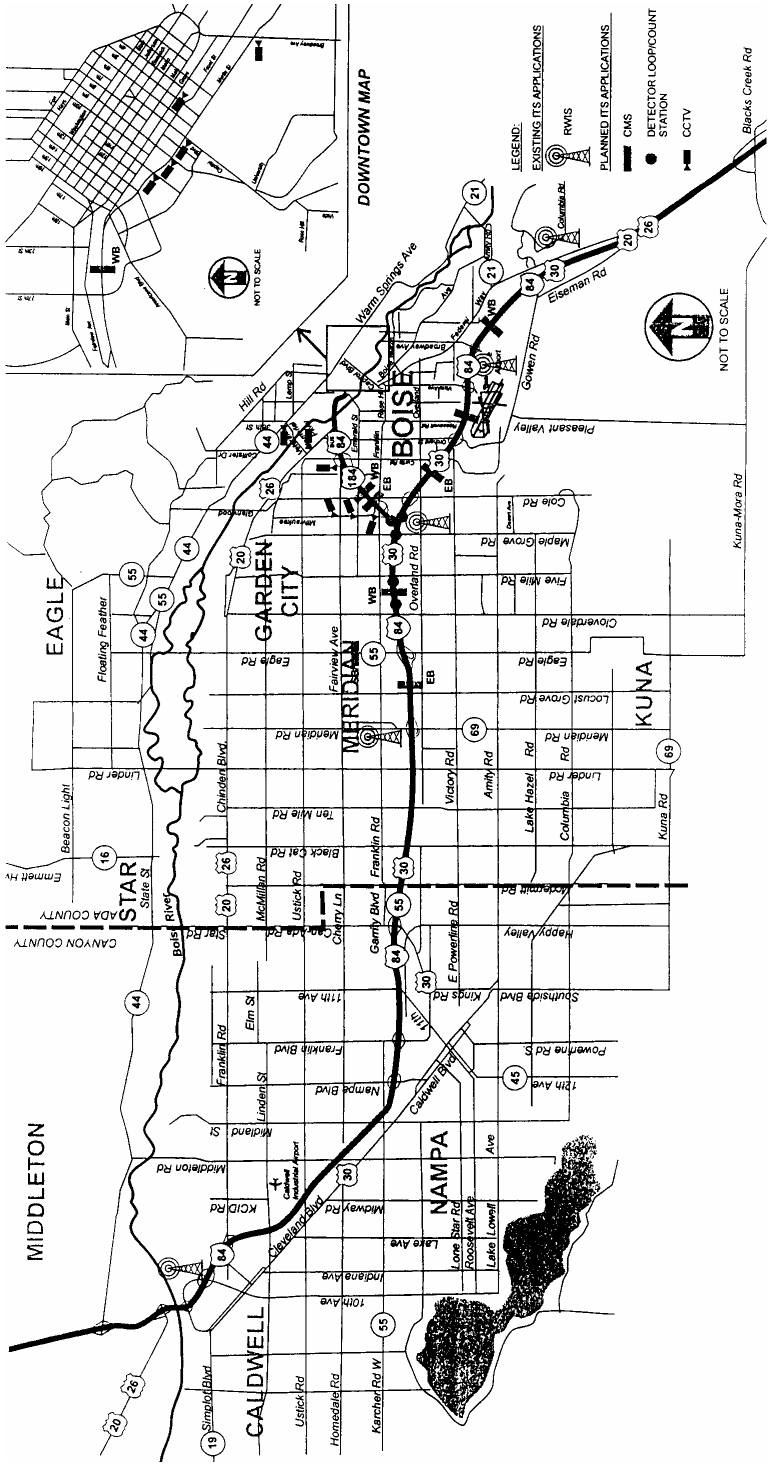


Figure 1-2. Treasure Valley ITS Components and their Deployment Locations

Source: Treasure Valley ITS-Freeway Management Master Plan, Meyer, Mohaddes Associates, Inc. (1999)

1.3.2 Development of an Incident Management Plan (IMP)

An IMP has been developed for the Treasure Valley that coordinates the incident management efforts among the transportation agencies in the area. The incident management plan provides scripted instructions for incident site management, re-routing of traffic along alternative routes and protocols that the TMC operator should follow. The plan provides a comprehensive checklist of steps that should be taken by all the response agencies to most effectively manage an incident, from detection through clearance and freeway flow restoration. System control software will be installed in the TMC that has the capability of controlling all of the system's components.

1.4 Problem Statement

Many incident management programs have been established in urban areas nationwide to help reduce the magnitude of incident-induced congestion. It has long been known that the weakest elements of these programs are the Automated Incident Detection (AID) algorithms and the incident recovery phase, particularly the utilization of traffic diversion strategies. Although diversion strategies are used in many areas, they have not been fully evaluated to determine their impact on the local transportation system. In most cases, in fact, only the impact on the freeway has been considered. Further, diversion is typically used only in extreme cases, but it might also be beneficial during incidents of moderate severity and duration. For example, the incident management handbook developed for the FHWA states, "In general, when two or more lanes of a freeway are expected to be shut down for two or more hours, institution of the alternate route plan should be considered."

If delay is to be minimized on a network as a whole, the incident management program will need to incorporate comprehensive traffic management strategies, and decision aids will need to be developed for defining recovery strategies. Careful analysis of diversion strategies including examination of the operational characteristics of the freeway and diversion routes can lead to far more efficient and effective incident management strategies.

1.5 Project Objectives

The purpose of this project is to enhance and build upon the work that was completed for the Treasure Valley IMP project by accomplishing some additional, and important, objectives:

1) A variety of AID algorithms are currently available, but most need calibration before they can be applied to a particular area. Each detection system varies in terms of detection rates, false alarm rates and times to detection. Off-line testing of the algorithms will be required before they can be implemented online in the system.

> **Project Objective One:** NIATT will test and evaluate six of the standard incident detection algorithms that are commonly used today and help to determine which ones may be suitable for use in the I-84 corridor.

2) Another important component of the freeway/arterial integrated management system is the effective operation of the signal systems on the parallel arterials where freeway traffic is being diverted. Freeway diversion plans were developed for the Treasure Valley corridor by Transcore and Six Mile Engineering. The study identified possible diversion routes and established incident response plans for a wide range of incident scenarios. To maximize the benefit provided by these diversion routes, effective signal control and management strategies can be devised for the actuated controllers in the I-84 corridor. Various congestion management schemes need to be evaluated, such as increasing cycle length and adding green time to the main street, measuring congestion, and testing other queue detection/control strategies.

> **Project Objective Two:** NIATT will develop and test signal control strategies that can be used in conjunction with the I-84 diversion route plans to improve traffic flow on parallel arterials for the I-84 corridor during freeway incidents.

3) The integrated freeway/arterial system simulation models for the Treasure Valley corridor will also be used to provide training for ITD personnel and TMC operators, as part of their preparation for detecting and managing incidents. The simulation models will allow them to test and evaluate incident response scenarios and diversion plans for a variety of incidents under different traffic flow conditions.

Project Objective Three: NIATT will develop a set of materials based on the simulation models that can be used to train practicing professionals and university engineering students to operate a traffic management center.

1.6 Scope of Work

1) The parameter values of the six algorithms presented in the Phase I Interim Report will be further examined and a new set of values will be developed and tested. After the parameter values are adjusted to reflect site-specific characteristics, recommendations can be made for the use of a particular algorithm or group of algorithms in the I-84 corridor.

2) In addition to the six algorithms presented and examined as part of phase-1 of the project. Phase II activities will include examining three additional algorithms: All Purpose Incident Detection (APID), McMaster, and Multiple Speed Thresholds Queue Detection (MSTQ). The three algorithms are likely to be used in the ACHD ATMS software. The three algorithms will be tested and evaluated for potential use in the ACHD incident detection subsystem.

3) The simulation models for the Treasure Valley corridor network will be further calibrated and validated. Another set of models the represent the future conditions of the network will also be developed.

4) The simulation model developed for the project will be used to evaluate diversion route plans proposed during incident situations. A methodology will be developed to allow traffic operators to quantify the potential benefits of

implementing diversion route plans. The methodology will employ a statistical technique [Mote Carlo simulation analysis] to take into account the uncertainty in incident duration and percent of motorists who comply with the diversion route signs.

5) Signal control plans will be developed and tested for the actuated controllers located on the arterial system networks in the proposed diversion route plans.

6) An ATMS lab will be established at the University of Idaho’s campus in Moscow, ID. The lab will be connected to the ACHD TMC through the state microwave/wireless network. [The lab configuration and layout are presented in Appendix B]. In addition to this lab, a Virtual Traffic Management Center (VTMC) will be established at Boise State University in Boise. The management center will be connected to ACHD TMC through a fiber optic network. Using real-time freeway data and the simulation models developed for this project, the labs will be used to train TMC operators to manage incidents under a variety of freeway operational conditions.
7) A set of materials will be developed to train practicing professionals and students in managing freeway incidents and TMC operations.

2. CURRENT FREEWAY OPERATIONAL CHARACTERISTICS FOR THE I-84 CORRIDOR

2.1 Freeway Data Collection and Management

Freeway traffic data were obtained from the ITD Division of Transportation Planning. ITD has embedded inductive loop sensors at fairly regular intervals along I-84 through Boise. The data from each detector station is collected and stored by a roadside Automatic Traffic Recorder (ATR). The ATR data is routinely downloaded and stored by a unit in the Division of Planning.

The ATR data is available in four formats. The format that was appropriate for our purposes is called the Individual Vehicle Records (IVR) format. IVRs provide speeds and length of vehicles by individual loops on a lane-by-lane basis. This is the most detailed level of data obtainable from the ATRs. From this level, data at any level of aggregation can be derived.

The ATRs located on I-84 within the Treasure Valley Corridor study area are listed in Table 2-1. The table also lists the type of data collected at each of these stations. As speed and occupancy measurements, which are typically used by incident detection algorithms, are the key factors in this study, stations that report volume only (West Nampa and Vista Rd.) were excluded from the data collection activities. However, some archived data for these stations were used to establish traffic flow profiles at these locations. IVR data were collected and maintained for the other seven stations (Robinson Rd., Five Mile Rd., Overland Rd, Orchard Rd., Broadway Ave., Jeans Place, and Blacks Creek). To account for the seasonal variation of traffic, the data collection covered the period from November 2000 through May 2001. In addition to the traffic data, weather condition data for the Boise area were collected through the national weather service center website.

Table 2-1. Automatic Traffic Recorders Located on I-84 within the Treasure Valley Corridor

Site Number	Location	Milepost	Data Type
094	West Nampa EB	32.4	Volume
	West Nampa WB	32.4	Volume
142	Robinson Rd. EB	39.7	Binned
	Robinson Rd. WB	39.7	Binned
121	Five Mile EB	47.93	Binned
122	Five Mile WB	47.93	Binned
260	Overland EB	49.73	Binned
263	Overland WB	49.73	Binned
261	Orchard EB	51.29	Binned
262	Orchard WB	51.29	Binned
263	Vista Rd. EB	53.1	Volume
264	Vista Rd. WB	53.1	Volume
265	Broadway EB	53.92	Binned
	Broadway WB	53.92	Binned
002	Jeans Place EB	58.73	Raw
	Jeans Place EB	58.73	Raw
87	Blacks Creek EB	62.1	Raw
	Blacks Creek WB	62.1	Raw

Figure 2-1 depicts the approximate locations of the detector stations in this segment of I-84 through the Boise urban area. The sets of three-digit numbers on either side of this schematic denote the ATR number. Some locations have the same number on both sides. For example, at Broadway the ATR number is 265 on both sides, while at Orchard the number in the Eastbound direction is 261, while in descending (or Westbound) direction it is 262. This means that at Broadway one ATR collects information for both directions of traffic, while at Orchard there is one for each direction. Loop sensors are installed at Vista, but they are not shown in this schematic because they are not “double-loop.” Two loops are needed for speed measurements, and since many of the proposed algorithms required speed information, the data from Vista was not applicable.

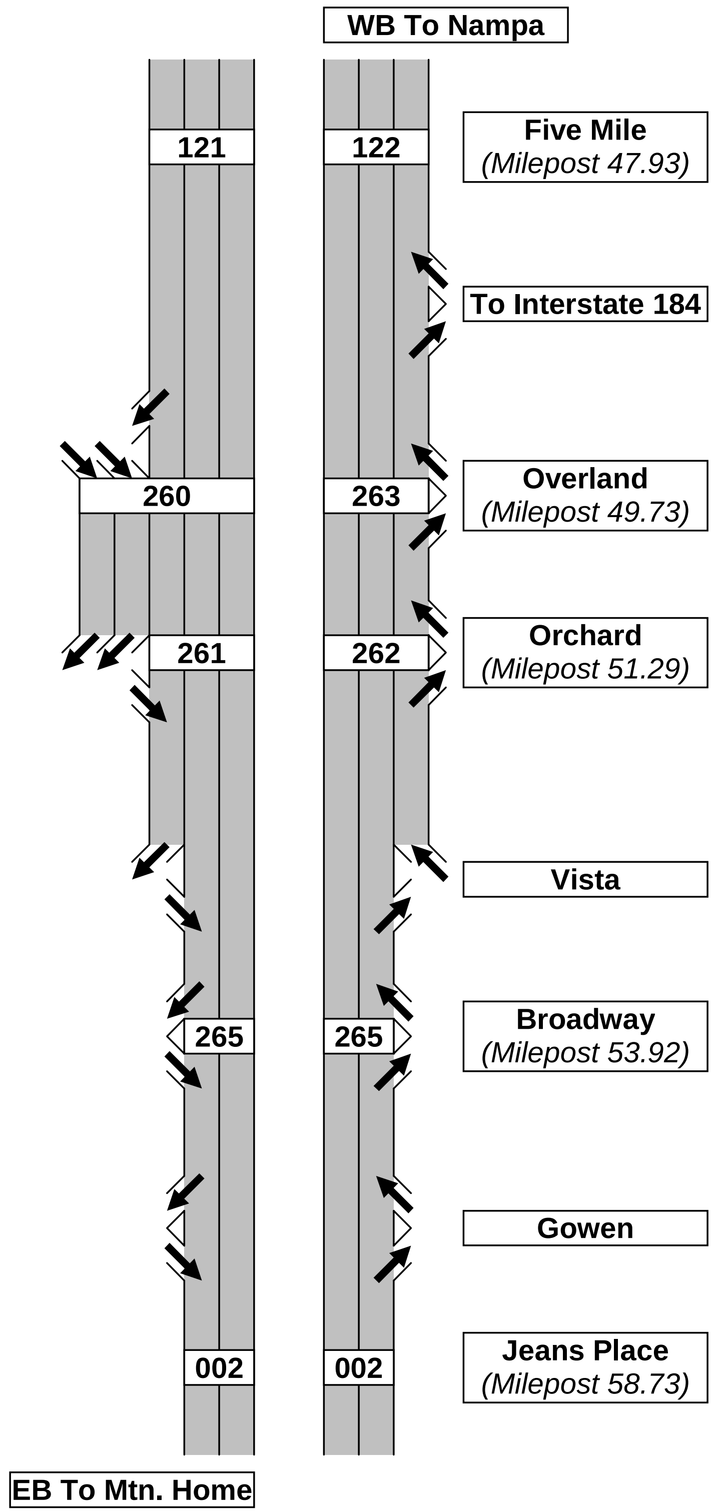


Figure 2-1. Detector Station Schematic

The first step in managing the freeway data was to transfer the raw (vehicle-by-vehicle) data to two Access databases. The first database included the vehicle-by-vehicle lane of travel, time, speed, and vehicle length data. The second database included the lane-by-lane volume, average speed, average detector occupancy aggregated over 30-second intervals, and weather condition (clear, rain, or snow). The files also included the volume, the weighted average speed, and the average occupancy for the lanes.

As the ATRs report speed and volume data only, the detector occupancy, used in many incident detection algorithms, was derived from the speed and volume data using the fundamental speed, flow, and density relationship: K=Q/V where K is the traffic density (vehicle per lane-mile), Q is the traffic flow (vehicle per hour), and V is the average speed (miles per hour). The percent occupancy was then obtained using the relationship:

$$\%OCC= \frac{1}{52.8} K(L_V + L_D) \text{ where:}$$

% OCC is the % of time the detector is occupied during the time interval

K is the traffic density (vehicle per lane-mile) during the time interval

L_v is the average vehicle length during the time interval (feet)

L_D is the detection zone length (feet)

2.1.1 Data Analysis

The freeway data were organized into separate files, with each file including traffic data for one detection station for a 24-hour period. Analysis of the freeway data was performed using the Statistical Package for Social Science software (SPSS version 10). The analysis of the data included generating speed confidence intervals for 14 locations along the freeway using the entire dataset. The speed confidence intervals represent the range of speeds that can be expected at these locations under "normal" traffic conditions. The speed confidence intervals were obtained for each 15-minute period and under different weather conditions. Table 2-2 presents an example of the hour-by-hour speed confidence intervals generated for the traffic at Broadway Ave.

Table 2-2. Speed Confidence Intervals (Broadway Ave. Milepost 53.92)

Time Interval	Eastbound Traffic		Westbound Traffic	
	Upper Limit	Lower Limit	Upper Limit	Lower Limit
Midnight - 1:00 AM	75	54	76	49
1:00 AM - 2:00 AM	75	54	77	47
2:00 AM - 3:00 AM	74	53	79	44
3:00 AM - 4:00 AM	74	54	77	45
4:00 AM - 5:00 AM	77	56	75	49
5:00 AM - 6:00 AM	77	57	76	53
6:00 AM-7:00 AM	76	54	77	52
7:00 AM - 8:00 AM	75	49	74	53
8:00 AM - 9:00 AM	76	52	74	52
9:00 AM - 10:00 AM	75	51	75	51
10:00 AM - 11:00 AM	75	52	75	51
11:00 AM - Noon	77	52	75	51
Noon - 1:00 PM	77	52	74	52
1:00 PM - 2:00 PM	75	53	74	50
2:00 PM - 3:00 PM	76	52	75	51
3:00 PM - 4:00 PM	75	53	76	45
4:00 PM - 5:00 PM	77	48	72	48
5:00 PM - 6:00 PM	77	48	74	51
6:00 PM - 7:00 PM	77	52	74	50
7:00 PM - 8:00 PM	75	51	75	54
8:00 PM - 9:00 PM	76	52	75	53
9:00 PM - 10:00 PM	75	54	76	52
10:00 PM - 11:00 PM	76	51	77	51
11:00 PM - Midnight	76	51	76	52

2.2 Traffic Flow Profiles

The traffic data were first analyzed to determine traffic flow characteristics on the Treasure Valley freeway system. Figures 2-2 and 2-3 present the average hourly traffic volumes during the morning and afternoon peak periods at different locations along Eastbound and Westbound I-84. The morning peak period was considered to be from 7:00 AM to 9:00 AM and the afternoon peak period was considered to be from 4:00 PM to 6:00 PM. Figures 2-4 and 2-5 present the volume/capacity ratio at the same locations for both the morning and afternoon peak periods. The capacity of was obtained using the following equation:

$$C = NC_{ideal}\, f_{HV}\, f_P \text{ where:}$$

N is the number of lanes

C_{ideal} is the ideal capacity and was assumed 2000 vph.

f_{HV} is the heavy vehicle adjustment factor based on the percent of heavy vehicles in the traffic. In the morning peak, the average HV percentage was 3.21%, whereas the average HV percentage increased to 5.4% in the afternoon peak period. Using these percentages, the adjustment factors were 0.987 and 0.966 for the morning and afternoon peak, respectively.

f_P is the driver population factor and was assumed 1.0, as most of the morning and afternoon peak periods drivers are commuters and familiar with the freeway.

As can be seen from these figures, the v/c ratio for most parts of the freeway is less than 0.73, indicating stable flow conditions with a level of service ranging from A to C. However, a segment of the freeway from milepost 48 to milepost 49 and from milepost 53 to milepost 55, the v/c ratio ranged from 0.73 to 0.91, indicating a high density and near capacity flow conditions with a level of service D.

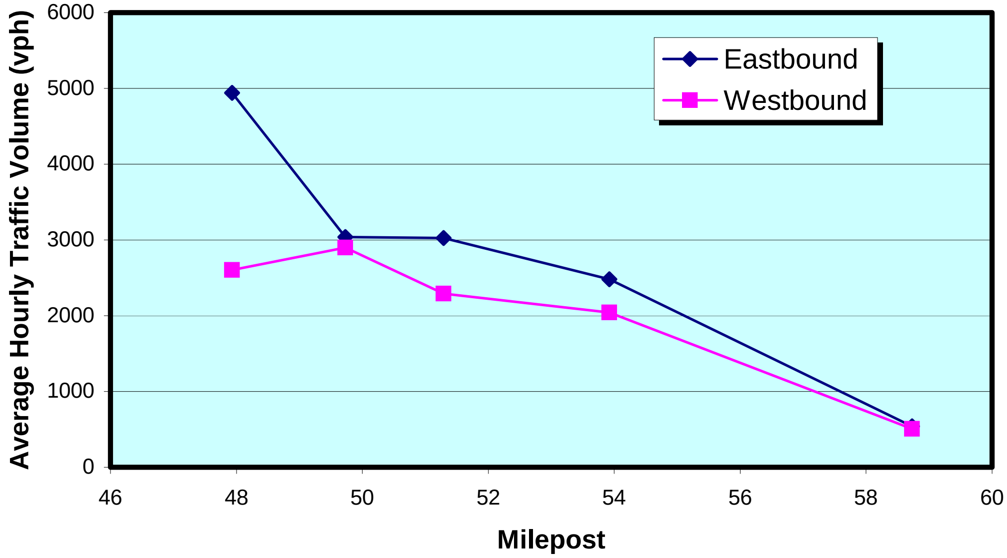


Figure 2-2. Average Hourly Traffic Volumes (Morning Peak Period)

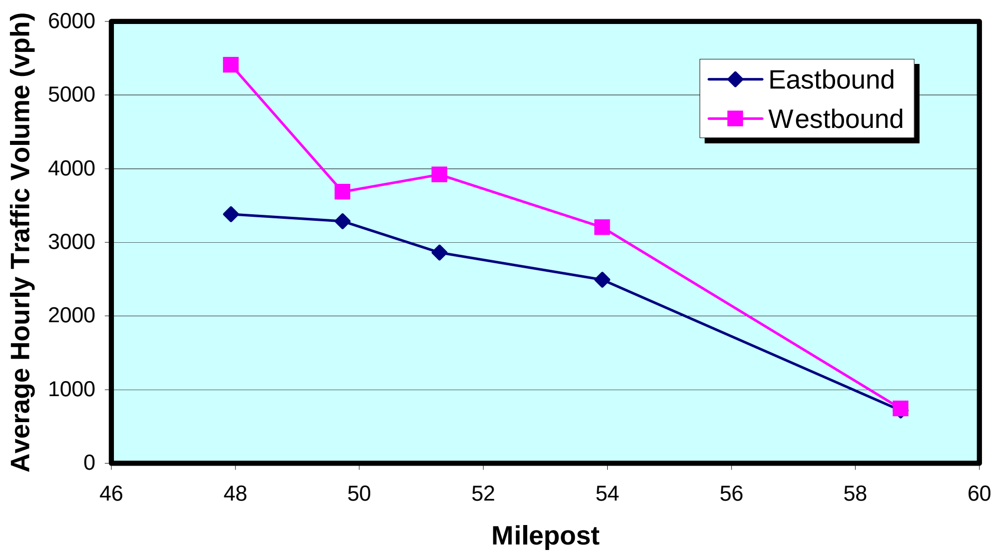


Figure 2-3. Average Hourly Traffic Volumes (Afternoon Peak Period)

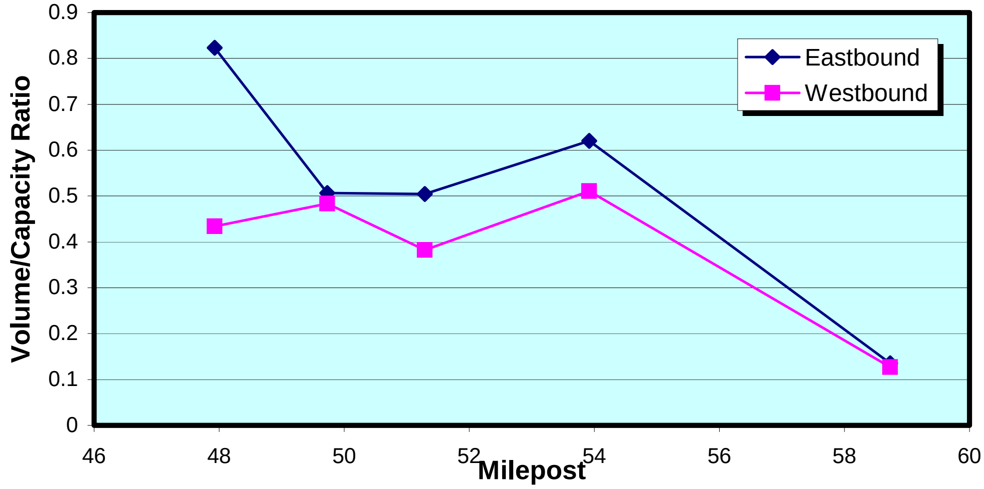


Figure 2-4. Volume/Capacity Ratio (Morning Peak Period)

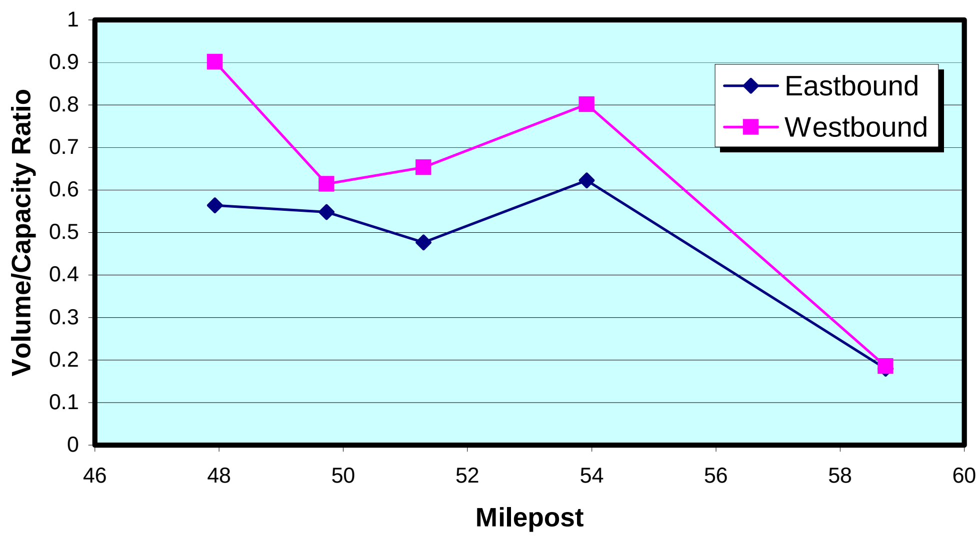


Figure 2-5. Volume/Capacity Ratio (Afternoon Peak Period)

Figure 2-6 presents the 24-hour volume variation for the Westbound traffic near Broadway Ave. The graph shows distinct morning and afternoon peak periods from 7:00 AM to 9:00 AM and from 4:00 PM to 6:00 PM, respectively. Figure 2-7 presents the average morning and afternoon peak-hour traffic volume for the period from September 2000 through May 2002.

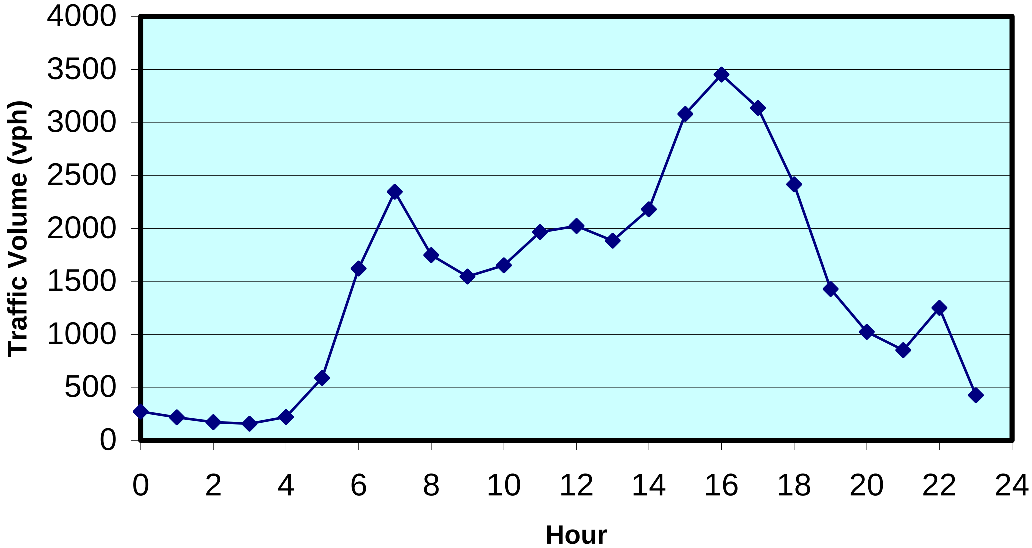
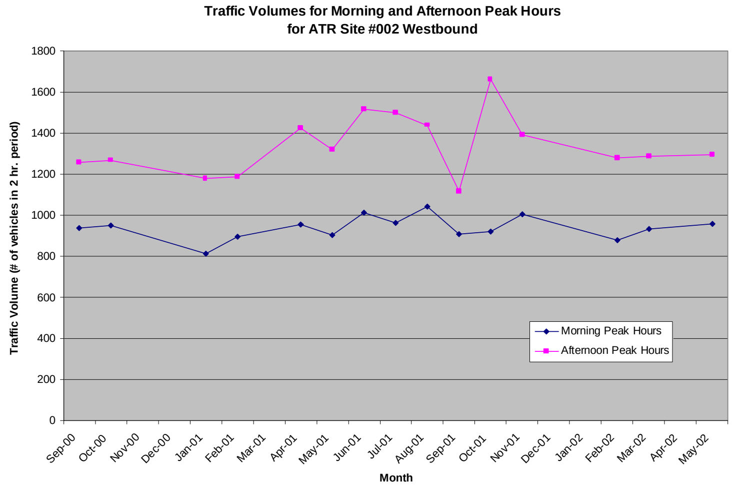
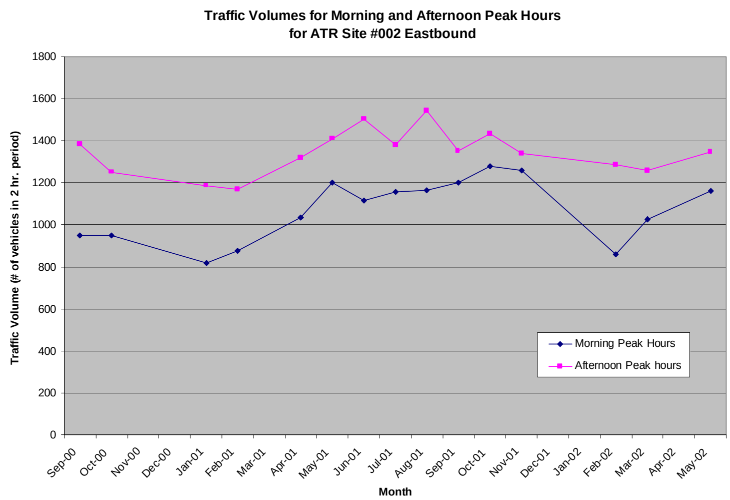


Figure 2-6. Hour-By-Hour Traffic Volumes for WB I-84 at Milepost 53.92 (Broadway Ave.)





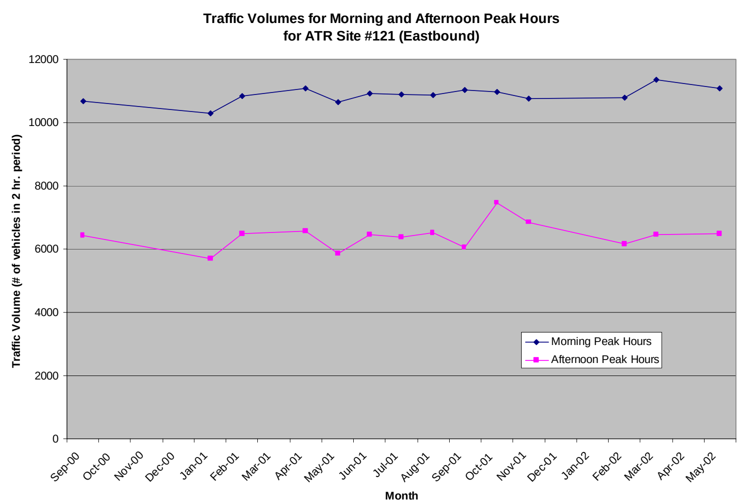
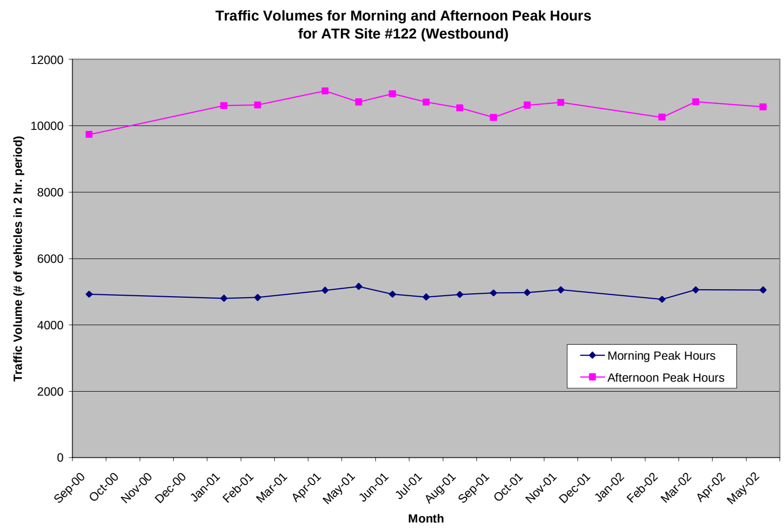
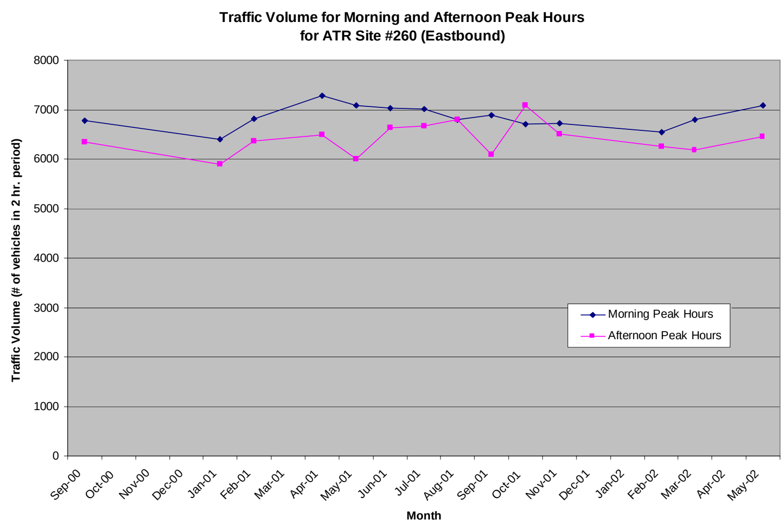


Figure 2-7. Average Peak-Hour Traffic Volumes. (September 2000 – May 2002)





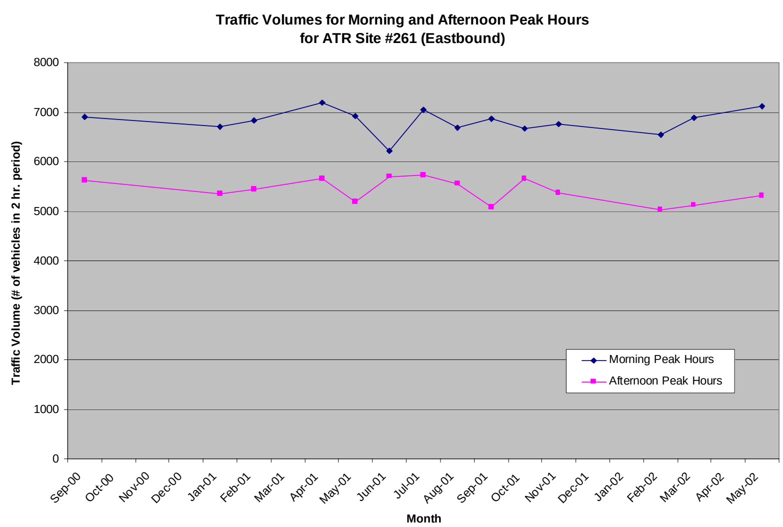


Figure 2-7 (Cont.) Average Peak-Hour Traffic Volumes. (September 2000 – May 2002)

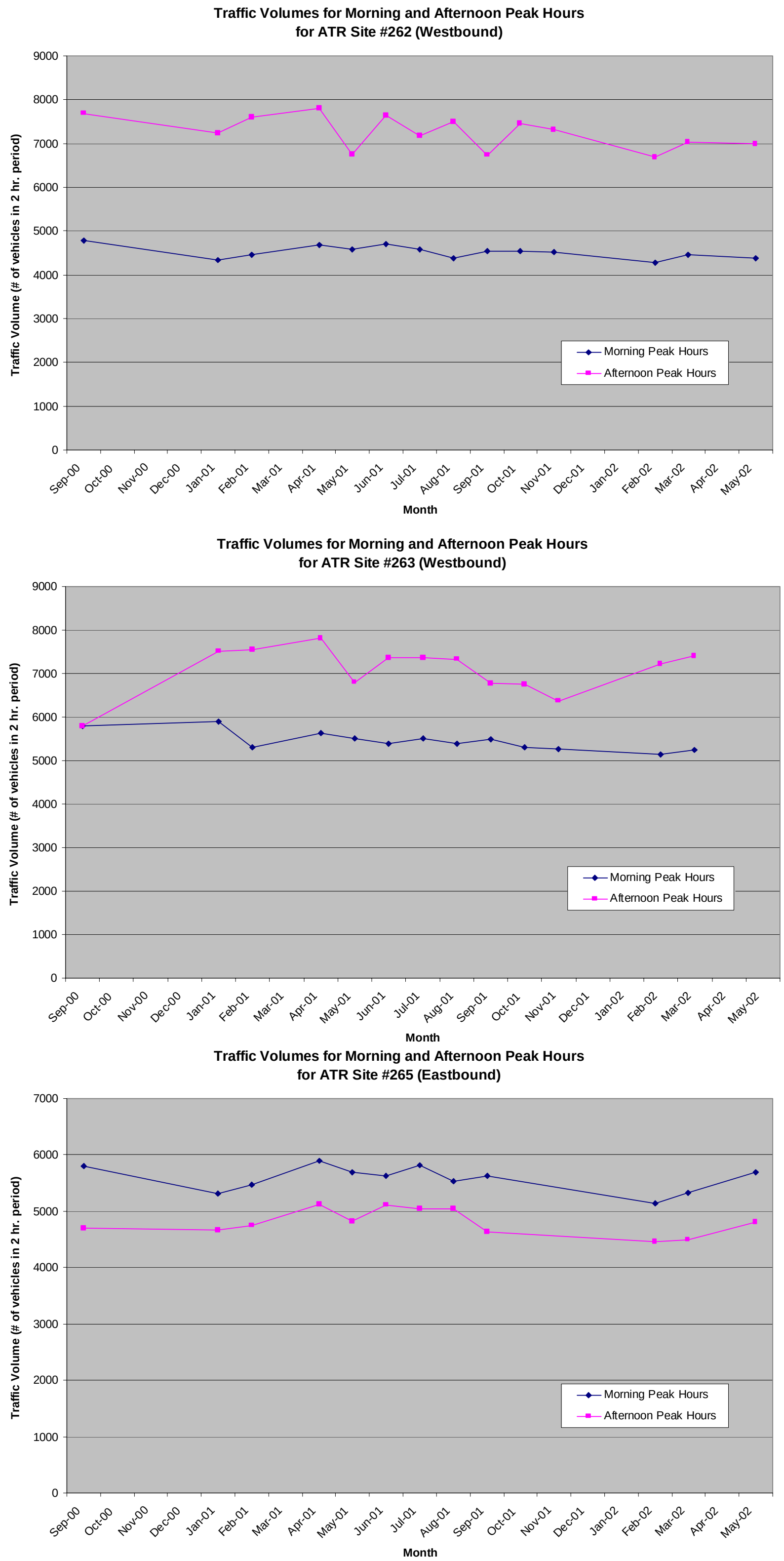


Figure 2-7 (Cont.) Average Peak-Hour Traffic Volumes. (September 2000 – May 2002)

2.3 Speed Profiles

Figures 2-8 and 2-9 present the average speed during the morning and afternoon peak periods at different locations along Eastbound and Westbound I-84. The average speed during the peak periods ranged from 59 mph to 61 mph, which is close to the free-flow speed of 64 mph. This again indicates that the freeway operates under stable free-flow conditions. The average speed in the congested areas ranged from 49 to 54, indicating a high density with near capacity flow conditions.

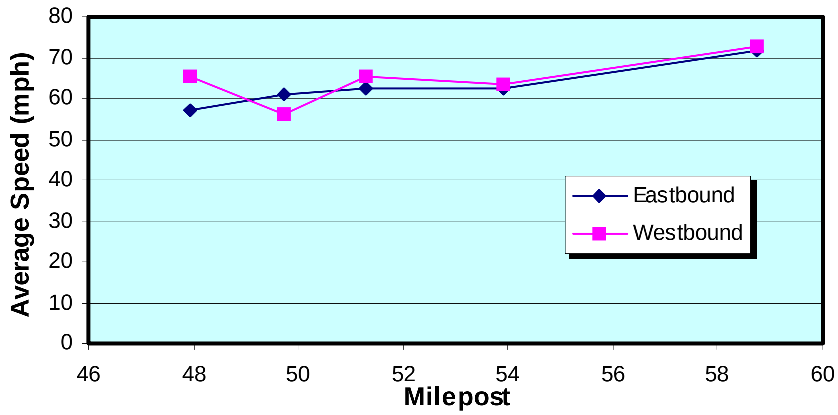


Figure 2-8. Average Speed (Morning Peak Period)

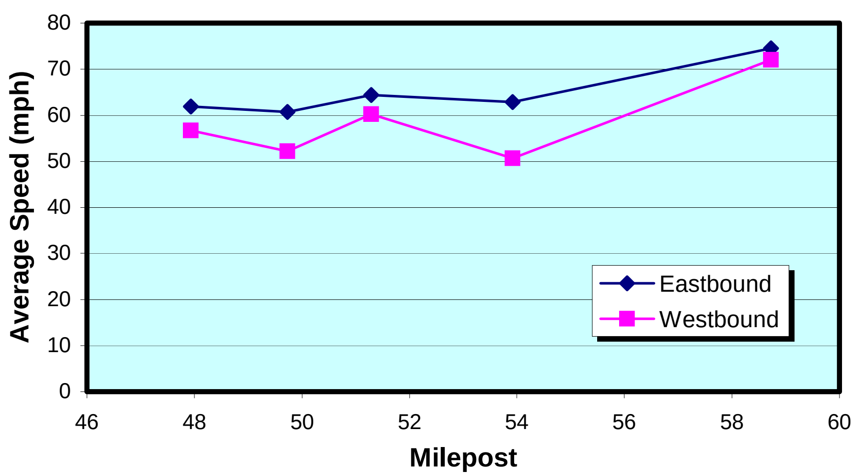


Figure 2-9. Average Speed (Afternoon Peak Period)

The same conclusion can be drawn from Figures 2-10 and 2-11, which show the 24-hour speed profiles at Broadway Ave. and Five Mile Road, respectively. At Broadway, in the high-density area, the average speed during the non-peak period was 63.4 mph, representing stable free-flow conditions; whereas the average speed during the afternoon peak period was 52.9 mph, indicating high-density and near capacity flow conditions. At Five Mile Road, the average speeds during the non-peak and morning peak periods were 63.1 mph and 58.2 mph, respectively. This again indicates that traffic at this location is functioning in a stable free-flow condition during both the peak and the non-peak periods.

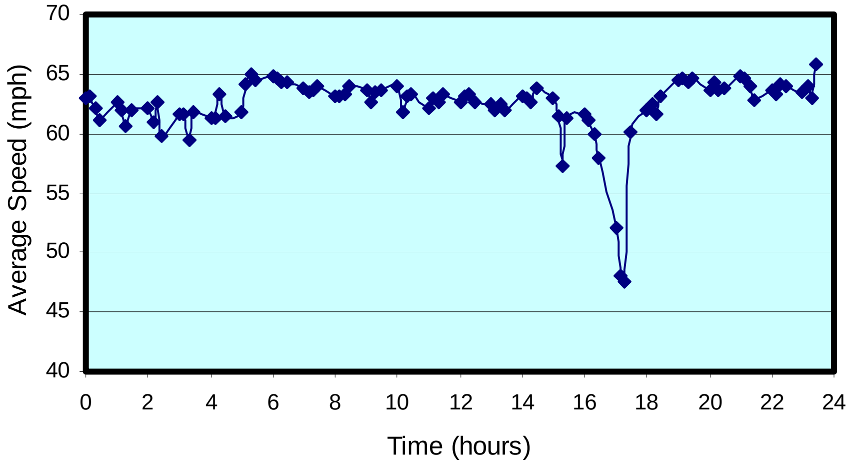


Figure 2-10 Average Speed Profile for Westbound Traffic at Broadway Ave

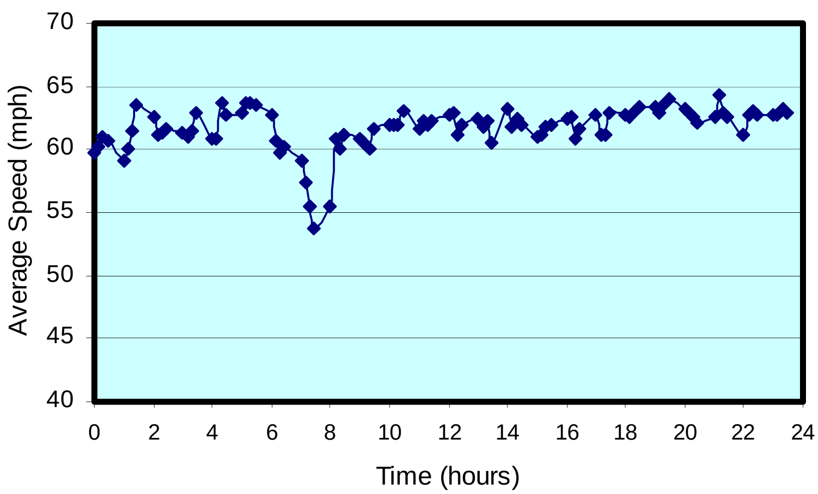


Figure 2-11 Average Speed Profile for Eastbound Traffic at Five Mile Road

It was also important to document changes in the average speed under different weather conditions. Figure 2-12 shows the speed profile at Broadway on January 19, 2001. The weather report on that date for the Boise area indicated snowfall beginning at 11:00 AM. As can be seen in the figure, there is a significant reduction in the average speed during snowy weather conditions. The average speed during this period dropped from 62.3 mph to 43.1 mph. The overall average reduction in speeds for all locations during snowy weather conditions was 17.3 mph. During rainy weather conditions, however, the reduction in the freeway operational speed was less drastic and averaged 1.8 mph.

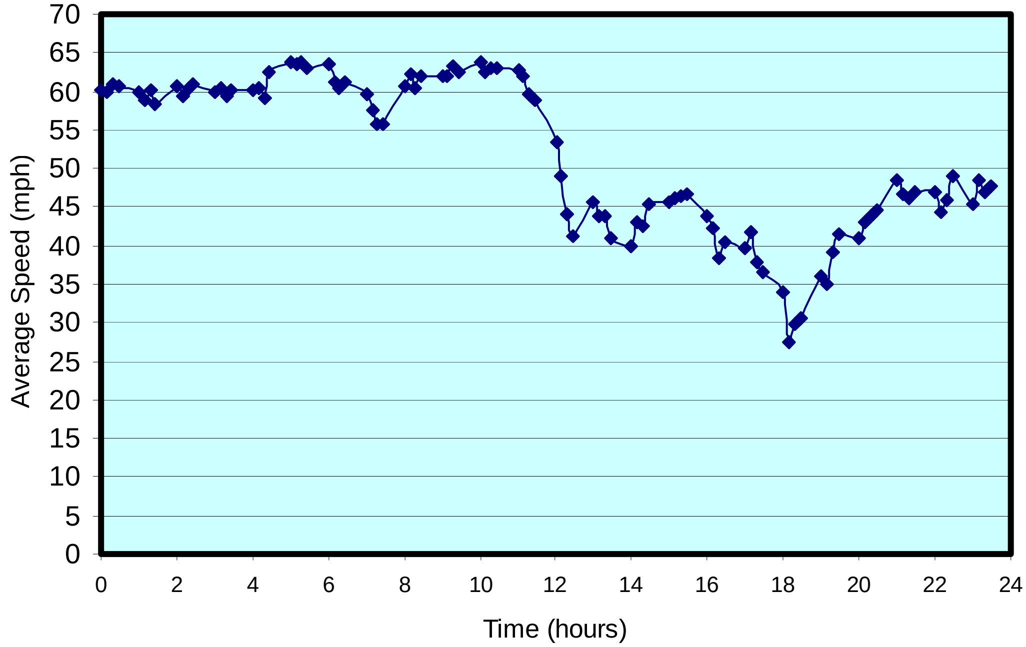


Figure 2-12 Average Speed Profile for Eastbound Traffic at Five Mile Road During Snowy Weather Conditions

2.4 Traffic Flow Characteristics

The objective of this part of the analysis was to determine the traffic flow characteristics (speed, flow and density) and how they interrelate for traffic in the Treasure Valley area. Knowing how I-84 traffic flows is fundamental to understanding normal traffic conditions and the expected operational characteristics during incident situations. For example, queue forming and dissipating characteristics will depend on, among other factors, the jam density, the flow and density of normal traffic conditions and the capacity of the freeway. In order to reliably model incidents and their effect on the freeway, it is important to examine these traffic flow characteristics and how they interrelate.

Figure 2-13 presents the speed-density relationship using the 30-second aggregated data at Overland Rd. The graph indicates that the free-flow speed for traffic at this location ranges from 63 mph to 68 mph and the jam density ranges from 220 vpm to 260 vpm. Figures 2-14 and 2-15 present the flow-density and speed-flow relationship for the same data. The two graphs show that a maximum flow of 6000 vph (2000 vph/lane) occurs at density of 124 vpm and a speed of 34 mph.

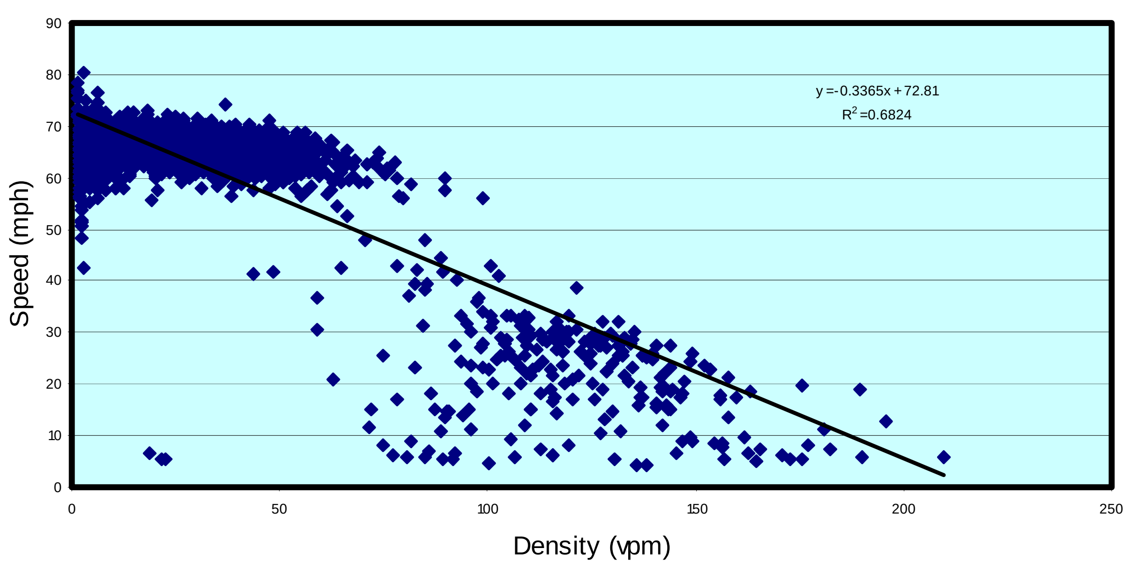


Figure 2-13. Speed/Density Relationship

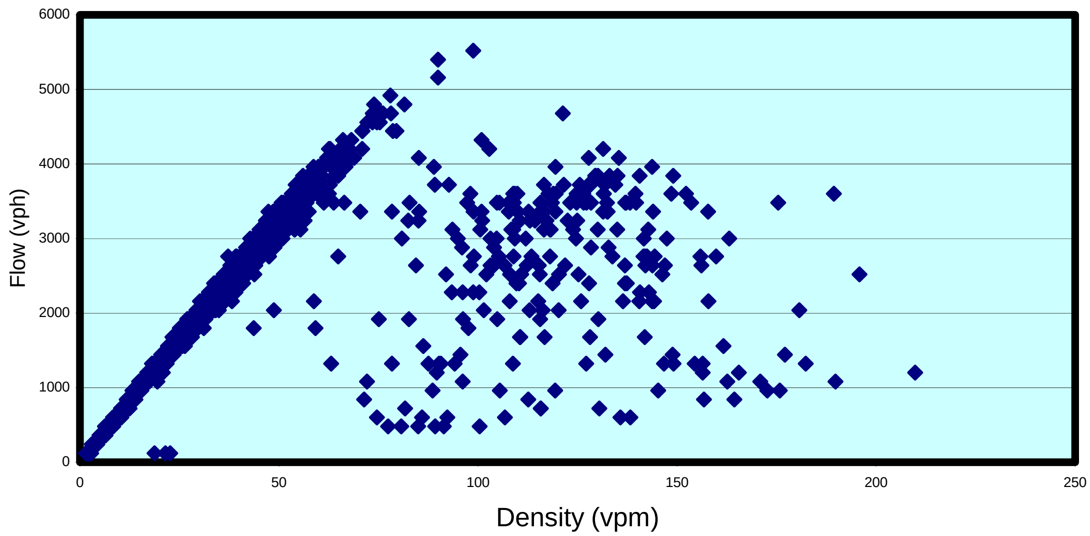


Figure 2-14. Flow/Density Relationship

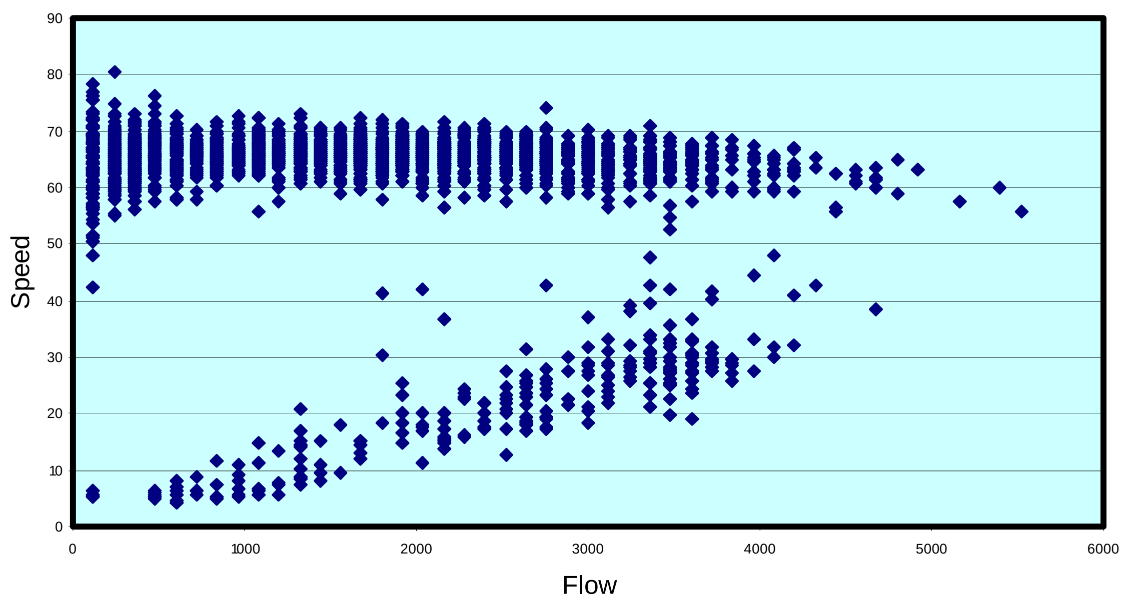


Figure 2-15. Speed/Flow Relationship

Queue forming characteristics help to determine the speed in which the queue resulting from an incident travels upstream of the incident. The queue forming speed is also important in order to determine the expected queue length and whether, or when, the queue will spill back and block upstream ramps. This speed is an important element in any incident management plan. The shock-wave analysis and the speed-density and flow-density relationships were used to determine queue forming characteristics during incident situations. The speed of the backward-forming shock wave resulting from the reduction of the freeway capacity during incidents can be obtained using the following equation:

$$V_f = \frac{Q_B - Q_A}{K_A - K_B},$$

where:

Vf	is speed of backward-forming shock wave
QB and KB	are the traffic flow and density at the incident location
QA and KA	are the traffic flow and density upstream from the incident (normal traffic flow)

Results from the shock-wave analysis for the segment of Westbound I-84 between Orchard Rd. (milepost 51.29) and Overland Rd. (milepost 49.73) are summarized in Table 2-2. The table presents the expected queue forming speed resulting from incidents with different severity levels.

Table 2-2 Queue Forming Speed Resulting from Incidents for the Segment Between Orchard Rd. and Overland Rd.

Time Period	Volume (Veh)	Speed (mph)	Density (vpm)	Queue Forming Speed (mph)		
				Three-Lane Closed	Two-Lane Closed	One-Lane Closed
12:00 AM - 2:00 AM	469	59.24	3.96	-1.76	0.00	0.00
2:00 AM - 4:00 AM	345	59.87	2.88	-1.41	0.00	0.00
4:00 AM - 6:00 AM	2232	62.18	17.95	-6.11	0.00	0.00
6:00 AM - 8:00 AM	7286	61.34	59.39	-18.88	-11.11	-3.33
8:00 AM - 1000 AM	4553	60.67	37.52	-13.02	-4.44	0.00
10:00 AM - 12:00 PM	4109	61.05	33.65	-11.58	-3.13	0.00
12:00 PM - 2:00 PM	4768	61.33	38.87	-13.19	-4.89	0.00
2:00 PM - 4:00 PM	5080	61.33	41.41	-13.37	-5.47	0.00
4:00 PM - 6:00 PM	6574	60.70	54.15	-16.83	-9.15	-1.47
6:00 PM - 8:00 PM	4218	60.69	34.75	-10.46	-3.02	0.00
8:00 PM - 10:00 PM	2660	59.20	22.47	-7.10	0.00	0.00
10:00 PM - 12:00 AM	1287	59.55	10.81	-3.74	0.00	0.00

3. INCIDENT DETECTION ALGORITHMS

3.1 Background

The integration of real time data that can be accessed by a variety of users each with different needs is a complex task. The integration will require deployment of new sensors and communication linkages, and a data base management system that is able to continuously accept a large number of transactions and queries. For example, data from loops on a twelve-mile section of I-84 will be transmitted to the center every 30 seconds; this information will be processed and made available to travelers on an Internet web site. And, these same data will be used to identify when an incident has occurred so that the appropriate agencies can be notified to deal with the problem as rapidly as possible.

One of the components of the integration project was effective incident detection and freeway management. For effective incident detection and freeway management, various automatic incident detection algorithms (AID's) are currently available. But most AID's need calibration before they can be applied to a particular area. Each system differs in terms of detection rates, false alarm rates, and times to detection. Off-line testing of the detection systems to detect incidents and false alarm rates will be required before they can be implemented online. If an adequate quantity of incident data is not available some off-line testing may need to be done using simulated data. There are simulation programs available to simulate the operation of freeways as well as arterial streets. Finally, after adequate testing of the available AID's are conducted with real and/or simulated data,

ITD personnel will need to be trained to apply these systems on a day-to-day basis and to continually update and improve them.

To accomplish this task ITD identified and funded a research project titled *Freeway Incident Detection and Management for the I-84 Corridor.* The following scope of work was identified for the research project:

1) Collect information about AID's in current use.
    a) Contact various traffic management agencies and obtain information about the AID's they use and the degree of confidence and satisfaction they have with their systems.
    b) Study the theoretical foundation of the AID's.

c) Obtain the algorithms and source codes for the AID’s, when possible.

2) Obtain data from ITD for a segment of I-84

3) Apply the AID’s on the data.
   a) Calibrate the AID’s on the data.
   b) Apply the AID’s.

4) Conclusion
   a) Comment on the performance of the AID’s.
   b) Recommend the most applicable AID for ITD.
   c) Report the findings.

3.2 Objective

The purpose of this project, *Freeway Incident Detection and Management for the I-84 Corridor, PhaseII, is* to complete the tasks that were not completed in the first phase. Specifically, the objective of the second phase project was to calibrate incident detection algorithms selected in the first phase and recommend algorithms that are suitable for use in the I-84 corridor.

3.3 Scope

In Phase II of this project, the following activities are proposed:

1. Calibrate the six algorithms presented in the Phase I Report by selecting and testing suitable parameter values for them.
2. After the parameter values are adjusted to reflect site-specific characteristics, make recommendations for the use of a particular algorithm or group of algorithms in the I-84 corridor.

Chapter 4 provides a detailed discussion of the logic of the algorithms evaluated in the first phase of this research is provided. The following chapter describes the output from the calibration effort for each of the six algorithms. A recommendation for the implementation for the I-84 corridor is provided in chapter 6 . Details related to traffic data and the calibration of the algorithms are provided in Appendices A and B.

4. IMPLEMENTED ALGORITHMS

A total of six algorithms were examined in this incident detection research. Three of the six were variations of the mean speed and difference in speed with persistence check algorithms implemented by Transcore in their Milwaukee Monitor ATMS system. The two Transcore algorithms mentioned above were also implemented as a part of this research. The last algorithm examined was Algorithm #8 from the California group of algorithms. Each of the six algorithms is described in the sections that follow.

4.1 Mean Speed Algorithm – Transcore

The first algorithm tested was the Mean Speed Algorithm obtained from TRANSCORE. TRANSCORE has implemented this algorithm in the Milwaukee Advanced Traffic Management system. The algorithm defines four states to describe the state of traffic: incident-free, incident tentative, incident confirmed, and incident continuing states. Figure 4-1 is the schematic that depicts the logic of the algorithm used by this method.

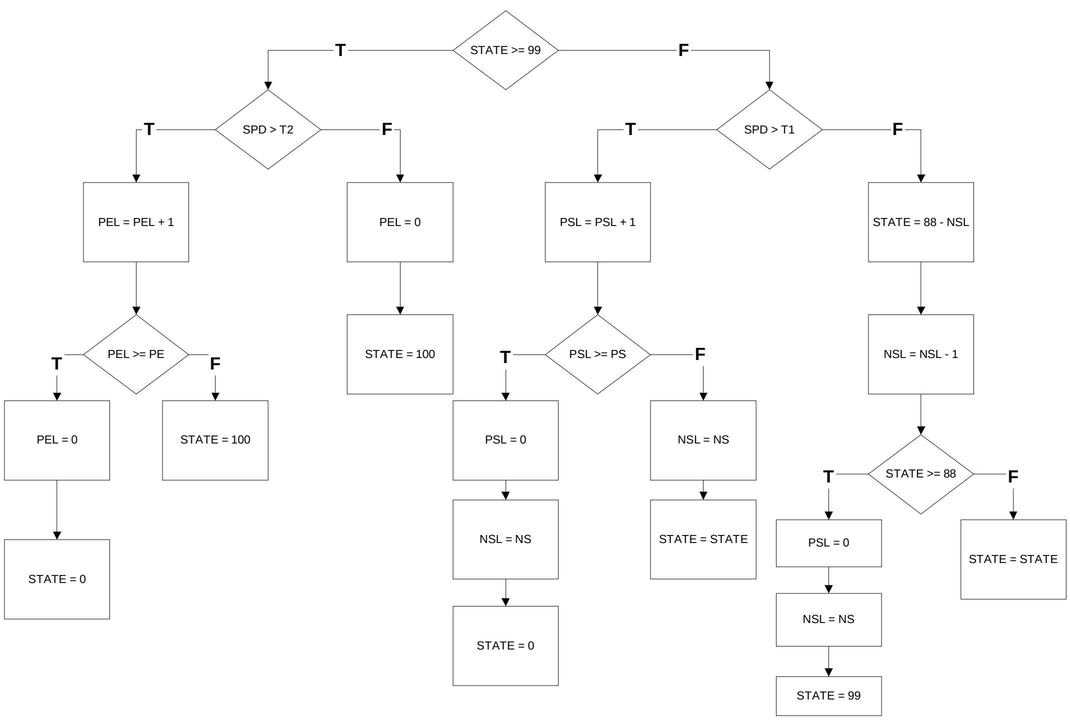


Figure 4-1 Mean Speed Algorithm - Transcore

The process starts with the traffic at a detector station in a certain state. The incident-free state is given a value of zero. The state of the traffic at the start of the algorithm is assumed to be incident-free. The traffic state will then transition to other states or remain at the incident-free state depending on the value of the mean speed of traffic at the station and various parameter values chosen by the user.

From an incident-free state the state of traffic can either transition to a tentative incident state or remain as incident-free. The transition to a tentative incident state will occur only when the mean speed of traffic at the location goes below a user-defined threshold T1. If the speed remains below this threshold for a user-defined number of consecutive intervals, NSL, the state will transition from tentative to confirmed. Conversely, if the speed remains above this threshold for a certain number of consecutive intervals specified by the variable PS, the state will revert back to an incident-free state. Once an incident is declared to be confirmed, the state of traffic can either remain as continuing incident or go back to an incident-free state depending on whether or not the mean speed goes over the threshold T2.

If the mean speed remains below T2 the incident state is said to be continuing. But if the mean speed is higher than T2 it has to remain at that level for a certain number of consecutive intervals before the state of traffic is declared to be incident free. The required number of consecutive intervals is specified in the variable PE.

To summarize, in the TRANSCORE Mean Speed Algorithm, once the mean speed of traffic goes below a certain threshold a tentative incident is declared. From the tentative incident state the state of the traffic can either transition to an incident confirmed state or revert back to an incident-free state depending on the fulfillment of certain specified conditions.

4.2 Mean Speed Algorithm – Modification One

The mean speed algorithm described above was modified in two ways for the purpose of this research. The Scope of Work for this project just required the testing of existing algorithms and does not require the development of new algorithms. The two modifications of the Mean Speed Algorithm that will be described in this and the next section are not entirely new algorithms; they are just simple modifications to the TRANSCORE algorithm to either simplify it or to improve it to make it more suitable to the I-84 data set.

In the first modification the objective was to simplify the algorithm. The states of traffic flow have been reduced from four to two: incident and no incident states. At every time interval the mean speed over all lanes is compared with two threshold speeds: T1 and T2. If the mean speed of traffic goes below T1 the state of the traffic is considered to transition from incident-free state to incident state. An incident state is declared to occur if the mean speed of traffic remains below T1 for a user-defined number of consecutive intervals. The variable that stores this number is denoted as PE in the flow chart shown in Figure 4-2.

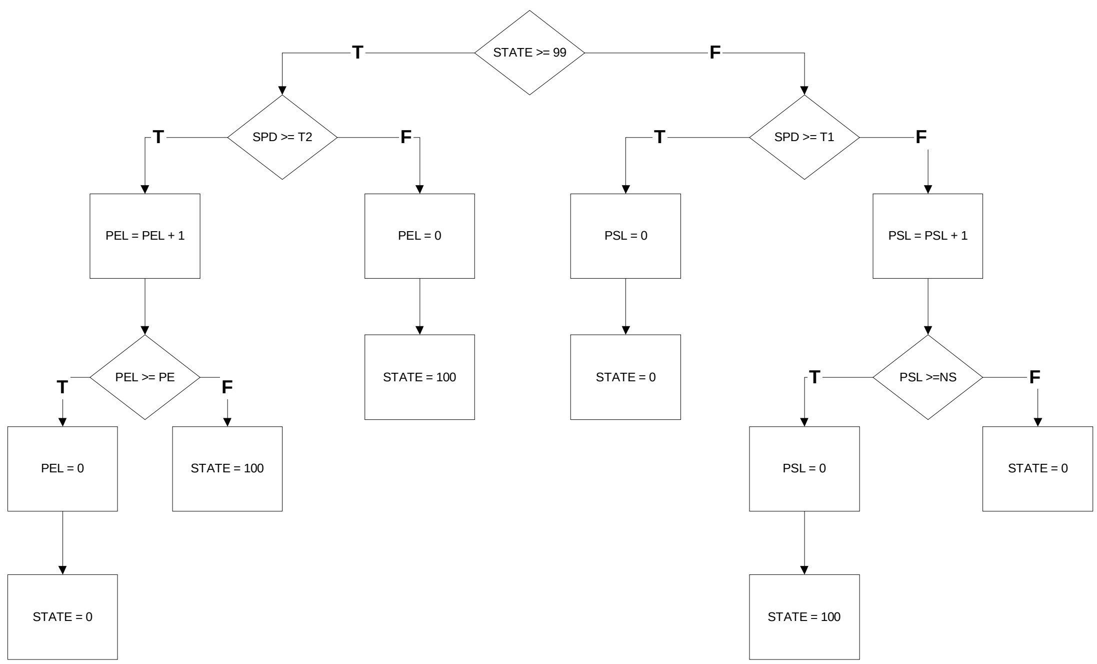


Figure 4-2 Mean Speed Algorithm – Modification One

Once the state of traffic enters an incident-present state the mean speed has to exceed another threshold speed, T2, for a certain number of consecutive intervals. This number is denoted by NS in the flow chart. T2 is chosen to be higher than T1 so that the state of the traffic can not improve to an incident-free state after an incident is declared unless the mean speed is unquestionably higher than what it was at before entering the incident-present state.

The state of the traffic can have two possible values, 0 and 100. State 0 is used to denote an incident-free state, while State 100 is the incident state. SPD is the mean speed for the direction during the last time interval. PEL stores the number of consecutive intervals during which the mean speed was higher than T2; this is the condition required for the algorithm to change the state from incident to no-incident state. PE is the threshold that PEL has to cross for the State to change to no-incident state. PSL is similar to PEL and keeps track of the number of consecutive interval during which the mean speed is below the threshold T1. If PEL exceeds the user defined value NS the State is considered to be an incident state.

4.3 Mean Speed Algorithm – Modification Two

Modification Two is different than the TRANSCORE algorithm in two respects. First, the number of states used is three: incident-free, tentative incident, and confirmed. The second and more significant difference is the logic used in transitioning from a tentative incident state to an incident confirmed state. The logic used in reverting to an incident-free state from an incident confirmed state is similar to the two algorithms described previously: when the mean speed is above the threshold T2 for a certain number of consecutive intervals the state of traffic returns to an incident-free state.

The transition from a tentative state to a confirmed state is based on the value of a variable defined as “RV” in Figure 4-3. The variable RV is defined as the ratio of difference in mean speed over two consecutive time intervals to the running average of the mean speed over a certain number of time intervals. The value of RV is compared to a user defined parameter denoted as RATIO. When RV exceeds this value the state is considered to transition from tentative to confirmed.

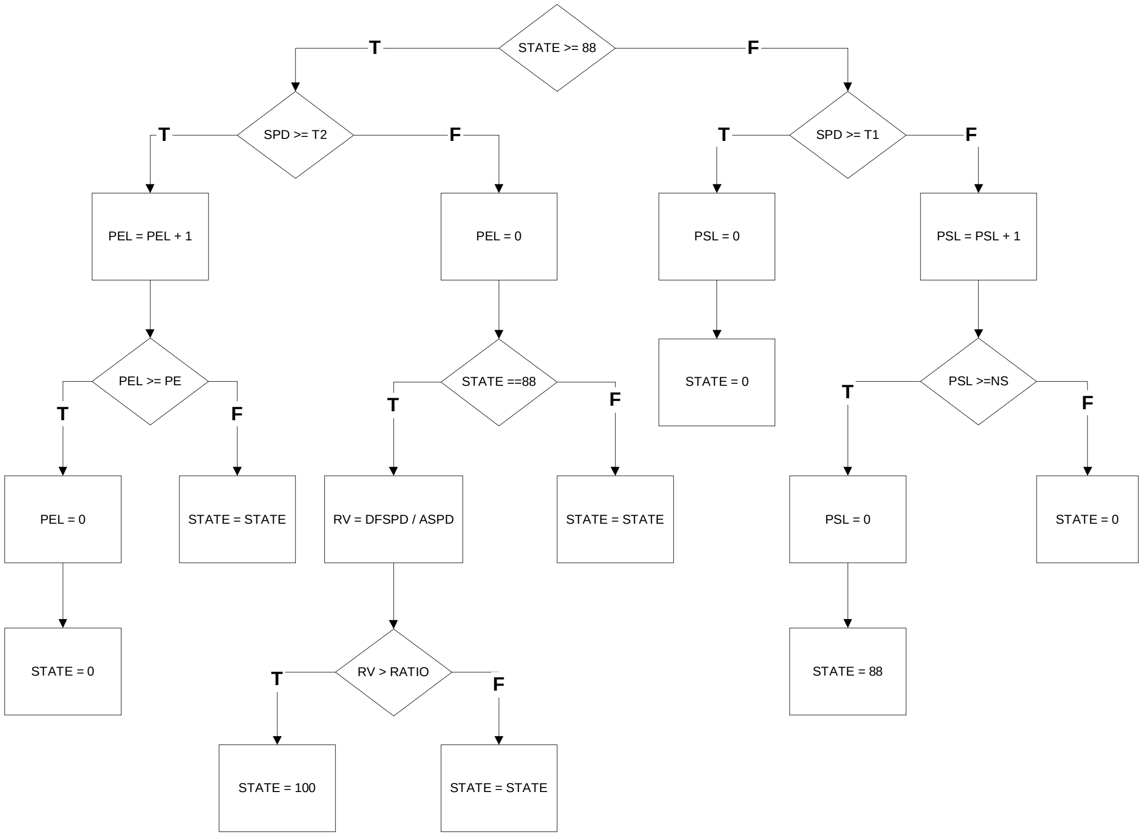


Figure 4-3 Mean Speed Algorithm – Modification Two

The idea behind the use of RV is to differentiate between incident and normal recurring congestion conditions. In the two algorithms described previously this transition is based on the value of the mean speed being lower than a threshold for some consecutive number of intervals. But such a condition can be satisfied when the decrease in mean speed is due to normal congestion besides being due to slow down caused by incident conditions. The use of the variable Ratio defined above is designed to distinguish between these two conditions.

During data processing for this project it was observed that the reduction in mean speed due to incident was more rapid than due to recurring congestion. The variable Ratio is expected to capture this distinction more accurately than the number of consecutive-intervals criteria used by the previous two algorithms.

4.4 Difference in Speed with Persistence Check – TRANSCORE

The next two algorithms described in this and the following section use information from two detector stations as opposed to the single detector section data used in the previous three algorithms. The variables used are: SPDDF, SPDD, and SPDRDF. SPDDF is the difference in speed between the mean speeds at a detector station and its adjacent downstream section. The difference is computed by subtracting the downstream speed from the upstream speed. SPDD is the mean speed at the downstream station. Finally, SPDRDF is the relative difference in speed between a detector station and its downstream counterpart. The relative difference in speed is computed by subtracting the downstream mean speed from the upstream mean speed and dividing the result by the upstream mean speed. TRANSCORE's algorithm is shown below in Figure 4-4.

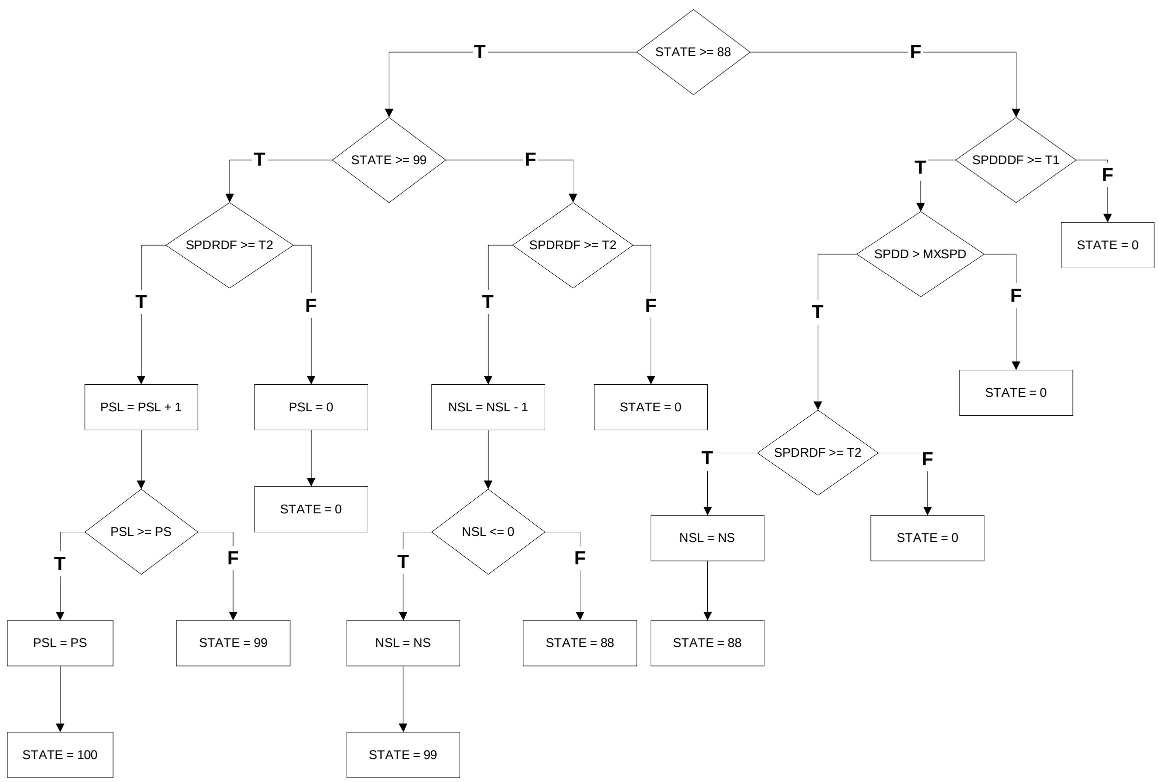


Figure 4-4 Difference in Speed with Persistence Check - TRANSCORE

As in the Mean Speed TRANSCORE algorithm there are four possible traffic states in this algorithm: free, tentative, confirmed, and continuing. Assuming, that the traffic state is incident free at the start of the processing, the algorithm tests to see if the speed difference is greater than the user-specified threshold T1. If it is, the second level test is to see if the downstream mean speed is greater than a second threshold, MXSPD, which is the lowest speed allowed at the downstream station for an incident to be confirmed. If this is also true, then the last test is to test if the relative difference in speed is greater than the threshold T2. If all of these three tests are satisfied in a given time interval, a tentative incident event is declared. If the test fails in any of the three steps, the state is said to remain incident-free.

Once a tentative incident is declared, the relative speed difference has to exceed T2 for few more consecutive intervals before an incident-confirmed state can be declared. The number of consecutive intervals required is specified by the parameter NS. If at any interval during this testing the relative speed difference goes below T2, the state of the traffic is declared to be incident-free.

And once a confirmed incident state is declared, the state at the next interval will either be incident-free or incident-continuing depending on whether or not the relative speed difference is below T2. In the most recent algorithm obtained from TRANSCORE, the incident-confirmed state is said to exist for some consecutive number of intervals before a continuing-incident state is declared. The consecutive number of intervals used for this test is stored in the parameter PS. This is counter intuitive, as one would find it more reasonable to declare an incident-continuing state if the situation required for a confirmed incident state persists at the next interval, instead of having to wait for PS number of times before declaring an incident- continuing state. But this is what TRANSCORE delivered and it was what was implemented at this state.

4.5 Difference in Speed with Persistence Check – Modification One

The TRANSCORE algorithm described in Section 2.4 above was modified to simplify it. The first modification in the modified algorithm depicted in Figure 4-5, is the use of the speed difference (SPDDF) only to transition from an incident-free state to a tentative-incident state. However, this test has to be satisfied for a user-specified number of consecutive intervals, NS, before the tentative-incident state is declared.

After a tentative-incident state is declared, the incident state is said to be confirmed only when the relative speed difference exceeds T2 for NS number of consecutive intervals. This requirement is similar to the one required by the TRANSCORE algorithm in which a tentative incident is not declared to be confirmed in the very next interval after attaining the tentative-incident state. The state is said to linger as tentative for a few more consecutive intervals before declaring a confirmed incident.

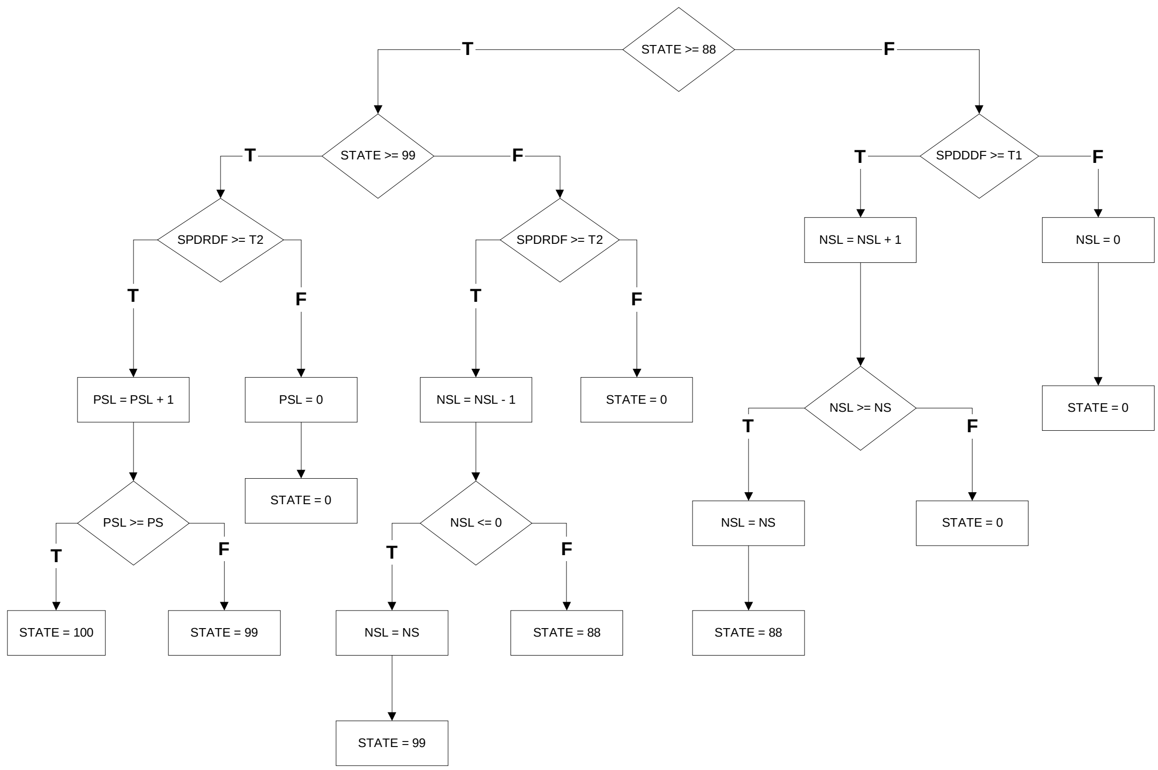


Figure 4-5 Difference in Speed with Persistence Check – Modification One

The test used to declare a continuing-incident state after the confirmation of an incident is again based on whether or not the relative speed difference exceeds T2. If it does, for PS number of consecutive intervals, the state is declared to be continuing and not just confirmed. The comment made at the end of the Section 2.4 also applies here; the transition from confirmed to continuing is not made after one interval only, even though it appears more reasonable to do so. This logic was maintained in the modified algorithm also, since the goal was to make minimal modification to the algorithm obtained from external sources.

4.6 California Algorithm #8

The last algorithm tested in this first phase of the research is Algorithm #8 of the California group of algorithms, which were developed by the California Department of Transportation a few decades ago. As depicted in Figure 4-6 this algorithm defines eight states of traffic flow, which are described below.

The incident-free state is given a value of zero. States with values of one through five are used to describe, respectively, compression wave conditions at the downstream station during the past one through five intervals. A tentative incident condition is given a state value of six. The incident-confirmed state has a value of seven, and the last remaining value of eight is given to the incident-continuing condition.

The other variables used in the algorithm are denoted by the following acronyms: OCCDF, OCCRDF, DOCC, and DOCCTD. OCCDF is the variable that stores the value of the difference in occupancies between a detector station and its downstream counterpart. This difference is also denoted as spatial occupancy difference.

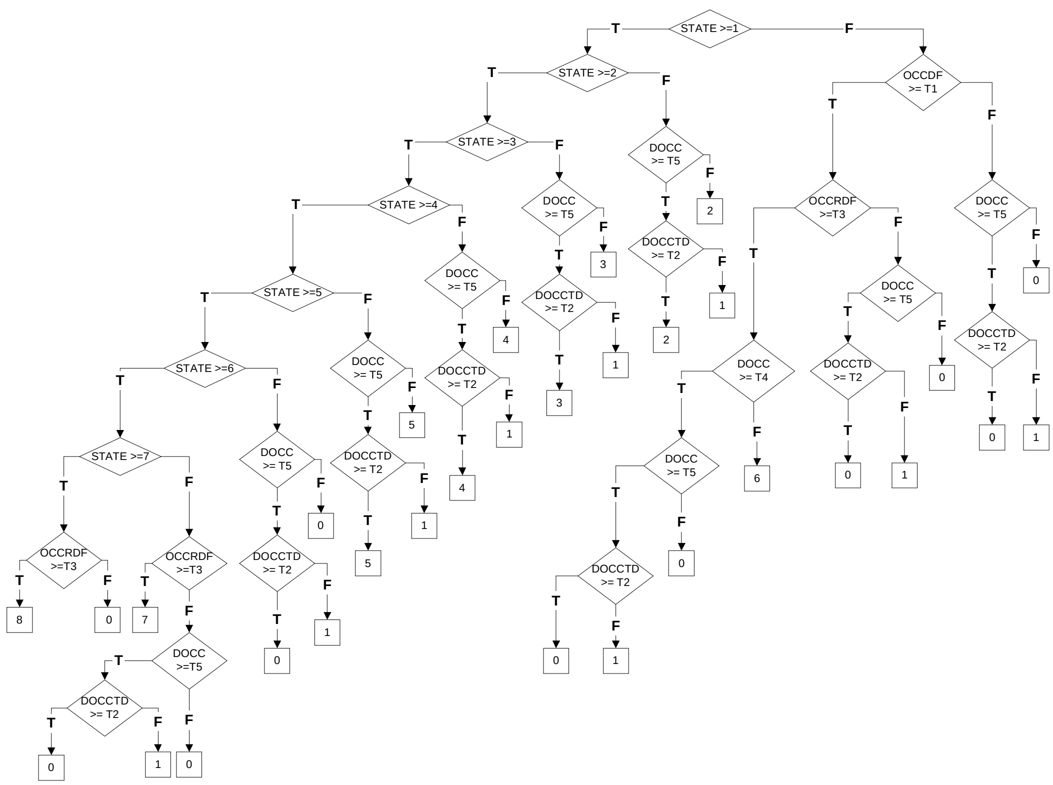


Figure 4-6 California Algorithm# 8

OCCRDF is the relative spatial occupancy difference. In other words, OCCRDF is OCCDF divided by the occupancy at the upstream station. DOCC is the downstream occupancy at the downstream station. And DOCCTD is the relative temporal downstream occupancy and is calculated by subtracting the occupancy at the downstream station during this period from the occupancy during the time interval two periods ago and dividing this difference by the occupancy at this location during the two-period ago time interval.

The equations used to calculate the four variables described above make use of occupancies at various stations at various time intervals. Denote the occupancy at station i during time interval t as OCC(i, t). Then OCCDF = OCC(i, t) – OCC(i+1, t), OCCRDF = OCCDF/OCC(i, t), DOCC = OCC(i+1, t), and DOCCTD = [OCC(i+1, t-2) – OCC(i+1, t)]/OCC(i+1, t-2). Note that t-2 denotes the time interval two periods ago. If the time interval used is one minute, then t-2 would be the time intervals two minutes ago.

The algorithm will require the user to specify the values of five parameter thresholds: T1 through T5. Assuming that the processing starts with an incident-free state (that is, with a state value of zero), three conditions have to be satisfied before a tentative incident is declared. The spatial occupancy difference, the relative spatial occupancy difference, and the downstream occupancy have to exceed or be equal to T1, T3, and T4, respectively. Once a tentative incident is declared, if the relative spatial occupancy difference, OCCRDF, exceeds T3 during the next time interval, the incident is confirmed. And the incident is declared to be continuing during subsequent intervals, as long as this condition is satisfied during each of those intervals.

If the conditions described above are not satisfied the state of the traffic flow is classified as incident-free or with a compression wave downstream during this or the last five intervals, depending on which of the various conditions shown in Figure 4-6 are satisfied.

5. ALGORITHM OUTPUT

5.1 Research Data

5.1.1 Traffic Flow Data

Data for testing the six algorithms described in Section 2 were obtained from the Division of Transportation Planning, Idaho Transportation Department (ITD). ITD has embedded inductive loop sensors at regular intervals along I-84 through Boise and the data from each detector station is collected and stored by a roadside Automatic Traffic Recorder (ATR). The ATR data is routinely downloaded and stored by a unit in the Division of Planning. This unit provided us with the required data.

The ATR data can be in four formats. The format that was appropriate for our purposes is called the Individual Vehicle Records format. Individual vehicle records provide speeds and length of vehicles by individual loops. This is the most detailed level of data obtainable from the ATR's. From this level, data at any higher level of aggregation can be easily generated.

The site selected for this research is a portion of I-84 between Five Mile Road and Jean's Place (Jean's Place is a detector station location just south of Gowen Road.). Figure 5-1 is a schematic that depicts the approximate locations of the detector stations in this segment of I-84.

The set of three-digit numbers along the two sides of this schematic denote the ATR number. As can be noted from the figure, some locations have the same number on both sides. For example, at Broadway the ATR number is 265 on both sides, while at Orchard the number in the Eastbound direction is 261 while in descending (or Westbound) direction it is 262. This means that at Broadway one ATR collects information for both directions of traffic, while at Orchard there is one each for each direction.

There are loop sensors at Vista, but are not shown in this schematic because the sensors there are not “double-loop”. Two loops are needed for speed measurements. Since many of the proposed algorithms required speed information, the data from Vista was not useful to us. Hence the single loop at Vista has not been shown in the schematic.

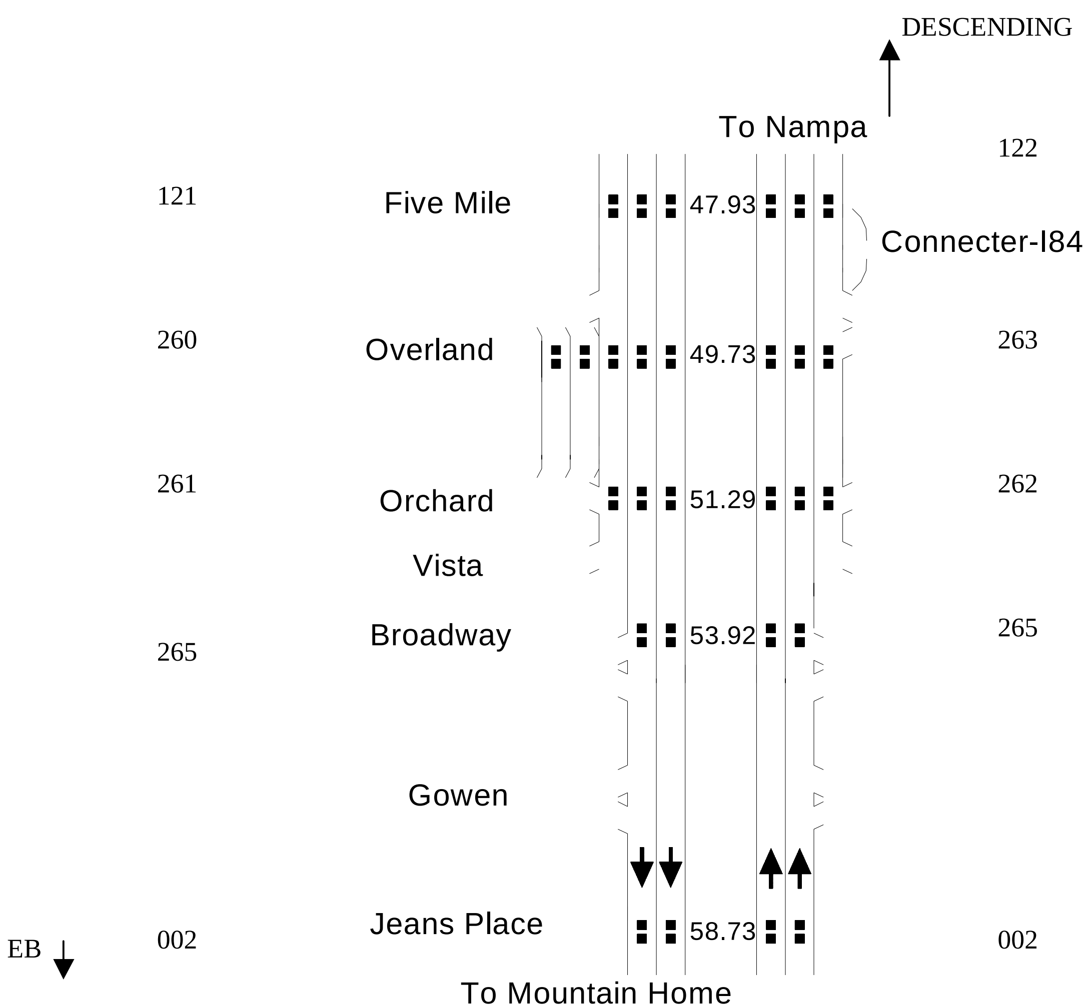


Figure 5-1 Detector Station Schematic

Incident data was obtained from ITD District 3 from their incident response logs. The incident response logs are maintained by drivers of two incident response trucks that drive over I-84 and I-184 for three hours each during the morning and afternoon hours. I-

184 is a short spur from I-84 to Boise downtown; it is not included in this research because no traffic flow data was available for this segment.

The incident response trucks provide assistance to motorists who are stuck on the freeway due to any of various possible reasons. The drivers of the response trucks note the approximate location and the time of the event. They also record the type of action taken for each event to which they respond. They are fairly complete logs; however, they do have a couple drawbacks. The start time of the incident does not appear to always be accurate; it seems to be a rough approximation based on when the response truck arrives. The location is also vague, since it is rounded to the nearest mile.

We have obtained copies of the ITD incident response logs starting from the month of September, 2000. From the response log data a spreadsheet for each month was constructed. The spreadsheet converts the log into an easily readable table. There are five different color-coded incidents that make up the table. They are abandoned vehicles, debris on the roadway, accident, motorist assistance, and traffic control. Each day was analyzed and recorded with the milepost and time of each occurrence for each color-coded event. A summary of the logs for one of the months is shown in the next page in Figure 5-2.

INCIDENT RESPONSE LOG

NOVEMBER

Abandoned
Debris
Accident/Wreck
Motorist Assistance
Traffic Control

	47	48	49	50	51	52	53	54	55	56	57
11/1/2000		8:17 AM(W)		7:40 AM		8:05 AM(E)			7:41 AM(W)		
11/2/2000	6:42 AM(E) 8:21 AM(E)		5:30 PM(W)	6:13 PM(E)		7:18 AM 8:46 AM 4:00 PM(E)					
11/3/2000	9:45 AM(W)			4:26 PM(E)		7:47 AM(E)	4:50 PM(W) 5:15 PM(W)			8:44 AM(E)	
11/6/2000	6:10 PM(W)							8:10 AM(W)		6:41 AM(W)	
11/7/2000				5:07 PM(W)				5:57 PM(W)			
11/8/2000	4:26 PM(E)					8:56 AM(E)					
11/9/2000	3:16 PM(W)				5:32 PM(W)						
11/13/2000			3:18 PM(E)		6:53 AM(E)		3:54 PM(E)	8:07 AM(E)			
11/14/2000		7:00 AM(W) 7:36 AM(W) 9:01 AM(E) 3:54 PM(E)	5:34 PM(W)					6:09 PM(E)	4:10 PM(E)		
11/15/2000		7:50 AM(W) 3:45 PM(E) 6:20 PM(E)			7:40 PM(W)		4:15 PM(W)				
11/16/2000		3:12 PM(E)	5:19 PM(E)			6:52 PM(W)		5:57 PM(E)		4:15 PM(E)	
11/17/2000	7:38 AM(E)		3:58 PM(E)				8:11 PM(W)		5:40 PM(W)		
11/18/2000	3:18 PM(W)		4:30 PM (E)								
11/20/2000			6:11 PM(W)			6:35 AM(E) 4:07 PM(W)	5:38 PM(W)	7:19 AM(W)			
11/21/2000								5:45 PM(W)			
11/22/2000	6:39 AM(E)					8:04 AM(W)					
11/24/2000				3:25 PM(E) 3:28 PM(E)							
11/27/2000	4:23 PM(W)	5:34 PM(W)			4:56 PM(E)						6:54 AM(W)
11/28/2000	7:21 PM(W) 8:30 AM(W)		8:27 PM(W) 4:21 PM(W)					3:45 PM(W)			
11/29/2000		8:45 AM(E)								5:01 PM(E) 5:14 PM(W)	
11/30/2000		6:22 AM(W)									

5.1.2. Congestion Data

To determine if all congestion on the interstate was due to accidents a thorough evaluation was conducted. The evaluation was set up to determine if there were days without any accidents that also showed congestion. To determine the afternoon congestion detectors 265, 262, and 263 were analyzed; in combination, these detectors measure traffic in the westbound direction. Detector 265 is at the Broadway overpass, 262 is near the Orchard overpass and 263 is near the Overland overpass. These specific detectors were chosen based on the fact that traffic flow for the peak afternoon traffic is in the westbound direction. The time frame for the evaluation consisted of three separate months spaced throughout the year to discount for inclement weather and seasonal patterns. The months that were chosen were January 2001, June 2001, and September 2001. Within each month only the weekdays were evaluated. Also, the days that had accidents listed in the ITD incident response logs were not used. These days had much more pronounced congestion that lasted longer and slowed traffic much more than the average day.

Congestion for this evaluation was defined as a speed drop of 10 mph or more from the average speed in the previous hour. A summary of the average start and end times are given in Table 5-1. The full list of data is given in Appendix A.

Table 5-1 Congestion periods

Month	Broadway		Orchard		Overland	
	Start	End	Start	End	Start	End
Jan-01	4:59	5:31	4:36	5:55	5:00	5:53
Jun-01	5:00	5:34	4:35	5:43	5:00	5:55
Sep-01	4:17	5:21	4:09	5:23	4:05	5:35
Average	4:45	5:28	4:26	5:40	4:41	5:47

As shown in the above table congestion always started around 4:30 and 4:45 pm and lasted until nearly 6:00 pm. If there was any congestion outside of these times it always correlated with a major accident. This congestion pattern took place nearly every day and was in a very discernable pattern. The shape of the speed drop due to congestion was very abrupt as compared to a day with an incident. However, the magnitude of the speed drop due to congestion was much less than that due to an accident. To illustrate, two plots of speed data are included here. Figure 5-3 shows the speed profile for a day with an incident while figure 5-4 shows a typical profile when there is no incident.

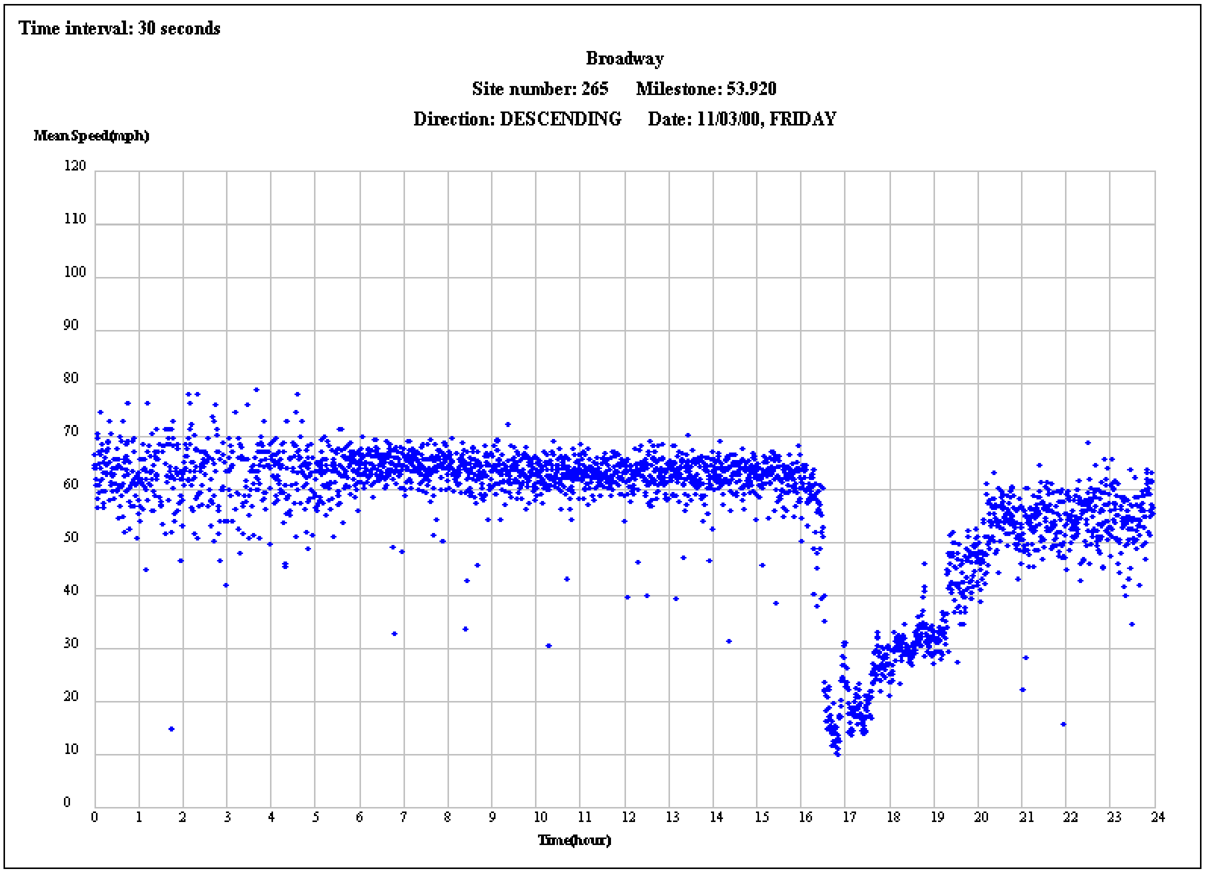


Figure 5-3 Speed Profile of Incident Day

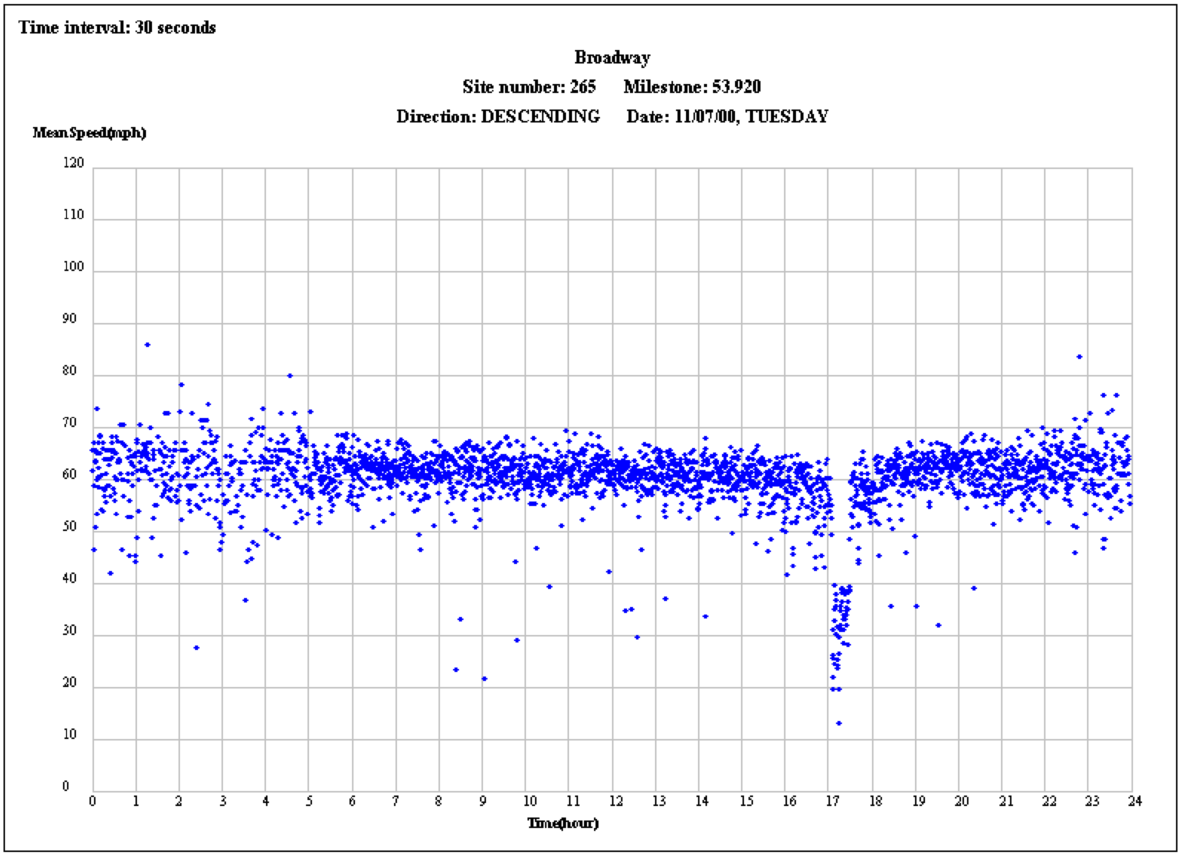


Figure 5-4 Speed Profile of no Incident Day

5.2 Algorithm Implementation

The implementation of the algorithms as well as the conversion routines for the traffic flow data was done in the Java Programming Language.

The first program that was written was the data conversion program. As mentioned previously, the raw individual vehicle records data provide speed and vehicle length information for each actuation in each lane. It was not convenient to plot speed data for a direction of travel using these raw data files. Processing of the raw data was needed for two reasons. First some form of time aggregation was needed since plotting individual speeds was not informative. Second, aggregation over lanes was also desired.

The time period used for aggregation by the algorithms described in Section 2 is either 30 seconds or one minute. For example, the California algorithm uses one-minute data; the other algorithms use 30-second data. So a convenient means of processing the data for various time-aggregations was needed. The data conversion program fulfilled that need by allowing the user to select this time.

To analyze the algorithms data from ITD was used. The mean speed algorithms use data from just one station. The difference-in-speed algorithms and the California algorithm use data from two adjacent stations. When data from adjacent stations are analyzed it must have an incident between the two stations, or immediately upstream of the most upstream detector for the algorithm to detect the incident. When selecting stations other factors to consider are flow-altering situations such as lane drops, on-ramps or off-ramps, and construction.

5.3 Output from Individual Algorithms

3.3.1 Mean Speed Algorithm – TRANSCORE

The first algorithm that was run was the basic Mean Speed Algorithm obtained from TRANSCORE. This algorithm defines four states to describe the state of traffic. This is a very basic algorithm that starts when the mean speed of traffic goes below a certain threshold a tentative incident is declared.

From the tentative incident state the algorithm can either transition to an incident confirmed state or revert back to an incident free state. Nine test days were picked at random which were based on the accident days listed in the incident response log. Four trials were run. A trial was considered successful if it predicted the correct start and end time of an incident. If either the start or the end was incorrect or there were erroneous predictions the trial was considered unsuccessful. On the fourth trial all test days were successful and then 18 days were used to test the parameters selected and they were all successful also. Table 5.2 shows the evolution of parameter selection. The full list of trial days are listed in Appendix B. Also, Figure 5-5 shows the graphic output run with trial 4 for September 17, 2001. This date will be used with all successive algorithms to show a comparison of each algorithm.

Table 5.2 Mean Speed Algorithm – TRANSCORE

		Trial 1	Trial 2	Trial 3	Trial 4
T1	Speed Start incident	35	40	45	40

T2	Speed end incident	50	50	50	50
NS	Intervals to start incident	10	10	10	10
PE	Intervals to end incident	5	5	5	5
PS	Interval to end tentative	5	5	8	8

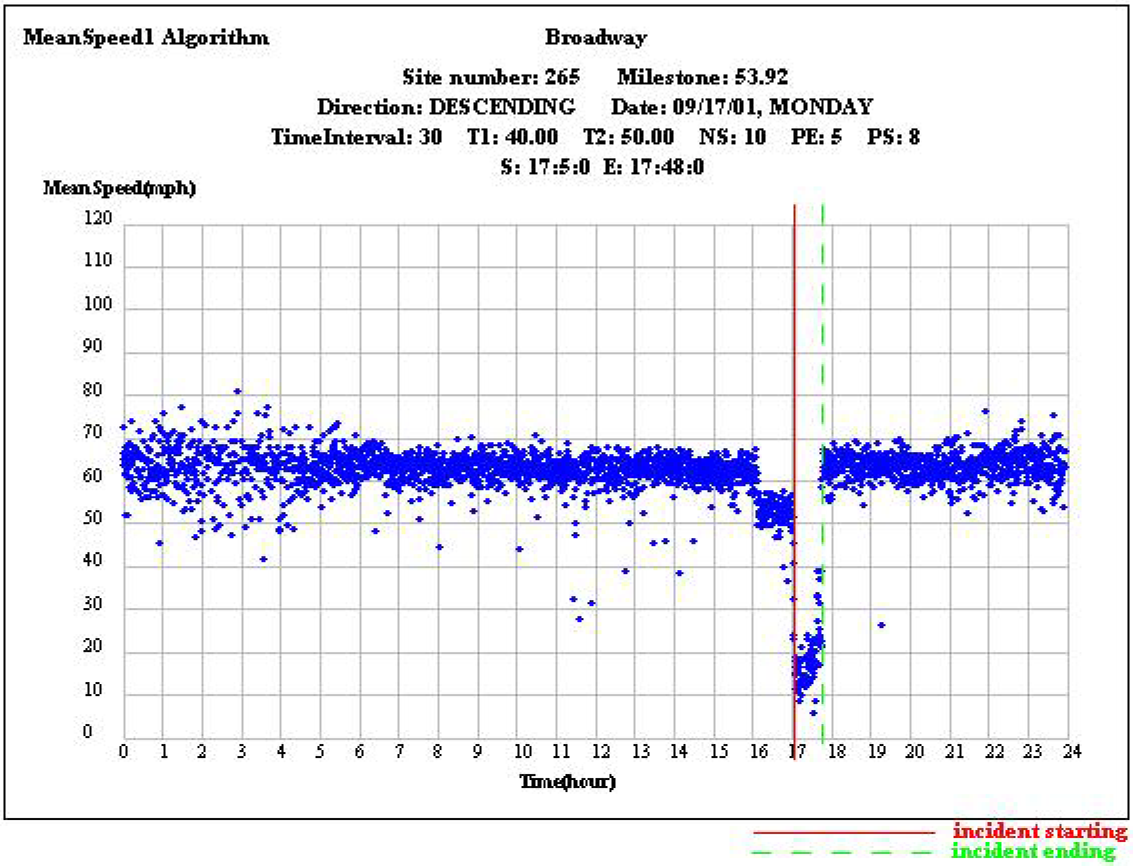


Figure 5-5 Mean Speed Algorithm – TRANSCORE

5.3.2 Mean Speed Algorithm – Modification One

The second algorithm tested was the Mean Speed Algorithm – Modification One. The first modification was to simplify the algorithm. The states of traffic have been reduced from four to two: incident and no incident states. At every time interval the mean speed over all lanes is compared with two threshold speeds: T1 and T2. If the mean speed of traffic goes below T1 the state of traffic is considered to transition from incident free to and incident state. An incident is declared if the mean speed remains below T1 for a user defined number of consecutive intervals.

Table 5.3 shows the selected parameter values. Trial 3 detected all the start and stop times correctly but allowed for some false detection of spectator slow downs in the opposing traffic. This slow down can be seen when using data from detector station 265. This is data from Broadway and when the data is run it plots data in both directions. Therefore it is easy to see the opposing traffic slowing due to an incident in the opposite direction.

Trial 4 was an improvement but did not remove all cases; whereas Trial 5 removed all cases and correctly predicted all incidents in the 23 trial days. A full list of the trial days and results are listed in Appendix B. Figure 5-6 shows the output with Trial 5 data and is again a plot of September 17 2001.

Table 5.3 Mean Speed Algorithm – Modification One

		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
T1	Speed Start incident	35	35	35	40	40
T2	Speed end incident	65	60	55	50	50
NS	Intervals to start incident	5	5	5	12	14
PE	Intervals to end incident	5	5	5	5	5

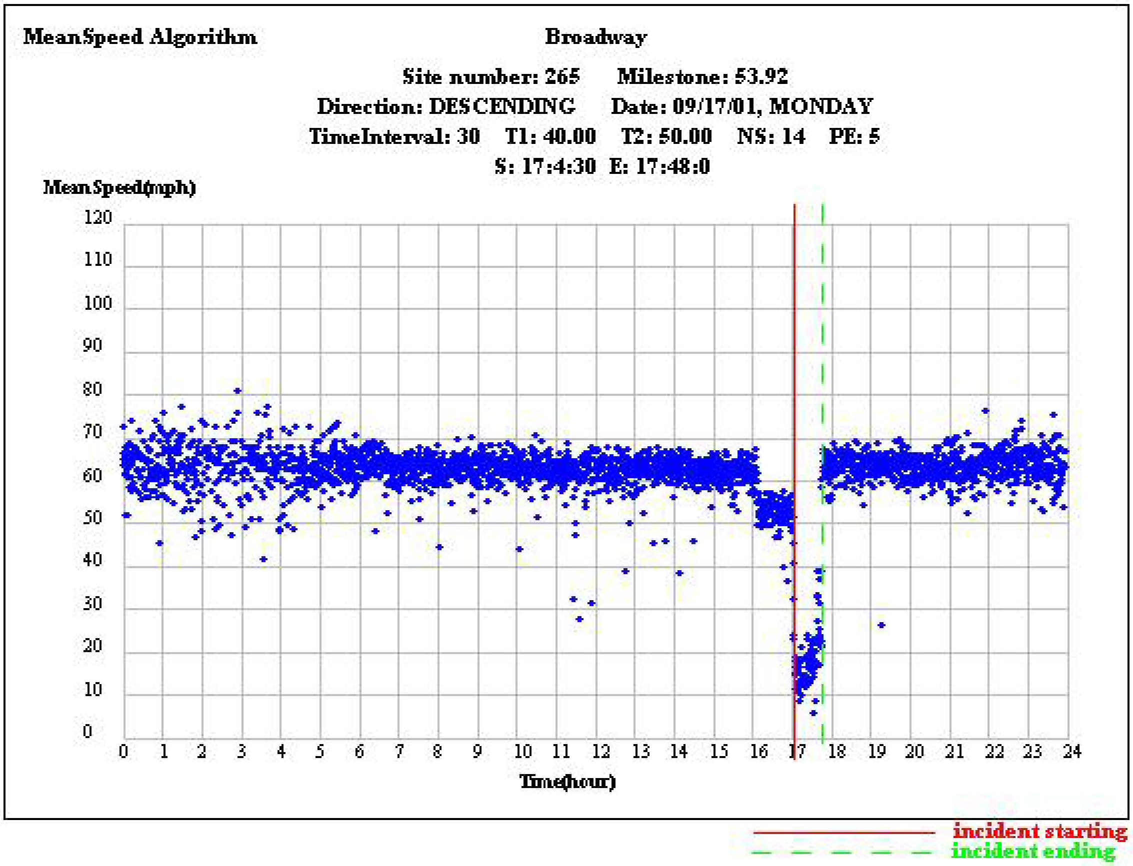


Figure 5-6 Mean Speed Algorithm – Modification One

5.3.3 Mean Speed Algorithm – Modification Two

The third algorithm tested was the Mean Speed Algorithm Modification Two. This is another modification of the original Mean Speed Algorithm where the number of states is three: incident free, incident and confirmed. Another modification is the difference in logic used to transition from a tentative incident state to a confirmed state.

During data processing it was observed that the reduction in average speed due to congestion was more rapid than that due to an accident. The variable ratio is expected to capture this distinction more accurately than in the previous two algorithms. Table 5.4 shows the selected parameter values for the seven trials. Trial 7 was used as the final test on 27 test days and accurately predicted all incidents. Figure 5-7 is a typical plot using Trial 7 data.

Table 5.4 Mean Speed Algorithm – Modification Two

		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7
T1	Speed Start incident	35	35	35	35	35	35	35
T2	Speed end incident	65	60	60	60	60	55	50
Ns	Intervals to start incident	5	5	5	5	5	5	5
PE	Intervals to end incident	5	5	5	10	5	10	10
Ave sp	Initial average speed	65	65	60	60	60	60	60
Gap	Intervals for gap	1	1	1	2	2	1	1
Ratio	Ratio for gap	0.17	0.17	0.17	0.17	0.17	0.17	0.17

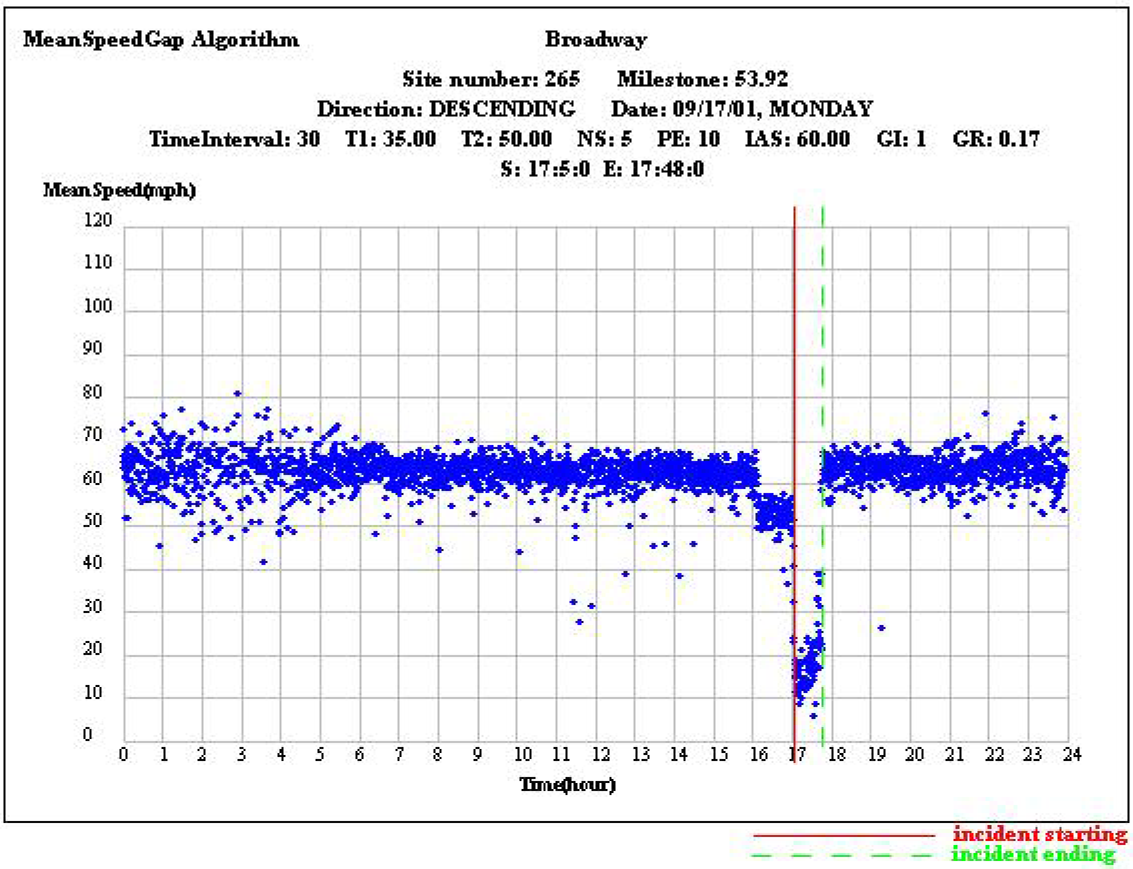


Figure 5-7 Mean Speed Algorithm – Modification Two

The previous three algorithms are all very similar with the second and third being modifications of the original Mean Speed algorithm. There was very little difference between the original and the simplified modification one algorithm. The modification two algorithm, however, was more complicated than the original and was also more accurate over all of the trials than the original.

As described in Section 2, this modification used the ratio of difference in mean speeds over two consecutive time intervals to the running average of the mean speed over a certain number of time intervals. It was this transition from tentative to a confirmed state that gave this algorithm greater success.

5.3.4 Difference in Speed with Persistence Check Algorithm – TRANSCORE

The fourth algorithm tested was the Difference in Speed with Persistence Check – TRANSCORE. This algorithm has four possible traffic states: free, tentative, confirmed, and continuing. It also uses data from two consecutive stations as opposed to the single detector used in the previous three algorithms. With this came the need to use data for accidents that were between the tested stations.

The stations used for the dual station algorithms were 265 and 262 westbound, and 261 and 265 eastbound. The testing of this algorithm consisted of 43 separate days in the eastbound direction and 37 in the westbound direction. They were picked from the incident response log for days that had an incident and are all 2001 data. Then 10 days were used as a test. These days were also picked from the log and coincided with days that had an injury accident reported. They were also 2001 data but were separate days from the original test days.

Table 5.5 shows the parameter values selected and Figure 5-8 show a speed plot using trial 2 data. Using the trial 2 variables the test data had a 90% success rate.   Only one out of the ten failed and it predicted the start of the accident incorrectly.

Table 5.5 Difference in Speed with Persistence Check Algorithm – TRANSCORE

		Trial 1	Trial 2
T1	Spatial difference in speed	18	20
T2	Relative spatial difference	0.01	0.03
Ns	Intervals end tentative	5	8
Ps	Intervals end confirmed	5	5
MAXSPD	Max speed in downstream station	60	60

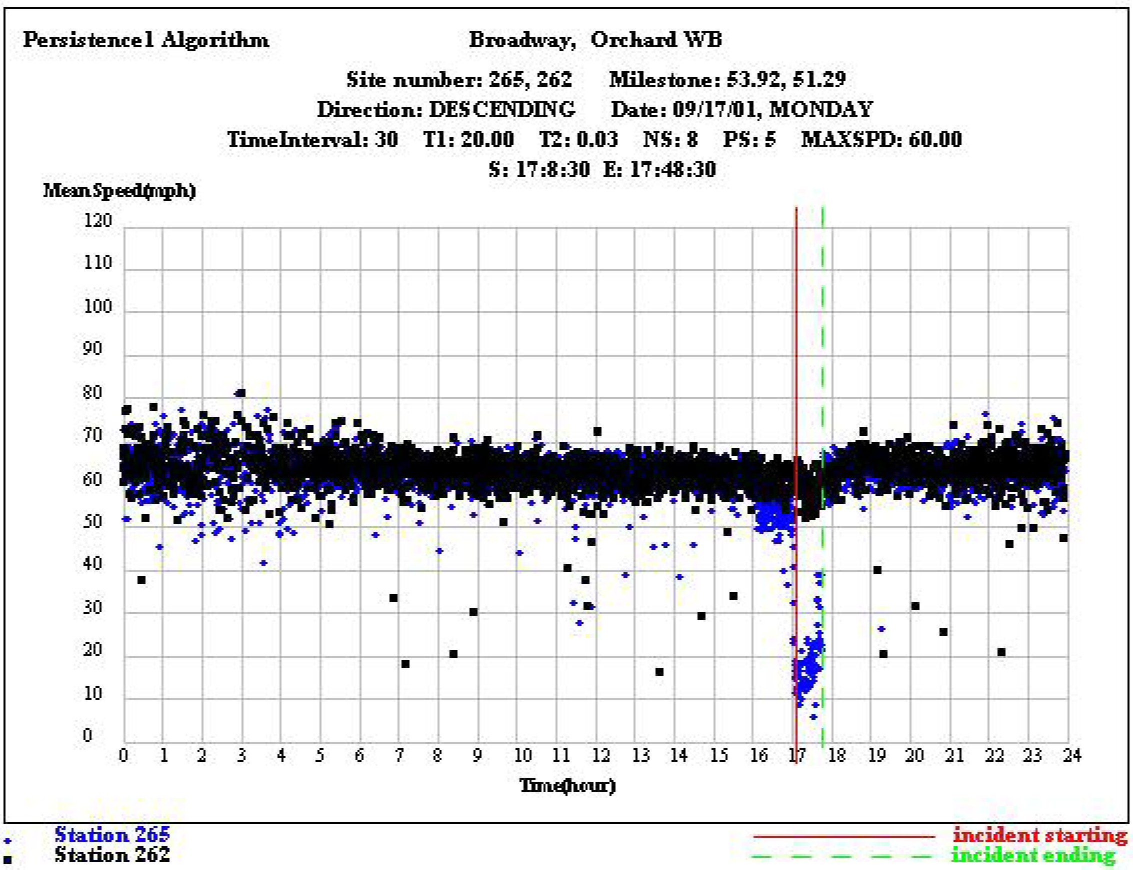


Figure 5-8 Difference in Speed with Persistence Check Algorithm – TRANSCORE

5.3.5 Difference in Speed with Persistence Check Algorithm – Modification One

The fifth algorithm tested was the Difference in Speed with Persistence Check – Modification One. This is a simplified version of the previous algorithm. It is simplified by the use of the speed difference (SPDDF) only to transition from an incident-free state to a tentative-incident state.

This simplified algorithm, however, did not work as well as the original algorithm. The same test days and scenario was used for this algorithm as in the previous test. Table 5.6 shows the results and the speed plot looks identical to the one in Figure 5-8. As shown in the appendix the eastbound trial days were very successful, with a 100% success rate using trial 5 data. The westbound trials, however, were not nearly as successful with only 26 out of 37 passing for a 70% success rate.

An additional problem was the prediction of too many incidents within the incident period. Instead of predicting the correct start and end they usually predicted three or more starts and stops, most likely due to the simplification of the transition from incident-free state to an incident state.

Table 5.6 Difference in Speed with Persistence Check Algorithm – Modification One

		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
T1	Spatial difference in speed	20	21	22	19	10
T2	Relative spatial difference	0.1	0.1	0.1	0.1	0.1
NS	Intervals confirmed incident	5	5	5	5	5
PS	Intervals continued incident	5	9	9	5	5

5.3.6 California Algorithm# 8

The final algorithm tested was the California Algorithm. This algorithm makes use of eight states of traffic flow, which were described in Section 2.6. It also requires the user to specify the values of five parameter thresholds: T1 through T5. This algorithm is the most complex of the six tested. During testing it was determined that two different sets of parameters are needed. One set for the westbound conditions and one set for the eastbound conditions.

At this time one distinct set was unable to determine the start and end of congestion in both directions. In the table below trial 3 did the best for the eastbound direction and trial 4 for the westbound direction. A typical speed plot looks identical to Figure 5-8. As seen in Appendix B, the success rate for the eastbound direction using trial 3 data was 33 out of 43 for a success rate of 77%. Here again, most of the failures were due to the algorithm predicting too many incidents. In the westbound direction, using trail 4 data, the success rate was 29 out of 37 for a success rate of 89%.

Table 5.7 California Algorithm# 8

	Trial 1	Trial 2	Trial 3	Trial 4
T1	7.4	4	4	4
T2	-0.259	-0.259	-0.259	-0.259
T3	0.302	0.302	0.302	0.55
T4	27.3	27.3	10.7	10.7
T5	30	30	30	30

5.4 Summary

The goal of this phase of research was to test and evaluate standard incident detection algorithms to determine which ones would be best suitable for use in the I-84 corridor. This was accomplished as described in the previous sections using real world incident data. Since the data used was from October 2000 thru early 2002 a stretch of I-84 was used that was not under construction or repair during these dates.

Based on the prediction capabilities of the various algorithms as described previously in this report, it is recommended that the algorithm to be used in this area should be one of the three variations of the Mean Speed Algorithms obtained from TRANSCORE. More specifically the best variation would be to implement the Mean Speed Algorithm – Modification Two. The simple nature of this algorithm combined with the use of the variable Ratio as described in Section 2 makes this algorithm the best choice.

6.0 TREASURE VALLEY ITS ATMS CONTROL SOFTWARE ALGORITHMS

6.1 Introduction

The objective of this section is to present and evaluate incident detection algorithms included in the Treasure Valley Intelligent Transportation System (ITS) Advanced Traffic Management System (ATMS) control software. The three algorithms included as part of the incident detection subsystem of the software are: the All Purpose Incident Detection (APID) algorithm, the McMaster Algorithm, and the Multiple Speed Threshold Queue (MSTQ) algorithm.

6.2 All Purpose Incident Detection (APID) Algorithm

The All Purpose Incident Detection (APID) algorithm made its first appearance in Toronto, Canada, as part of the COMPASS advanced traffic management system (ATMS). The APID consists of six subroutines: three routines for heavy, medium and light traffic conditions, a termination routine, a compression wave test, and a persistence test routine. The algorithm is based on four California algorithms. Preset thresholds govern the logic of three basic inputs: absolute occupancy difference, relative occupancy difference, and downstream. The APID algorithm falls into the category of "comparative or pattern recognition" because it compares data from detectors at two discrete locations. Occupancy and volume data are critical for the operation of the algorithm. To reduce the possibility of inaccurate incident detection, the APID uses "smoothed-occupancy" as the detection variable to reduce false-alarm rates.

Considerable research showed that the algorithm operates well in high traffic-volume situations; however, under low traffic-volume conditions performance diminishes. The APID algorithm demonstrated robustness and has shown superiority in changing weather. However, it remains extremely sensitive to equipment failure, specifically that of the loop detectors.

6.3 McMaster Algorithm

The McMaster algorithm, developed in 1988, is based on the catastrophe theory, which shows discrete changes in one variable while smooth continuous changes take place in related variables. The McMaster algorithm compares past trends to current data, unlike comparative or pattern-based algorithms, which evaluate data against preset thresholds. This permits the differentiation between recurrent congestion and incident, a trait found almost exclusively in the McMaster algorithm. Inputs necessary for the algorithm are speed, flow, and occupancy, although speed is not necessary for the logic to function. Theoretically, the use of those three inputs, would give the equation more opportunity for use. Templates charts are created for each section of highway where the algorithm is employed. These templates are then divided up into six sections. Each section is considered an "operation state", which is simply the condition of traffic flow, described as congested or non-congested. If data from a certain station suggest congestion at a particular location, the next downstream station's state is examined. If no congestion is found at the downstream detector the system activates an alarm.

One of the significant advantages of he McMaster algorithm is its ability to discern between recurrent congestion and incidents. The algorithm identifies incidents when it detects drastic drop in speed without accompanying rise in flow and occupancy. The algorithm achieves a very low false alarm rate but it demonstrated a lower detection rate. Unlike the APID algorithm, the McMaster does not use a comparative approach for congestion determination. McMaster algorithm can use input data from single stations, not paired. Thus, the algorithm is less subject to equipment failure and natural occupancy perturbations due to changes in roadway geometry. However, proper calibration of the algorithm takes much time and labor. However, there are three additional problems in the algorithm logic: the inability to negotiate compression waves, the lack of high-quality data screening, and the inability to identify the location of the incident relative to the detector.

The Single Station McMaster Algorithm uses six categories, each depending on flow-occupancy and speed-occupancy relationships, to classify traffic in congested conditions and four categories for locations without recurring congestion. These categories guide the algorithm logic. The basic logic of the algorithm remains the same as the original McMaster algorithm, but the results are more refined. Specious data points are filtered by persistence checks and data collected by detectors update the lower limit of speed and occupancy for the algorithm.

6.4 Multiple Speed Threshold Queue (MSTQ) Detection Algorithm

The Multiple Speed Threshold Queue (MSTQ) detection algorithm detects queues as the name states. The algorithm alarm is triggered when a queue is identified by persisting changes in the speed of traffic. The multiple thresholds of response allow the algorithm to filter out problematic data, thereby reducing the number of false alarms declared by the system. In the event that a queue overlaps more than one detector, the same multiple thresholds reduce the declaration of multiple queues for one area of congestion. The only necessary input for this algorithm is speed. Once speed data has been gathered from a station a check is performed to seek out congested areas. Different thresholds of speed within the algorithm define levels of congestion. A congested station falls into one of three categories: primary very slow congestion, primary slow congestion, or secondary slow congestion. When a station persists in the congested state it may become "system confirmed". The locations of queues are established through the use of those stations considered "system confirmed". After a station has been considered as primary or secondary congested, the algorithm uses two clearance thresholds to determine whether the congestion at the station dissipated. The algorithm uses primary and secondary clearance thresholds.

The simplicity of the MSTQ is one of its strongest points. Multiple thresholds allow most faulty queue detections to go unnoticed. The simplicity of the algorithm should allow it a great deal of application flexibility. The logic uses paired stations detectors for analysis. Because of this, there are some inherent risks in the algorithm. As with any comparative algorithm, it is probably very sensitive to detector failure. If either the downstream or upstream detectors fail, the algorithm will cease to function correctly at that location. Also, speed data is not as prevalent as occupancy and flow data. This might further limit usage of the algorithm.

6.6 Evaluation of the ATMS Control Software Incident Detection Algorithms

Delay in the deployment of the Treasure Valley ITS AMTS control software (expected implementation date: December 2003) did not permit testing the three algorithms included in the software under real operation conditions as was originally planned. Alternatively, the algorithm general logics were replicated and examined using the Treasure Valley speed, occupancy, and volume data collected for a sample of 20 actual incidents occurred between August 2001 and December 2002. The three dependent variables used for the selection process are: Detection Rate (DR), and Time to Detect (TTD). It should be noted that tests were based on the published documentations of the general algorithm logics which may be different than the actual logics implemented in the Treasure Valley ITS ATMS software. Results are presented in Table 6-1. Sample of the speed and volume data used in the analysis are presented in Figure 6-1. Results from these tests should give a general indication of the expected performance of the algorithms. Once the ATMS control software is fully functioning, more tests are needed using the software to examine the actual performance of the algorithms and to fine tune the algorithm parameters using site specific data.

Table 6-1 Comparison of Quantitative Attributes of Selected Incident Detection Algorithms

Algorithm	DR (%)	Average TTD (min)
APID	90%	12:18
McMaster	85%	7:42
MSTQ	85%	10:55

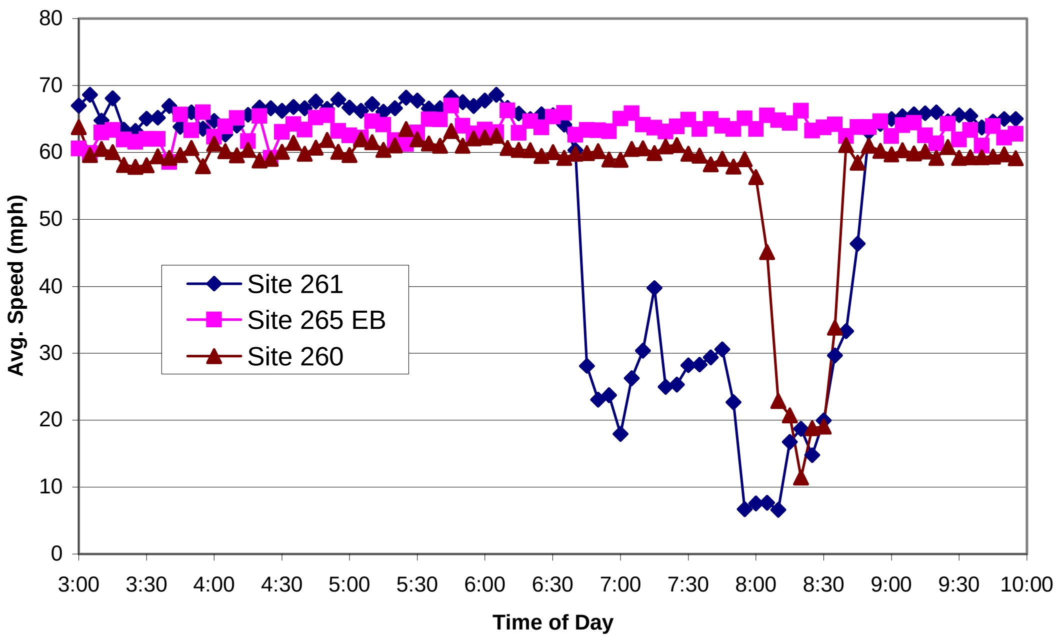


Figure 6-1. Average Speeds for Sites 261, 265 EB, and 260 on 9/13/00.

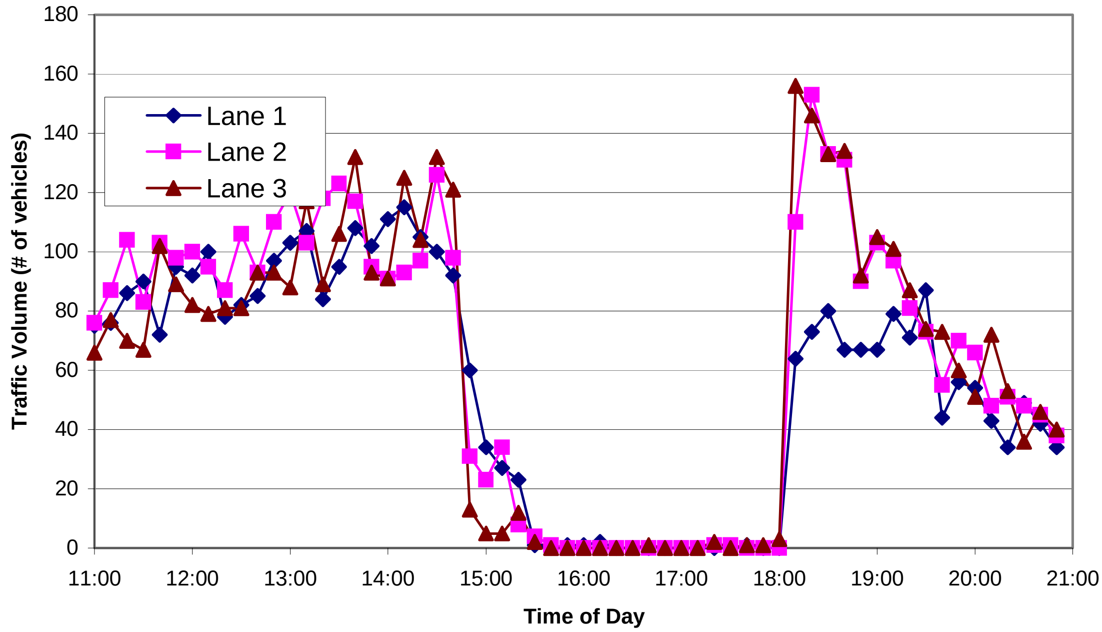


Figure 6-2. Traffic Volumes for Site 263 on 1/29/01.

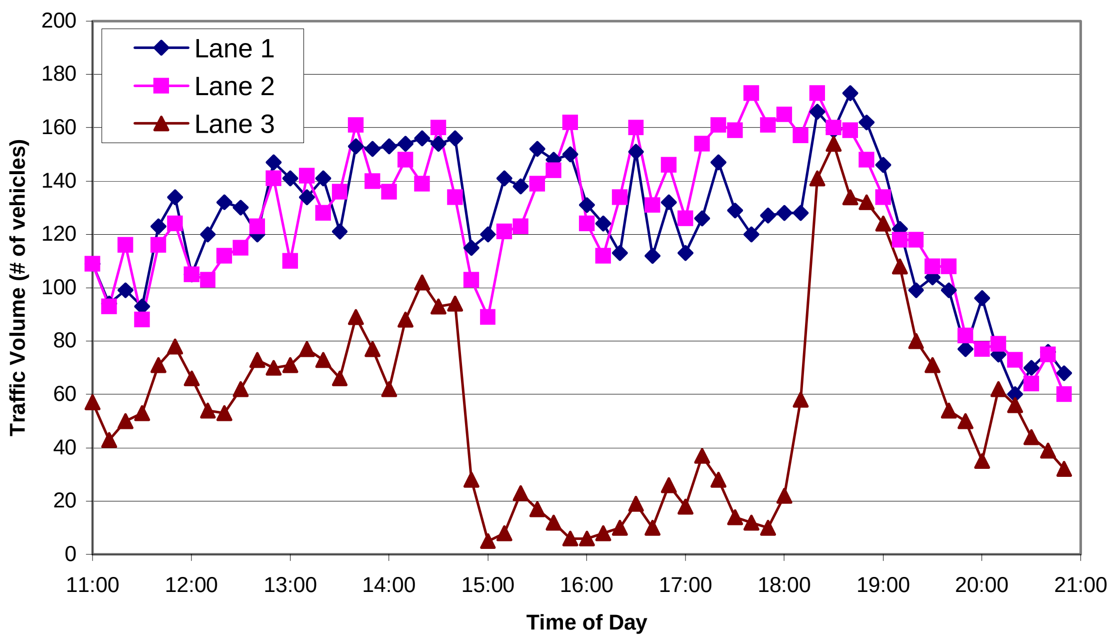


Figure 6-3. Traffic Volumes for Site 122 on 1/29/01.

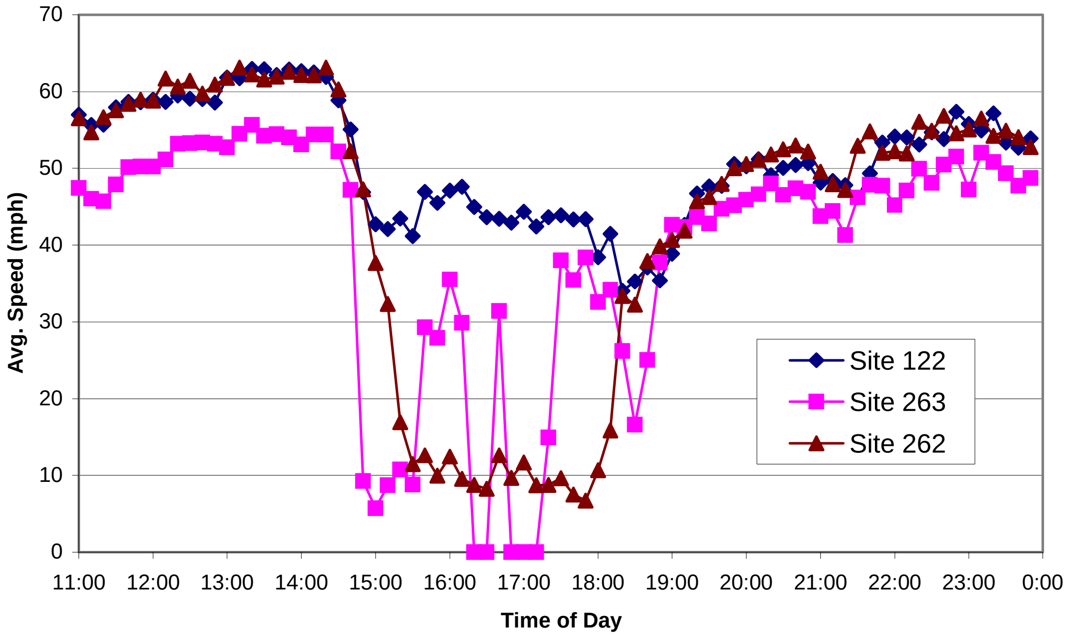


Figure 6-4. Average Speeds for Sites 122, 263, and 262 on 1/29/01

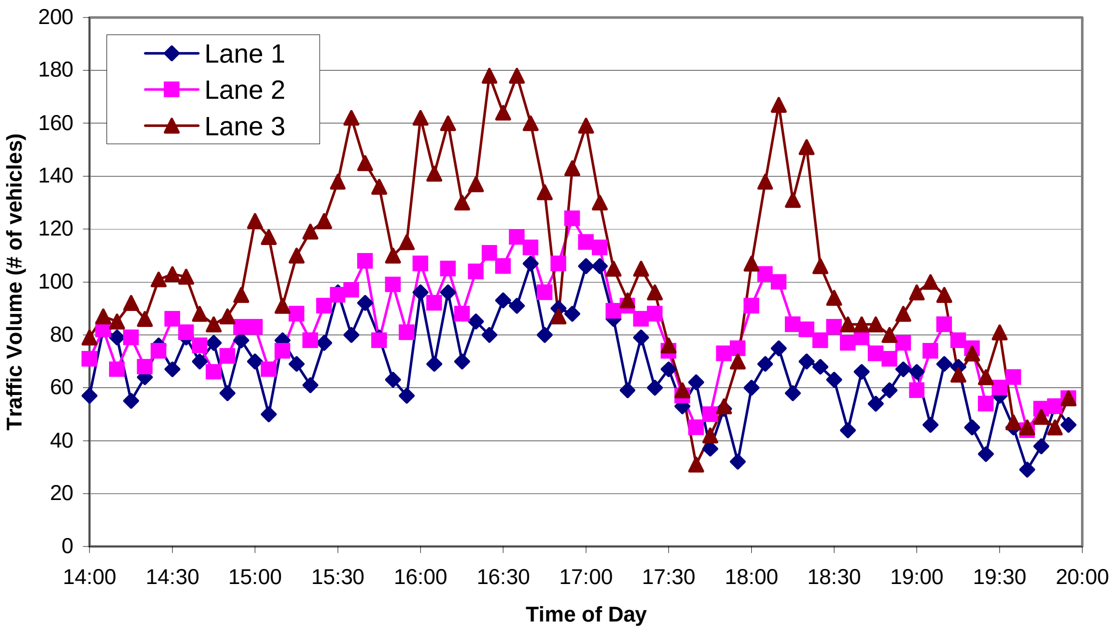


Figure 6-5. Traffic Volumes for Sites 263 on 8/15/01.

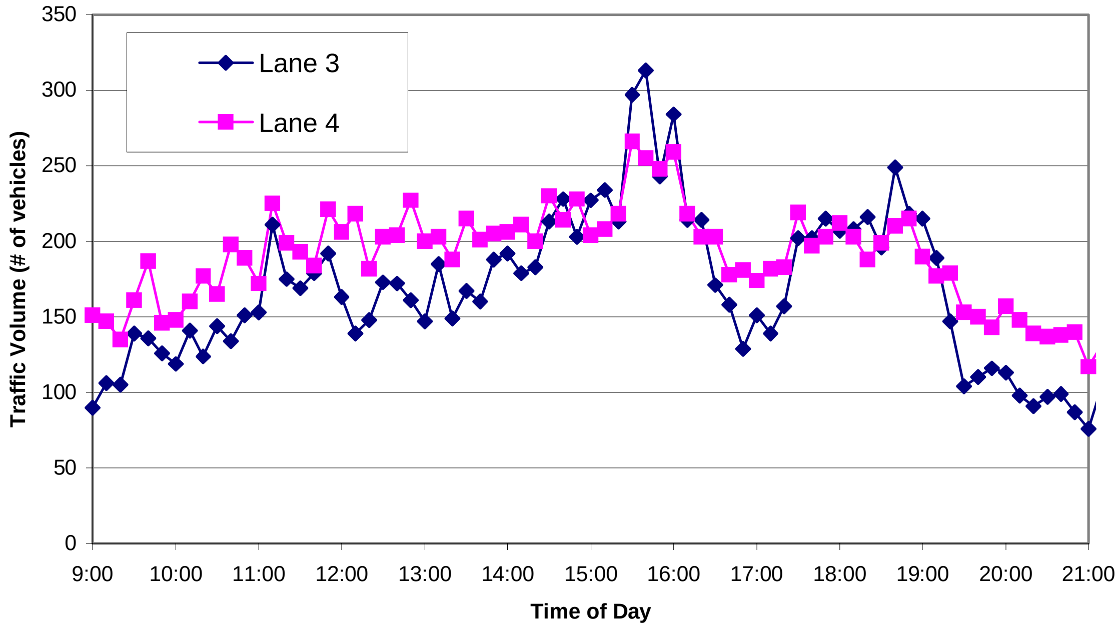


Figure 6-6. Traffic Volumes for Site 265 on 5/17/02.

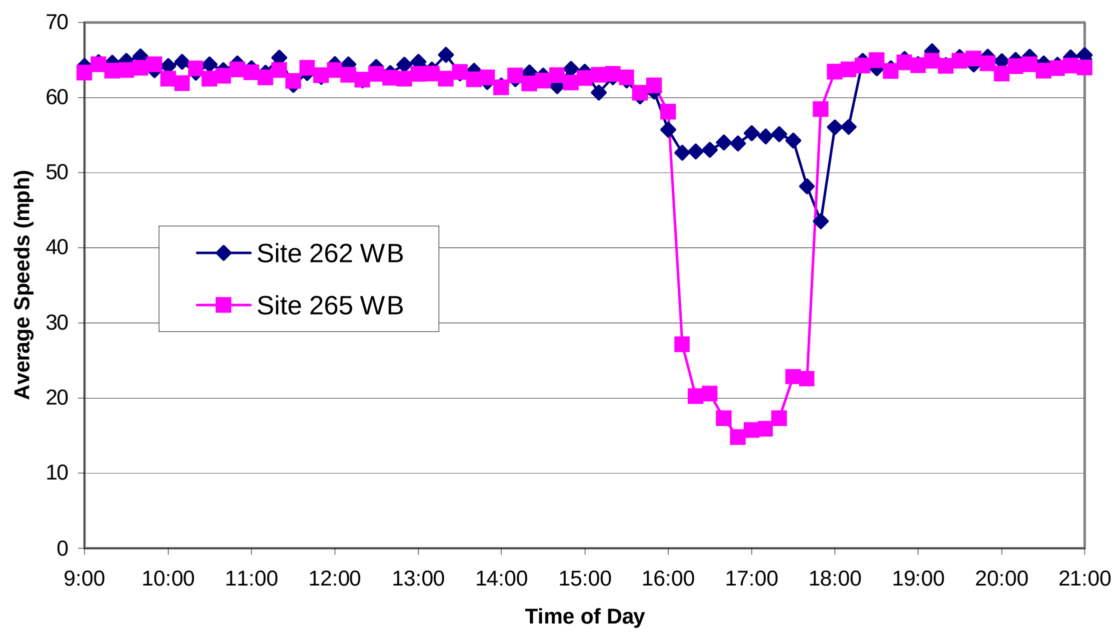


Figure 6-7. Average Speeds for Site 262 and 265 WB on 5/17/02.

7.0 OPTIMAL CONTROL PLANS DURING INCIDENT SITUATION

7.1 Introduction

This section of the report introduces a methodology to identify optimal traffic control plans on the diversion routes during incident situations. The methodology is based on a feedback simulation-based approach to evaluating freeway diversion route plans in integrated incident management systems using real-time data. The proposed approach employs an anticipatory technique to estimate demand and incident severity based on real-time data transmitted to the TMC through a fiber optic communication network and a library of historical traffic volume and incident data. Using the anticipated volume and incident data in a microscopic simulation model for the freeway and arterial systems network, an optimal decision about freeway diversion plans can initially be reached. Using real-time freeway volume data, the initial plans can be reevaluated and readjusted accordingly.

In severe incident situations, when an incident closes all lanes for more than two hours, ACHD TMC has developed plans for a full diversion of the freeway traffic. The plans use temporary traffic control devices, Dynamic Message Signs (DMS), and flaggers to manage traffic along the diversion routes. During less severe situations, when incidents partially close the freeway for shorter durations, diverting some of the freeway traffic to the surface street network may provide significant reduction to the area-wide incident-based delay. Traffic operators need, however, to make certain decisions regarding the type of control the need to be implemented to accommodate the diverted traffic. The proposed approach is intended to be used as a decision-making tool to assist traffic operators determining the optimal traffic control plans. Once an incident is confirmed, traffic operators need to evaluate different options and determine:

1. Whether to start diverting traffic form the freeway to the surface street network,
2. What percentage of the freeway traffic that should be diverted to achieve optimal network-wide operations, and

3. How to adjust the timing plans for the traffic signals along the diversion routes to optimally manage arterial system

Optimal signal timing plans [optimal cycle length, offsets, and green splits] for the actuated controllers along the diversion routes were developed using a variety of optimization tools:

1. Manually to provide one-way progression for the diverted traffic,
2. Using TRANSYT [hill-climbing macroscopic optimization],
3. Using TRANSYT [Genetic Algorithm optimization], and
4. Using Synchro [minimizing network-wide delay and stops]

Cycle lengths examined in the analysis ranged from 160 seconds to 240 seconds. To ensure uniformity in the arterial systems operation, no changes were made to the intersections' phasing plans (sequence). Optimal signal control plans for the diversion routes depend on many parameters, most importantly, the amount of traffic being diverted from the freeway and the volume/capacity ratio at the intersections along the diversion routes prior to and at the time of diversion. The process of developing and testing optimal timing plans are described thoroughly in the traffic incident management training materials developed as part of this project.

The developed optimal plans were compared using CORSIM microscopic simulation. Ten incidents with different severity levels and durations were used as a case study for the evaluation. Results from the analysis showed that the proposed evaluation framework produced optimal diversion route plans. The benefit of using real-time operational characteristics in the evaluation seems to be greater for incidents of moderate severity and duration. The results showed that the proposed approach can be used as a decision-making tool for real-time incident management, specifically for developing and testing diversion plans using real-time data.

7.2 The Proposed Evaluation Framework

Figure 7-1 presents the proposed feedback evaluation framework for the Treasure Valley Corridor's freeway diversion route plans using an integrated microscopic simulation model. The proposed evaluation framework utilizes real-time traffic data obtained from the detector stations located along the freeway and a database set that includes average demand on the freeway at different locations for every 15-minute time interval. This provides accurate estimates of freeway demand during the incident duration. Similarly, a database set that includes incident data for the corridor will be utilized to estimate incident severity and its expected duration. A comparison between the freeway's anticipated demand and its reduced capacity will determine the excess volume that needs to be diverted. The reduction in freeway capacity was estimated based on the capacity reduction factors presented in exhibit 22-6 in the Highway Capacity Manual (HCM 2000.)

The integrated simulation model can then be used to determine network-wide performance measures under different pre-optimized signal timing plans for the diversion routes. The performance measure, to be maximized in this study is the relative percentage reduction in network-wide total travel time, which is defined as following:

$$P_i = \left(\frac{TTT_{DoNothing} - TTT_{Diversion}}{TTT_{DoNothing} - TTT_{NoIncident}} \right)$$

Where:

P_i	is the performance measure for diversion plan i
$TTT_{DoNothing}$	is the network-wide total travel time under the incident with no diversion plans
$TTT_{Diversion}$	is the network-wide total travel time under the incident with diversion plans
$TTT_{NoIncident}$	is the network-wide total travel time under no incident

Once the optimal signal timing plan for the diversion routes is determined, the simulation model can be used, with updated demand and incident severity, to determine duration of freeway traffic diversion (T_D.)

7.3 Simulation Model Development

Several simulation models are available to conduct analyses of arterials or freeways, CORSIM, MITSIM, VISSIM, and AIMSUN2 for example. Some even include Origin/Destination based Dynamic Traffic Assignment for modeling diverted vehicles that complete their trips instead of returning to the freeway. But few simulation models have the ability to model both arterials and freeways simultaneously, taking into consideration the effects of one on the other. The CORSIM microscopic simulation model combines the NETSIM and FRESIM models for arterials and freeways, respectively, allowing for a system-wide analysis of both freeway and surrounding arterial network.

CORSIM has the capability to model incidents on both the freeway and arterial streets in the coded network. Freeway incidents may take the form of complete lane blockages or merely slowdowns resulting from incidents or other activities taking place on the shoulder. CORSIM also models the rubbernecking phenomenon. The term rubbernecking refers to the tendency of drivers of vehicles in lanes adjacent to the incident to slow down as they pass the incident location. This reduction in speed, results in lower lane throughput and therefore lower lane capacity. In the case of a blocked lane, the loss of capacity is likely to be greater than simply the proportion of original capacity that is physically blocked. For example, a four-lane freeway with two lanes blocked retains only 25 percent of its capacity (Exhibit 22-6, HCM2000).

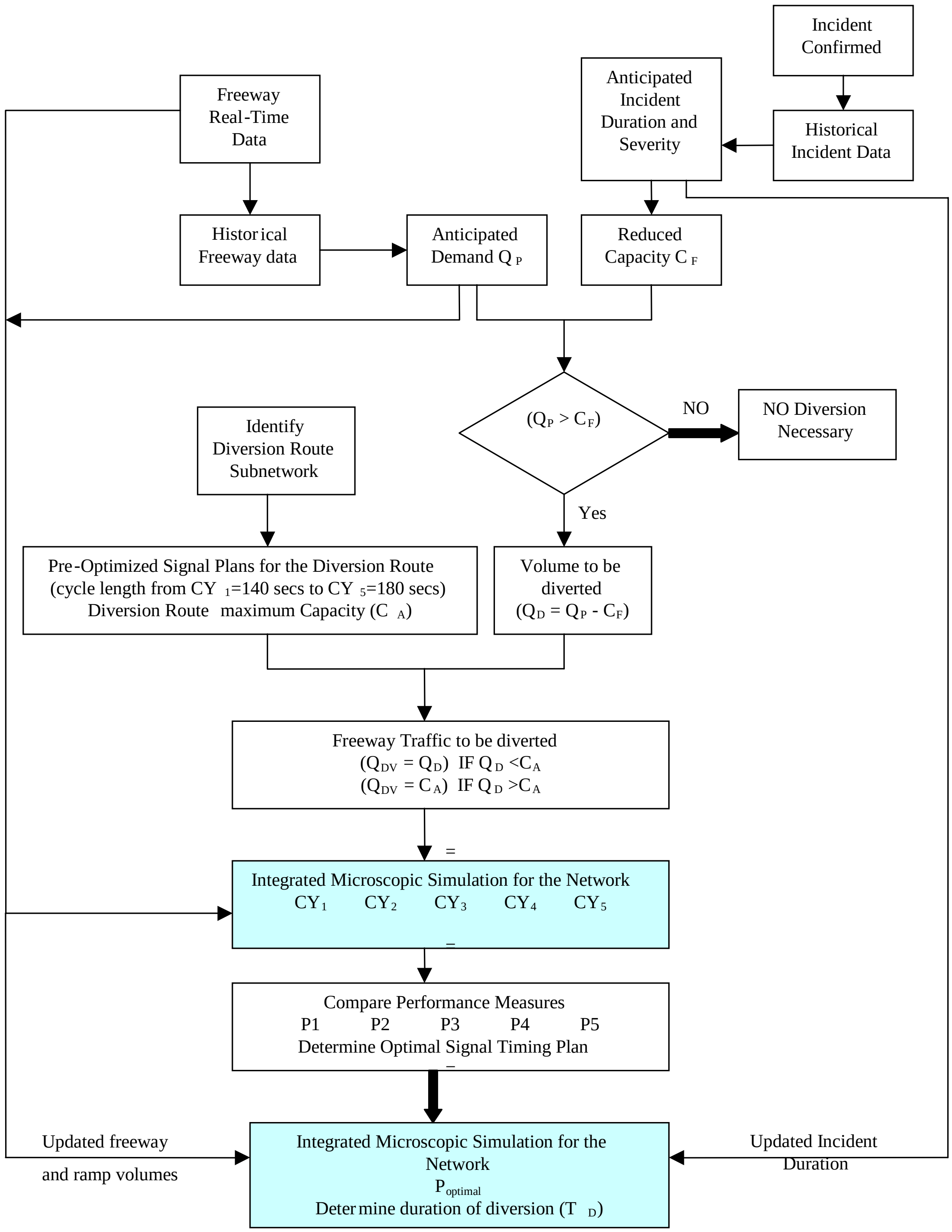


Figure 7-1. The Proposed Evaluation Framework

The added loss of capacity is attributable to the rubberneck factor at the incident location. The specification of an incident consisting of only rubbernecking can be used to simulate the effects of an incident on the shoulder. The FREESIM manual suggests that a secondary incident consisting of only rubbernecking be placed at the upstream end of the primary incident. This secondary incident should have the same duration as the primary incident. The fact that COSRIM can reliably model freeway incidents, in addition to its ability to model integrated freeway and arterial system networks, made it the logical choice to be used in this study. Traffic Software Integrated System (TSIS) version 5.0 was used in this project. TSIS represents the Windows shell application for CORSIM and other software that integrates with it. Due to the relatively complex CORSIM input data process, a decision was made to use another program (SYNCHRO 4.0) to build the network, and then transfer it to CORSIM. A SYNCHRO file has been developed for the arterial and surface-street network from a MicroStation map of the Treasure Valley area.

Once a determination was made to use CORSIM as the main simulation model for this study and SYNCHRO to build the network, data acquisition efforts began, to collect data required for the model development. The Treasure Valley corridor follows Interstate 84 from Milepost 25 to Milepost 60, through the cities of Caldwell, Nampa, Meridian, and Boise. This network covers the entire Boise metropolitan area. The study area consists of 211 intersections—93 signalized and 118 unsignalized. Of the 211 intersections, 142 are located in Ada County and the remaining 69 intersections are located in Canyon County. As the maximum number of nodes allowed in any CORSIM model cannot exceed 500 nodes, a determination was made to divide the study area into two separate networks, one for each county. Figure 7-2 presents the SYNCHRO model for the Ada county arterial network, and Figure 7-3 presents the CORSIM integrated freeway and arterial systems network for Ada County.

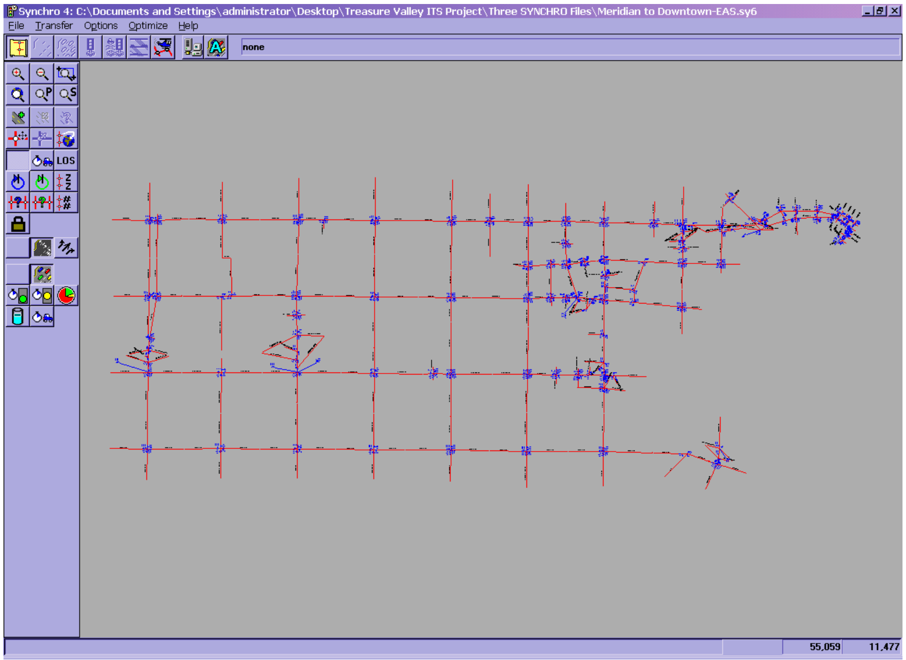


Figure 7-2 Synchro Model for Arterial Systems Network for Ada County

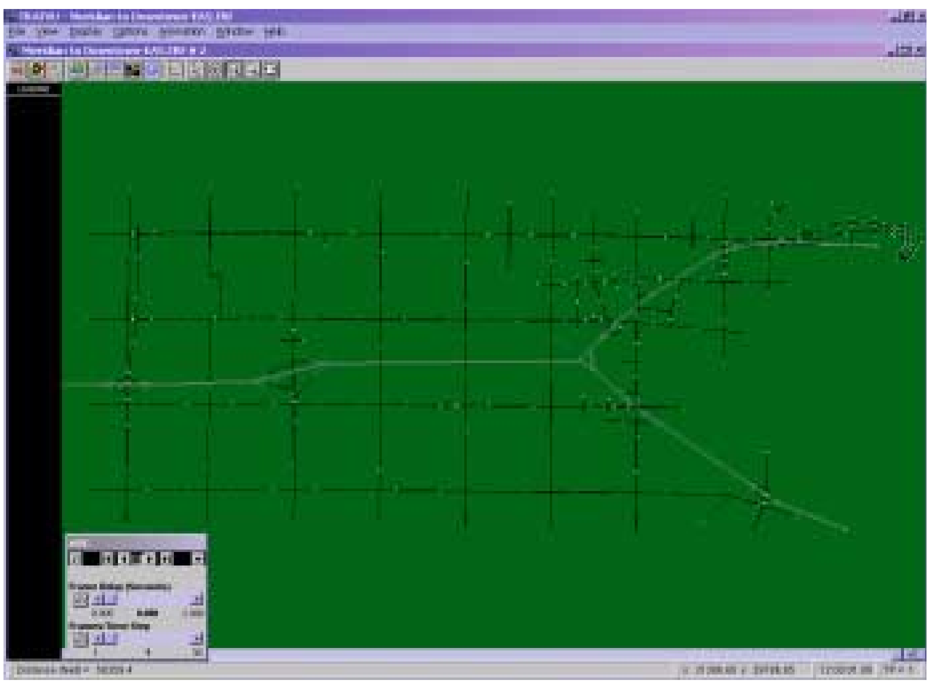


Figure 7-2 CORSIM Model for the Ada County Network

7.4 Calibration and Validation of the Simulation Models

The CORSIM simulation model is built upon a basic set of stochastic algorithms that attempt to represent vehicular traffic flow through various types of roadway systems under various conditions. Because of the stochastic nature of simulation programs, their use requires that two basic steps be completed prior to finalizing any analysis results. First, traffic flow characteristics and driver behavior components of the model need to be calibrated to conditions observed or measured in the field. Second, the calibration needs to be linked directly to validation of the model, involving a comparison of simulated and observed traffic flow conditions of the system under study. This comparison is intended to provide a direct measurement of how well the model results match existing and observed traffic flow conditions.

To calibrate and validate the freeway model, detectors were placed on the freeway and the average detector occupancy was used as the main calibration factor. Traffic volumes in the freeway were chosen to match those reported by the ITD counting stations. Driver behavior characteristics, such as car-following sensitivity factors and percent of different driver types in the traffic were adjusted to reflect the conditions in the field. The difference between the average detector occupancy in CORSIM and in the field ranged from 3% to 11%, with an average value of 7.3%. This relatively low error indicates that the freeway simulation models are validated and can reliably represent the actual traffic conditions in the field.

Considering the extraordinary size of the arterial systems network in the model, there were not enough data available to carry out a comprehensive calibration and validation analysis for the arterial systems simulation model. Throughput data, in the form of average hourly volumes, were available for some intersections on the diversion routes. These traffic volumes were used in calibrating the arterial system simulation models for both Ada and Canyon Counties. The difference between the simulated and field volumes ranged from 4% to 19%, with an average of 11.2%. Considering the size of the network and the quality of the traffic and turning movement data available, this relatively high error rate seems tolerable, and the simulation model can be used in the analysis with a considerable degree of confidence to perform the comparative evaluation study for the diversion route plans.

7.5 Evaluation Methodology and Optimal Signal Control Plans

The validated simulation model is used to evaluate freeway diversion route plans using the proposed evaluation framework. A case study consisting of 10 actual incidents that occurred during the morning or afternoon peak period was chosen for the analysis. These incidents were selected from the 48 incidents that occurred on I-84 from September 11, 2000 to February 28, 2002.

The traffic volumes reported at the time of the incident were used, along with average demand data to estimate traffic demand at and during the time of the incident, as described earlier in this paper. The difference between the predicted and actual values ranged from 3.31% to 7.85%. This relatively small difference indicates that the proposed prediction method is effective in predicting realistic demand levels. The proposed demand prediction method can be used in the evaluation of different incident management strategies.

Comparisons between the predicted demand and freeway-reduced capacity for incidents 2 and 6 are presented in Table 7-1. This step is important to determine the freeway demand that need to be diverted. For example, congestion resulting from incident 2 could be eased if the excess demand of 337 vehicles (or 1348vph), or part of them were diverted to the arterial systems network. The average spare capacity of the diversion route is 2234vph. The spare capacity is enough to accommodate the diverted freeway traffic. For the more severe incident (incident 6), the excess freeway volume during the incident blockage is 1525 vehicles (2550vph), which is higher than the average spare capacity of the diversion route (2087vph). This means that only a percentage of the freeway traffic, equal to the spare diversion route capacity, can be effectively diverted to the arterial network.

Five signal-timing plans with cycle length ranged from 140 seconds to and 180 seconds were considered in this study. The signal timing plans for the coordinated actuated signals along the diversions routes were optimized off-line based on average volume during different time periods. Offsets were optimized to provide maximum throughput for the freeway traffic diverted to the corridor. Results from the simulation model analyses are presented in Tables 7-2 and 7-3 for the 10 incidents examined in this study. Table 7-2 presents network-wide Total Travel Time (TTT) in vehicle-hours with and without freeway diversion route plans. Table 7-3 presents the relative percentage reduction in network-wide TTT (Pi.)

The results show that the relative percent reduction of TTT as a result of freeway diversion route plans are much higher for incidents that have moderate severity and/or duration. The percent reduction in TTT for severe incidents was much lower, mainly due to the limited capacity of the Treasure Valley’s diversion routes. The benefit of using real-time operational characteristics in the evaluation seems also to be greater for incidents of moderate severity and duration. The results indicated that the proposed evaluation framework can be used successfully in evaluating different diversion route alternatives and identify the optimal alternative among them. The use of real-time demand and vehicle-mix data in the integrated microscopic simulation model allowed for a more accurate estimation of the expected benefit of the proposed diversion alternatives.

Table 1. Example of Demand-Capacity Comparisons for incidents 2 and 6

Time Period	Expected Demand	Freeway Capacity	Difference
INCIDENT 2			
17:45 – 18:00	634	297	337
18:00– 18:15	591	2059	N/A
INCIDENT 6			
16:45 – 17:00	853	0	853
17:00– 17:15	912	240	672
17:15 – 17:30	944	900	44
17:15 – 17:30	921	900	21

Table 2. Network-Wide Total Travel Time (Vehicle-Hours) Under Different Signal Timing Plans

Incident Duration (minutes)	TTT (No Incident)	TTT (Do Nothing)	Cycle Length for the Signal Timing Plan				
			CL= 160 sec	CL= 180 sec	CL= 200 sec	CL= 220 sec	CL= 240 sec
14	5388	5701	5423	5421	5409	5436	5506
17	5657	5881	5726	5714	5696	5709	5720
15	4957	5727	5311	5304	5321	5335	5328
19	6196	7410	6718	6694	6653	6648	6631
22	5550	6810	6158	6151	6148	6123	6109
26	6196	7870	7211	7188	7164	7166	7179
31	5280	7001	6119	6088	6080	6071	6089
36	6466	8949	8112	8089	8061	8042	8009
54	4634	7487	6844	6832	6829	6811	6799
61	5388	9246	8321	8309	8298	8276	8244

Table 3. Performance Measures for Different Signal Timing Plans

Incident	Incident Duration (minutes)	Percentage reduction in network-wide total travel time (P_i) for Different Signal Timing Plans				
		CL=160	CL=180	CL=200	CL=220	CL=240
1	14	0.888	0.895	**0.933**	0.847	0.623
2	17	0.693	0.747	**0.827**	0.769	0.720
3	15	0.540	**0.550**	0.527	0.509	0.518
4	19	0.570	0.590	0.624	0.628	**0.642**
5	22	0.517	0.523	0.525	0.545	**0.556**
6	26	0.394	0.407	**0.422**	0.420	0.413
7	31	0.513	0.531	0.535	0.540	**0.530**
8	36	0.337	0.346	0.358	0.365	**0.379**
9	54	0.225	0.230	0.231	0.237	**0.241**
10	61	0.240	0.243	0.246	0.252	**0.260**

7.6 Evaluating Incidents under Uncertainty

There are several uncertainties associated with incidents that affect the incident management and alternate route planning and operations. Some of the major uncertainties are: 1) the actual duration of the incident and the traffic demand expected during the incident duration cannot be accurately predicted, 2) there is no effective way in practice to achieve a theoretical optimum diversion from an open freeway, and 3) the routing of vehicles that are diverted cannot be accurately predicted.

A methodology for analyzing freeway diversion routes in integrated incident management systems under uncertainties is presented in this paper. The proposed methodology uses Monte Carlo simulation to generate a set of possible combinations of independent parameters that later be used in a microscopic traffic simulation model to yield a set of values of an output parameter that reflects the network-wide quality of service. The description of the methodology and its application is presented in the following sections.

7.6.1 The Proposed Methodology

We consider the situation where we are attempting to analyze an incident situation using a certain dependent response parameter y, and that this response parameter depends on independent vector variable $x = \{x_1, x_2, \ldots, x_n\}$. For example, the dependent response y might be the network-wide total delay, travel time, or stops and the independent variables might be incident duration, percent of drivers who comply with the diversion signs, traffic demand levels, etc. We consider the typical case where we are uncertain about the exact values of the independent variables. However, we will assume that the distribution of the average, standard deviation and Probability Density Functions (PDF) of each of these independent variables are known $\{f_1(x_1), f_2(x_2), \ldots, f_n(x_n)\}$.

The multiple uncertainties in the model inputs must be combined and evaluated simultaneously to determine the uncertainty propagation and the overall uncertainty of model predictions. Simulation iterations can be used to evaluate the model repeatedly, with each run of the model representing a possible outcome. The inputs to the model are simulated by sampling one value from each independent variable obtained from the variable's PDF, Figure 7.4; the corresponding value of the model output can then be calculated.

In the proposed methodology, Monte Carlo (MC) trials are used to generate *r* possible combinations of the input variables $x_{j1}, x_{j2}, \ldots, x_{jn}$ from their PDFs $\{f_1(x_1), f_2(x_2), \ldots, f_n(x_n)\}$. We then conduct *r* simulation runs of the network's microscopic traffic simulation model with each run conducted at a different *x* value.

Let y_i be the response (obtained from the microscopic simulation modeling) and $x_{j1}, x_{j2}, \ldots, x_{jn}$ be one possible combination among r combinations of the values of the "design" independent variables used as input to the simulation model. We can now fit a regression model to examine the dependence of the response *y* on the independent variable $\{x\}$:

$$y_j = \left[\sum_{i=1}^{n} \beta_i f_i(x_{ij}) \right] + z_j, \qquad j = 1,2,\ldots,r$$

Where *"z"* is a "noise" variable modeling the chance variability of the simulation output. The PDF of the response "y" can now be obtained: $f(y) = \{y_1, y_2, \ldots, y_r\}$. The response density function and regression model for the response variable can now be used to assess the alternative diversion route plans and better quantify their potential benefits.

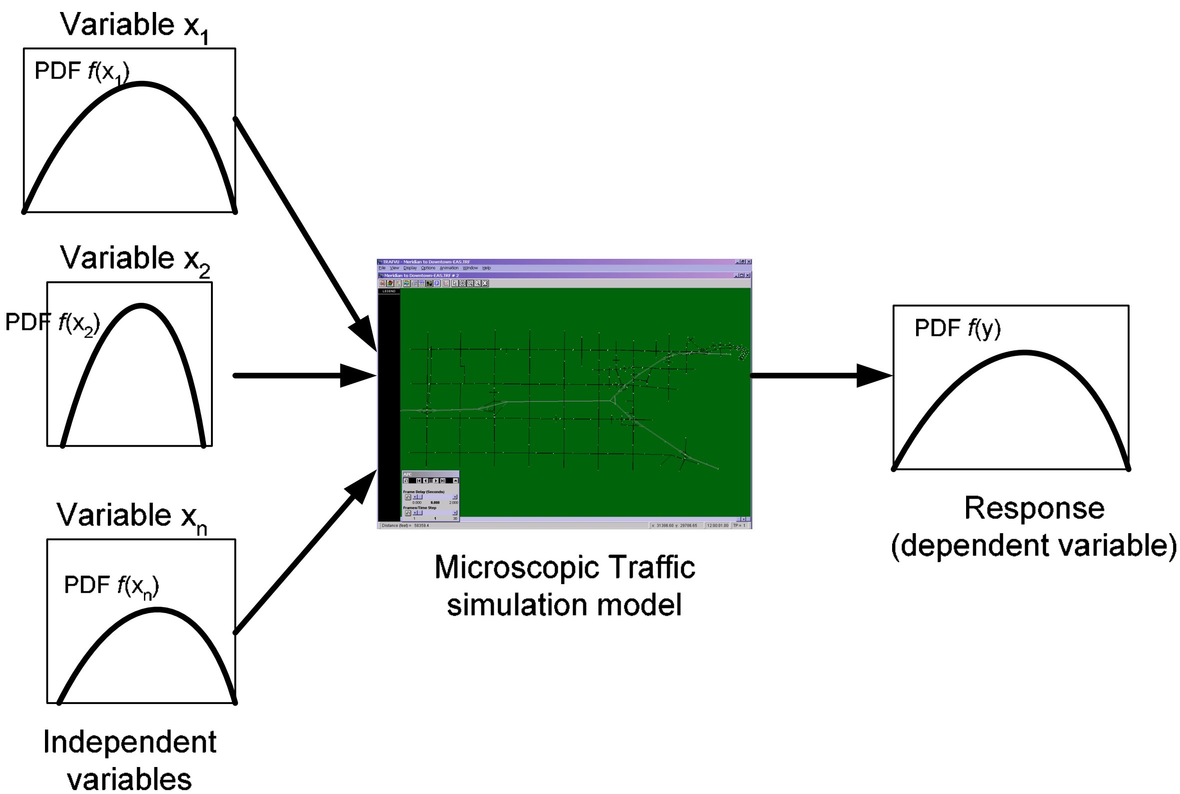


Figure 7.4 Proposed Framework for Analyzing Incidents with Uncertainties

7.6.2 Methodology Application

7.6.2.1 The response "independent variable"

The CORSIM integrated simulation model for the Treasure Valley corridor was used to determine network-wide performance measures. The response or the dependent variable chosen for this study is the relative percentage reduction in network-wide total travel time, which is defined as following:

$$P_i = \left(\frac{TTT_{DoNothing} - TTT_{Diversion}}{TTT_{DoNothing} - TTT_{NoIncident}} \right)$$

Where:

P is the output response value (performance measure)

$TTT_{DoNothing}$ is the network-wide total travel time with no diversion plans

$TTT_{Diversion}$ is the network-wide total travel time with diversion plans

$TTT_{NoIncident}$ is the network-wide total travel time under no incident

7.6.2.2 Independent variables and their PDFs

Two independent variables were used in the analysis "n=2"; the incident duration (x_1) and the percent of drivers who complied with the advisory diversion signs (x_2). Although the actual duration of an incident is not known until it is cleared, two methods for predicting it are prevalent in the literature. The first is a probability-based method, and the second relies on regression analysis using incident data. The typical incident duration frequency distribution is not symmetrical; it has a long tail in the positive direction and no negative values. Data from the Treasure Valley area shows that the distribution of incident durations is heavily skewed, with about 75% of the incidents lasting less than 30 minutes. This is consistent with prior research showed that the log-normal distribution fits the data adequately.

The regression method uses incident data to predict incident severity and duration based on other factors such as the number of vehicles involved, peak or off-peak time of day, and the pavement wetness. Regression analysis on network's incident data did not yield any significant relationship between incident duration and other factors. A normal distribution with an average of 23 minutes and a standard deviation of 9 minutes was selected as the PDF for the incident duration (x_1) variable in this analysis. These values should be selected based on the incident characteristics. It was assumed that the incident will close two of the three lanes of the freeway for the entire duration of the incident.

Drivers' compliance to advisory diversion signs and messages depends on many factors: driver familiarity with the network, level of congestion, reliability of the disseminated messages, socioeconomic characteristics and the availability of suitable alternate routes. Voluntary diversion rates can be as high as 23% in response to DMS's and as high as 57% in response to radio and DMS's. Based on the Treasure Valley specific data, a normal distribution function with an average of 16% and a standard deviation of 6% was selected as the PDF for percent compliance (x_2) variable in this analysis.

7.6.2.3 The Monte Carlo Simulation process

In the Monte Carlo simulation method, real events are simulated by simple events. These events should be repeated until sufficient simulation of the modeled event is achieved. Each trial may be represented as an experiment. This concept has been traditionally applied in evaluating the probabilistic density function of a function of random variables. Using the two PDFs for (x_1) and (x_2), a total of 200 combinations of [(x_1), (x_2)] were generated (r = 200). These values were input to the traffic simulation model (200 runs) and the corresponding values of the model output were obtained. For, other input parameters, such as traffic demand on the freeway and the arterial system, the values was estimated based on historical data as described in section 7.2 of this report.

7.6.3 Methodology Results

Figure 7.5 shows the frequency distribution and the PDS for the response parameter (the Performance Index P_i). Figure 7.6 presents a scatter plot for (P_i). The Performance index threshold, below which no diversion route plans would be activated (0.385), is also shown in the figures. This threshold value is determined by the agency operating the incident management program based on the cost of diversion route plans deployment and the expected delay reduction benefit. For the case presented, most of the performance measure values for the examined cases fall below the threshold value, accordingly, no diversion plan should be activated for this incident situation. The R^2 value for the model was 0.923, indication a high correlation between the dependent and independent variables. The regression model resulted from the analysis can be used to precisely determine the expected performance measure once more accurate estimates of the independent variables are available.

Results showed that the proposed methodology allows for better assessment of the potential delay reduction benefits of diversion route plans. The methodology uses Monte Carlo simulation to generate a set of possible combinations of independent parameters that later be used in a microscopic traffic simulation model to yield a set of values of an output parameter that reflects the network-wide quality of service. These values could be used to determine the distribution of the probability density function for the response parameter and to develop a regression model that examines the dependence of the response on the independent parameters.

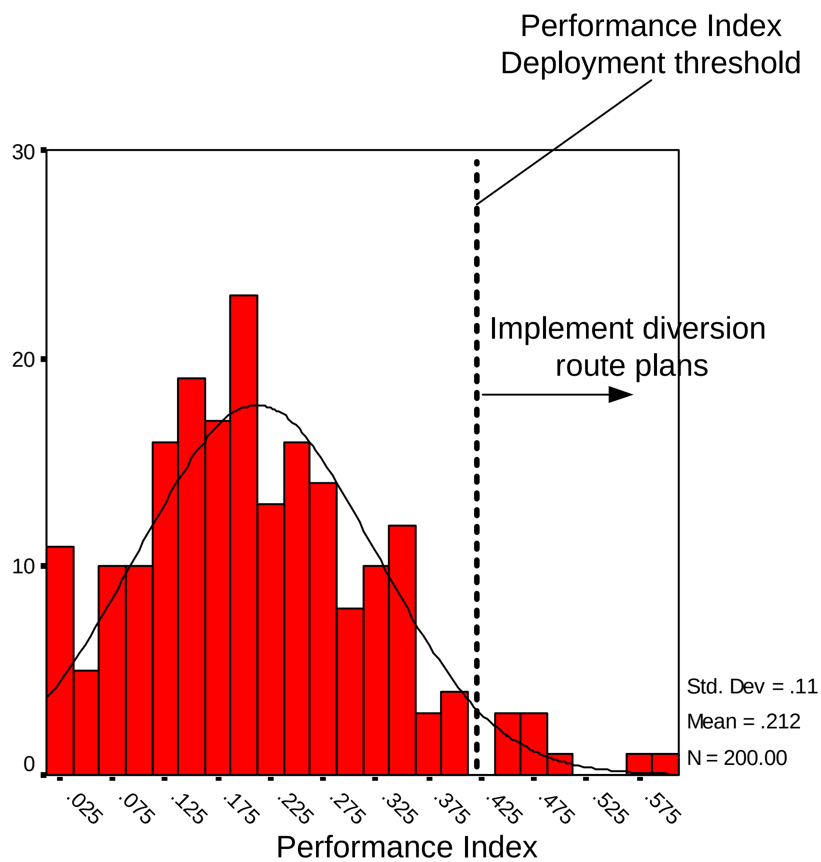


Figure 7.5 Performance Measure frequency distribution

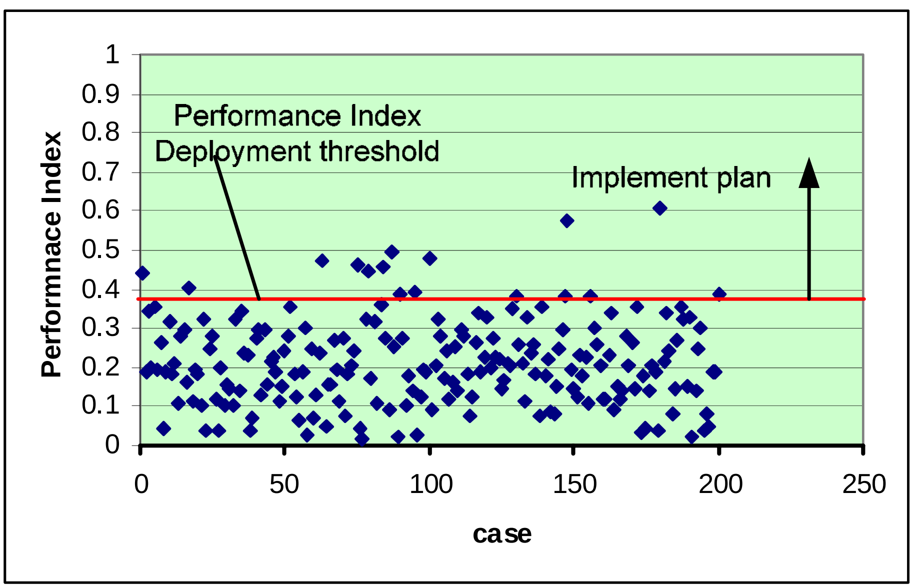


Figure 7.6 Perforce Measure Values for the 200 runs

APPENDIX A

January 2001   Congestion Averages

Westbound							
Date	Day	265		262		263	
		Beg	End	Beg	End	Beg	End
1/1/01	Monday						
1/2/01	Tuesday	5:00	5:40	5:00	5:30	5:10	5:50
1/3/01	Wednesday	5:00	5:20	4:40	5:20	5:10	5:50
1/4/01	Thursday	5:00	5:30	4:40	5:30	5:10	7:00
1/5/01	Friday	5:00	5:30	4:40	5:50		
1/6/01	Saturday						
1/7/01	Sunday						
1/8/01	Monday	5:00	5:20	5:00	5:45		
1/9/01	Tuesday	5:00	5:20	4:40	5:40	5:00	5:40
1/10/01	Wednesday	5:00	6:00	4:00	7:00	5:00	6:10
1/11/01	Thursday	5:00	5:40	4:20	6:00	5:00	6:00
1/12/01	Friday	5:00	5:40	5:00	6:10	5:00	6:00
1/13/01	Saturday						
1/14/01	Sunday						
1/15/01	Monday	4:40	5:40	4:50	5:40	5:00	5:30
1/16/01	Tuesday	5:00	5:30	4:30	6:00	5:00	5:40
1/17/01	Wednesday	5:00	5:30	5:00	5:40		
1/18/01	Thursday	5:00	5:20			5:00	5:50
1/19/01	Friday						
1/20/01	Saturday						
1/21/01	Sunday						
1/22/01	Monday	5:00	5:30	4:40	5:40		
1/23/01	Tuesday	5:00	5:20	4:30	5:50	4:30	6:00
1/24/01	Wednesday	5:00	5:30				
1/25/01	Thursday	5:00	5:20	4:00	7:00	5:00	5:20
1/26/01	Friday	5:00	5:30	4:30	5:30		
1/27/01	Saturday						
1/28/01	Sunday						
1/29/01	Monday						
1/30/01	Tuesday	5:00	5:40	4:30	6:00	5:00	6:00
1/31/01	Wednesday	5:00	5:40	4:30	6:30	5:00	5:40
Averages		4:59	5:31	4:36	5:55	5:00	5:53

June 2001 Congestion Averages

Westbound							
Date	Day	265		262		263	
		Beg	End	Beg	End	Beg	End
6/1/01	Friday	5:00	5:30				
6/2/01	Saturday						
6/3/01	Sunday						
6/4/01	Monday	5:30	5:50	4:20	6:00	5:00	6:00
6/5/01	Tuesday	5:10	5:50	4:40	5:30		
6/6/01	Wednesday	5:00	5:30	4:40	5:30		
6/7/01	Thursday	5:00	6:00	4:20	6:00	5:00	6:00
6/8/01	Friday	5:00	5:20	4:40	5:30	4:50	5:10
6/9/01	Saturday						
6/10/01	Sunday						
6/11/01	Monday	5:00	5:50	4:00	6:00	5:00	6:00
6/12/01	Tuesday	5:00	5:30	5:00	6:00	5:40	6:10
6/13/01	Wednesday	5:00	5:20	4:30	5:45	5:00	5:40
6/14/01	Thursday	5:00	5:20	4:40	5:30	5:20	6:00
6/15/01	Friday	5:00	5:30	4:30	5:45		
6/16/01	Saturday						
6/17/01	Sunday						
6/18/01	Monday			4:50	5:30		
6/19/01	Tuesday	5:00	5:30	4:30	5:45	5:00	6:00
6/20/01	Wednesday	5:00	5:30	4:00	6:00	5:10	6:00
6/21/01	Thursday	5:00	5:50	5:00	6:30	5:00	6:30
6/22/01	Friday	5:00	5:20	5:20	5:30		
6/23/01	Saturday						
6/24/01	Sunday						
6/25/01	Monday	5:00	5:20	4:30	5:20	5:00	5:40
6/26/01	Tuesday			4:20	5:40	5:10	6:00
6/27/01	Wednesday	4:30	6:00	4:00	6:00	4:00	6:00
6/28/01	Thursday	5:00	5:30	5:00	5:30	5:00	5:50
6/29/01	Friday	5:00	5:20	5:00	5:20		
6/30/01	Saturday						
Averages		5:00	5:34	4:35	5:43	5:00	5:55

September 2001 Congestion Averages

Westbound								
Date	Day	265		262		263		
		Beg	End	Beg	End	Beg	End	
9/1/01	Saturday							
9/2/01	Sunday							
9/3/01	Monday							
9/4/01	Tuesday	5:00	5:30	5:00	5:40	5:10	5:30	
9/5/01	Wednesday	4:20	6:00	4:30	6:00	4:20	5:30	
9/6/01	Thursday	5:00	5:40	4:30	5:40			
9/7/01	Friday	4:50	5:30	4:10	5:50	5:00	6:00	
9/8/01	Saturday							
9/9/01	Sunday							
9/10/01	Monday	5:00	6:00	4:50	5:30			
9/11/01	Tuesday	4:30	5:30	4:50	5:30			
9/12/01	Wednesday	4:20	6:00	4:00	5:10	4:00	6:00	
9/13/01	Thursday	3:00	5:50	3:00	6:00	3:40	5:10	
9/14/01	Friday	4:00	5:20	4:50	5:20	4:00	5:10	
9/15/01	Saturday							
9/16/01	Sunday							
9/17/01	Monday	4:10	5:50	5:00	5:40	4:00	6:00	
9/18/01	Tuesday	4:30	5:30	4:30	5:20	4:30	5:50	
9/19/01	Wednesday	4:20	5:10	4:30	5:00	4:10	5:20	
9/20/01	Thursday	4:20	5:50	4:20	6:00	4:00	5:40	
9/21/01	Friday	4:30	5:30	4:00	6:00	3:30	5:30	
9/22/01	Saturday							
9/23/01	Sunday							
9/24/01	Monday	5:00	5:30	4:00	6:00	4:00	5:10	
9/25/01	Tuesday	4:20	5:30	4:00	6:00	3:10	5:30	
9/26/01	Wednesday	5:00	5:40	4:50	5:30	4:00	6:00	
9/27/01	Thursday	4:40	5:40	3:50	5:50	4:00	6:00	
9/28/01	Friday	4:50	5:40	4:20	5:40	4:00	5:00	
9/29/01	Saturday							
9/30/01	Sunday							
Averages		4:17	5:21	4:09	5:23	4:05	5:35	

APPENDIX B

MEAN SPEED ALGORITHM

		runMeanSpeed-1GUI.bat			
		Trial 1	Trial 2	Trial 3	Trial 4
T1	Speed Start incident	35	40	45	40
T2	Speed end incident	50	50	50	50
NS	Intervals to start incident	10	10	10	10
PE	Intervals to end incident	5	5	5	5
PS	Interval to end tentative	5	5	8	8

Trial Days 2001

Detector	Month	Day	
121	11	39	Trial 1 predicted most incidents but left some out due to the low incident start speed
121	12	9	
122	12	9	Trial 2 predicted all incident starts but failed to predict the end
260	9	14	Trial 3 predicted some invalid start incidents due to the increase in T1
260	12	9	
261	9	14	Trial 4 predicted all start and end times correctly
261	12	9	
262	11	15	All 4 trials were run on the 9 trial days
262	12	8	

Then the 18 test days were run with trial 4 data and were all successful

Test Days 2001

Detector	Month	Day
262	12	9
263	12	7
263	12	9
263	12	21
265	11	4
265	11	15
265	11	22
265	12	6
265	12	7
265	12	8
265	12	12
265	12	13
265	12	14
265	12	15
265	12	19
265	12	20
265	12	21
265	12	22

MEAN SPEED ALGORITHM - MOD ONE

runMeanSpeedGUI.bat

		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
T1	Speed Start incident	35	35	35	40	40
T2	Speed end incident	65	60	55	50	50
NS	Intervals to start incident	5	5	5	12*	14
PE	Intervals to end incident	5	5	5	5	5

Trial Days 2001			Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Detector	Month	Day					
260	9	14	N	Y	Y	Y	Y
261	9	14	Y	Y	Y	Y	Y
262	11	15	N	Y	Y	Y	Y
262	12	8	N	Y	Y	Y	Y
263	12	7	N	N	Y	Y	Y
263	12	21	N	N	Y	Y	Y
265	11	4	N	Y	Y	Y	Y
265	11	15	Y	Y	Y	Y	Y
265	11	22	Y	Y	Y	Y	Y
265	12	8	Y	Y	Y	Y*	Y

Test Days 2001				
Detector	Month	Day		
265	12	6		Y
265	12	7	Trial 3 detected all start and stop times	Y
265	12	8	but allowed spectator slowdown	Y
265	12	13	on opposite side	Y
265	12	14		Y
			* Trial 4 was an improvement on spectator	
265	12	15	slowing but did not remove	Y
265	12	19	all cases	Y
265	12	20		Y
265	12	21		Y
265	12	22		Y
			Trial 5 removed all test cases of spectator	
121	12	9	slowing on opposite lane	Y
122	12	9		Y
263	12	9		Y

MEAN SPEED ALGORITHM - MODIFICATION TWO

		runMeanSpeedGap1GUI.bat						
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7
T1	Speed Start incident	35	35	35	35	35	35	35
T2	Speed end incident	65	60	60	60	60	55	50
Ns	Intervals to start incident	5	5	5	5	5	5	5
PE	Intervals to end incident	5	5	5	10	5	10	10
Ave sp	Initial average speed	65	65	60	60	60	60	60
gap	Intervals for gap	1	1	1	2	2	1	1
ratio	Ratio for gap	0.17	0.17	0.17	0.17	0.17	0.17	0.17

Trial Days 2001			Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7
Detector	Month	Day							
121	11	30	N	Y	N	N	N	Y	Y
121	12	9	N	Y	Y	N	Y	Y	Y
122	12	9	Y	Y	Y	Y	Y	Y	Y
260	9	14	N	N	N	N	N	Y	Y
260	12	9	----	----	----	----	----	----	----
261	9	14	Y	Y	Y	Y	Y	Y	Y
261	12	9	----	----	----	----	----	----	----
262	11	15	N	Y	Y	N	Y	Y	Y
262	12	8	N	N	N	Y	Y	Y	Y
262	12	9	----	----	----	----	----	----	----
263	12	7	N	N	N	N	N	Y	Y
263	12	9	N	N	N	N	N	N	Y
263	12	21	N	N	N	N	N	N	Y
265	11	4	N	N	N	N	N	N	Y
265	11	15	N	N	N	N	N	N	Y
265	11	22	N	Y	Y	N	N	Y	Y
265	12	6	N	Y	Y	N	N	Y	Y
265	12	7	N	Y	Y	Y	Y	Y	Y
265	12	8	N	Y	Y	Y	Y	Y	Y
265	12	12	N	Y	Y	Y	Y	Y	Y
265	12	13	N	N	N	N	N	N	Y
265	12	14	N	N	Y	Y	Y	Y	Y
265	12	15	N	Y	Y	Y	Y	Y	Y
265	12	19	N	Y	Y	Y	Y	Y	Y
265	12	20	N	Y	Y	Y	Y	Y	Y
265	12	21	N	N	N	N	N	N	Y
265	12	22	N	N	Y	Y	Y	Y	Y

---- No incident this day, used to make sure there are no false detections

N Did not predict the correct start or end time or both

Y Did predict the correct start and end of the simulation

Trials were run in batches of 9 days per batch to allow the program to function properly

PERSISTENCE ALGORITHM

			runPersistence-1GUI.bat	
			Trial 1	Trial 2
T1	Spatial difference in speed		18	20
T2	Relative spatial difference		0.01	0.03
NS	Intervals end tentative		5	8
PS	Intervals end confirmed		5	5
MAXSPD	Max speed in d/s station		60	60

1	No incident
2	Algorithm detects but wrong start
3	Algorithm detects but wrong end
4	To many predicted incidents
5	incident depicted correctly
6	Incident but no prediction

Eastbound 2001

Detector	Month	Day	Trial 1	Trial 2
261	1	9	4	5
261	1	10	4	5
261	1	18	4	5
261	1	31	6	6
261	2	3	1	1
261	2	8	1	1
261	2	13	4	5
261	2	17	1	1
261	2	23	4	5
261	3	3	1	1
261	3	7	4	5
261	4	1	1	1
261	5	3	5	5
261	5	8	1	1
261	5	18	4	5
261	5	25	4	5
261	5	31	5	5
261	6	13	4	5
261	6	20	4	5
261	6	22	4	5
261	8	7	1	1
261	8	29	4	5
261	9	1	1	1
261	9	6	5	5
261	9	7	1	1
261	9	8	4	5
261	9	11	3	5
261	9	12	1	1
261	9	13	4	5
261	9	14	4	5
261	9	18	4	5
261	9	20	4	5

261	9	22	1	1
261	9	25	1	1
261	9	27	4	5
261	10	5	1	1
261	10	6	1	1
261	10	23	1	1
261	10	27	4	5
261	12	7	4	5
261	12	11	4	5
261	12	14	6	5
261	12	24	1	1

Westbound 2001

Detector	Month	Day	Trial 1	Trial 2
262	2	8	5	5
262	2	23	4	5
262	3	7	4	5
262	3	29	4	5
262	5	10	5	5
262	5	16	6	6
262	5	24	4	5
262	5	26	4	5
262	6	6	4	5
262	6	12	4	5
262	6	16	4	5
262	6	26	4	4
262	8	2	4	5
262	8	4	4	5
262	8	17	4	5
262	8	18	4	5
262	8	25	1	1
262	8	29	5	5
262	9	7	4	5
262	9	11	1	1
262	9	12	1	1
262	9	13	1	1
262	9	14	4	5
262	9	22	4	5
262	10	11	4	5
262	10	18	4	5
262	10	26	4	5
262	11	3	4	5
262	11	8	6	6
262	11	9	4	5
262	11	15	6	6
262	11	17	1	1
262	11	21	4	5
262	11	22	1	1

262	12	4	4	5
262	12	8	4	4
262	12	15	1	1

Test Days 2001

Detector	Month	Day	Trial 1	Trial 2
262	1	14	1	1
262	2	3	4	5
262	2	7	4	5
262	3	7	4	5
262	5	18	4	2
262	10	2	4	5
262	10	9	4	5
262	10	11	4	5
262	11	10	4	1
262	12	8	4	5
	1	No incident		
	2	Algorithm detects but wrong start		
	3	Algorithm detects but wrong end		
	4	Too many predicted incidents		
	5	Incident depicted correctly		
	6	Incident but no prediction		

PERSISTENCE ALGORITHM – MODIFICATION ONE

		runPersistenceGUI.bat				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
T1	Spatial difference in speed	20	21	22	19	10
T2	Relative spatial difference	0.1	0.1	0.1	0.1	0.1
NS	Intervals confirmed incident	5	5	5	5	5
PS	Intervals continued incident	5	9	9	5	5

1	No incident
2	Algorithm detects but wrong start
3	Algorithm detects but wrong end
4	Too many predicted incidents
5	Incident depicted correctly
6	Incident but no prediction

Eastbound 2001

Detector	Month	Day	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
261	1	9	5	5	5	5	5
261	1	10	5	5	1	1	1
261	1	18	4	4	4	4	5
261	1	31	2,3	2,3	2,3	4	5
261	2	3	1	1	1	1	1
261	2	8	1	1	1	1	1
261	2	13	5				5
261	2	17	1				1
261	2	23	1				1
261	3	3	1				1
261	3	7	1				1
261	4	1	1				1
261	5	3	5				5
261	5	8	1				1
261	5	18	5				5
261	5	25	5				5
261	5	31	1				1
261	6	13	5				5
261	6	20	5				5
261	6	22	5				5
261	8	7	1				1
261	8	29	5				5
261	9	1	1				1
261	9	6	1				1
261	9	7	1				1
261	9	8	1				1
261	9	11	1				1
261	9	12	1				1
261	9	13	5				5
261	9	14	1				1
261	9	18	5				5
261	9	20	5				5
261	9	22	1				1
261	9	25	1				1
261	9	27	5				5
261	10	5	1				1
261	10	6	1				1
261	10	23	1				1
261	10	27	1				1
261	12	7	5				5
261	12	11	5				5
261	12	14	1				1
261	12	24	1				1

Westbound 2001

Detector	Month	Day	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
262	2	8	5				5
262	2	23	4				4
262	3	7	4				4
262	3	29	5				5
262	5	10	1				1
262	5	16	1				1
262	5	24	4				4
262	5	26	5				5
262	6	6	4				4
262	6	12	5				5
262	6	16	5				5
262	6	26	1				1
262	8	2	4				4
262	8	4	5				5
262	8	17	4				4
262	8	18	5				5
262	8	25	1				1
262	8	29	1				1
262	9	7	4				4
262	9	11	1				1
262	9	12	1				1
262	9	13	1				1
262	9	14	5				5
262	9	22	1				1
262	10	11	5				5
262	10	18	4				4
262	10	26	4				4
262	11	3	5				5
262	11	8	5				5
262	11	9	5				5
262	11	15	5				5
262	11	17	1				1
262	11	21	5				5
262	11	22	1				1
262	12	4	4				4
262	12	8	4				4
262	12	15	1				1

Test Days 2001

Detector	Month	Day	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
262	1	14	1	1	1		1
262	2	3	6	6	6		6
262	2	7	2	2	2		5
262	3	7	4	4	4		5
262	5	18	5	5	5		5
262	10	2	5	5	5		5
262	10	9	5	5	5		5
262	10	11	5	5	5		5
262	11	10	1	1	1		1
262	12	8	5	5	5		5
	1	No incident					
	2	Algorithm detects but wrong start					
	3	Algorithm detects but wrong end					
	4	Too many predicted incidents					
	5	Incident depicted correctly					
	6	Incident but no prediction					

CALIFORNIA ALGORITHM

runCalifornia8GUI.bat

	Trial 1	Trial 2	Trial 3	Trial 4
T1	7.4	4	4	4
T2	-0.259	-0.259	-0.259	-0.259
T3	0.302	0.302	0.302	0.55
T4	27.3	27.3	10.7	10.7
T5	30	30	30	30

1	No incident
2	Algorithm detects but wrong start
3	Algorithm detects but wrong end
4	Too many predicted incidents
5	Incident depicted correctly
6	Incident but no prediction

Eastbound 2001

Detector	Month	Day	Trial 1	Trial 2	Trial 3
261	1	9	7	3	5
261	1	10	7	3	5
261	1	18	3	3	5
261	1	31	4	4	5
261	2	3	6	3	6
261	2	8	1	1	1
261	2	13	4	4	4
261	2	17	1	1	1
261	2	23	1	1	1
261	3	3	7	3	5
261	3	7	2	2	5
261	4	1	1	1	1
261	5	3	5	5	5
261	5	8	1	1	1
261	5	18	4	4	4
261	5	25	4	4	4
261	5	31	4	4	4
261	6	13	2	2	6
261	6	20	4	4	5
261	6	22	5	5	5
261	8	7	1	1	1
261	8	29	1	1	1
261	9	1	1	1	1
261	9	6	1	1	1
261	9	7	1	1	1
261	9	8	1	1	1
261	9	11	1	1	5
261	9	12	3	3	3
261	9	13	5	5	5

261	9	14	7	3	6
261	9	18	4	4	5
261	9	20	4	4	5
261	9	22	1	1	1
261	9	25	1	1	5
261	9	27	6	6	5
261	10	5	1	1	1
261	10	6	1	1	1
261	10	23	1	1	1
261	10	27	4	4	4
261	12	7	6	6	5
261	12	11	5	5	5
261	12	14	4	4	4
261	12	24	1	1	5

Westbound 2001			Trial 1	Trial 2	Trial 3	Trial 4
Detector	Month	Day	4	4	4	5
262	2	8	4	4	4	5
262	2	23	4	4	4	5
262	3	7	4	4	4	5
262	3	29	4	4	4	1
262	5	10	4	4	4	6
262	5	16	4	4	4	5
262	5	24	5	5	5	5
262	5	26	4	4	4	5
262	6	6	4	4	4	5
262	6	12	4	4	4	5
262	6	16	5	5	5	6
262	6	26	4	4	4	5
262	8	2	4	4	4	5
262	8	4	4	4	4	5
262	8	17	4	4	4	6
262	8	18	4	4	4	5
262	8	25	4	4	4	6
262	8	29	4	4	4	5
262	9	7	1	1	1	1
262	9	11	4	4	4	1
262	9	12	4	4	4	5
262	9	13	4	4	4	5
262	9	14	4	4	4	2
262	9	22	4	4	4	4
262	10	11	4	4	4	2
262	10	18	4	4	4	5
262	10	26	4	4	4	5
262	11	3	4	4	4	5
262	11	8	4	4	4	5
262	11	9	5	5	5	5
262	11	15	4	4	4	5

262	11	17	4	4	4	4
262	11	21	4	4	4	5
262	11	22	4	4	4	5
262	12	4	4	4	4	5
262	12	8	4	4	4	5
262	12	15	4	4	4	5

Test Days 2001			Trial 1	Trial 2	Trial 3	Trial 4
262	1	14	1	1	1	1
262	2	3	4	4	4	6
262	2	7	4	4	4	5
262	3	7	4	4	4	5
262	5	18	4	4	4	5
262	10	2	4	4	4	4
262	10	9	4	4	4	5
262	10	11	4	4	4	4
262	11	10	4	4	4	5
262	12	8	4	4	4	5
	1	No incident				
	2	Algorithm detects but wrong start				
	3	Algorithm detects but wrong end				
	4	Too many predicted incidents				
	5	Incident depicted correctly				
	6	Incident but no prediction				

APPENDIX C

NIATT's Advanced Traffic Management Laboratory

The University of Idaho's National Institute for Advanced Transportation Technology (NIATT) is in the process of developing an Advanced Traffic Management Laboratory that can be used for both research and teaching. The lab will be funded through the ITD/UI Cooperative Transportation Research Program, the FHWA, and the USDOT UTC program. This document describes the goals and objectives of the laboratory for achieving those objectives. The ATMS lab will part of the new expanded Traffic Controller Laboratory, now under design with completion scheduled for summer of 2003. The expanded laboratory will include twenty traffic signal controller units, and 20 Controllers Interface Devices (CIDs), enabling students to design and test traffic signal timing plans for large-scale networks of signalized intersections using hardware-in-the-loop-simulation models. Another component of the lab is a TRANSIM modeling

Goals/ Objectives

The goals of this laboratory are as follows:

- Provide a facility for undergraduate and graduate laboratory instruction.
- Provide a facility for conducting research on Advanced Traffic Management Systems.
- Provide a facility for disseminating state of the practice in traffic management and freeway/arterial systems operations to practicing professionals in both the public and private sector.

Lab Initial Components/Requirements

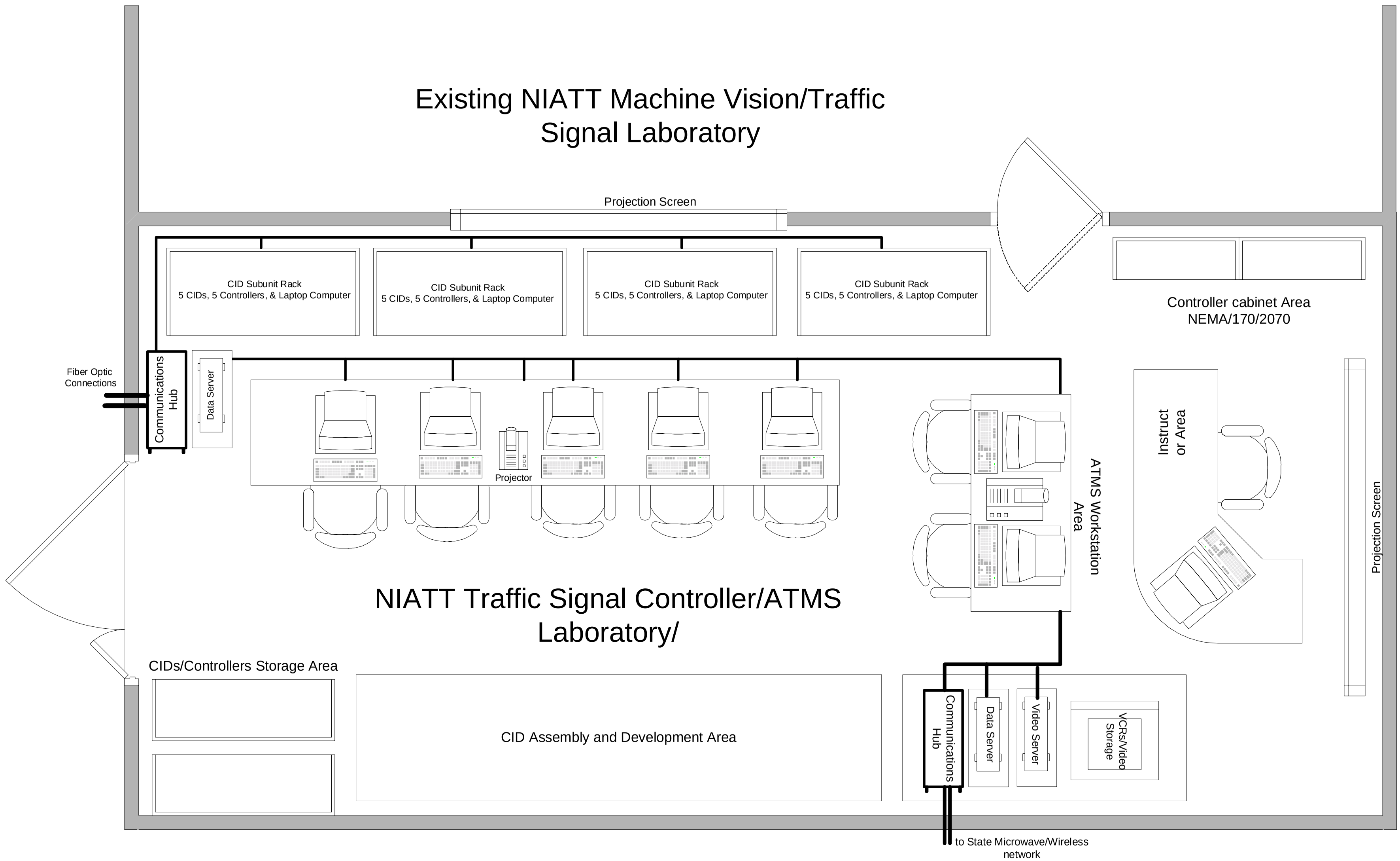
1.1 Laboratory shall have communication infrastructure capable of transmitting CCTV video images and traffic and signal status data from ACHD TMC center in Boise.

1.2 Laboratory shall have communication infrastructure capable of transmitting CCTV video images and traffic and signal status data of the City of Moscow traffic signal system.

1.3 Laboratory shall have data and video servers capable of managing the video and traffic data of transmitting CCTV video images and traffic and signal status data from the ACHD TMC center in Boise.

1.4 The lab shall have VCRs and a permanent computer projector (with screens), capable of projecting multi-video input.

1.5 The lab shall have two workstations and an appropriate number of PC's capable of running ATMS software, Simulation programs, and a variety of data analysis tools.


Existing NIATT Machine Vision/Traffic Signal Laboratory
Projection Screen
CID Subunit Rack
5 CIDs, 5 Controllers, & Laptop Computer
CID Subunit Rack
5 CIDs, 5 Controllers, & Laptop Computer
CID Subunit Rack
5 CIDs, 5 Controllers, & Laptop Computer
CID Subunit Rack
5 CIDs, 5 Controllers, & Laptop Computer
Controller cabinet Area
NEMA/170/2070
Fiber Optic Connections
Communications Hub
Data Server
Projector
ATMS Workstation Area
Instruct or Area
Projection Screen
NIATT Traffic Signal Controller/ATMS Laboratory/
CIDs/Controllers Storage Area
CID Assembly and Development Area
Communications Hub
Data Server
Video Server
VCRs/Video Storage
to State Microwave/Wireless network