Demonstration of the Application of Traffic Management Center Decision Support Tools

Final Report

Contract: BDK80 977-24

FIU Project: 800001644

Prepared for

The Florida Department of Transportation

by

Florida International University

Lehman Center for Transportation Research

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Disclaimer

Metric Conversion Chart

APPROXIMATE CONVERSIONS TO SI* UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
^{o}F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^{o}C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

Technical Report Documentation Page

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16. Abstract

Decision support tools were developed in previous Florida Department of Transportation (FDOT) research projects to allow for better analysis and visualization of historical traffic and incident data, in support of incident management and traffic management centers (TMCs). The goal of this demonstration project is to implement the use of these decision support tools at a traffic management center in Florida and demonstrate the benefits of these tools in a traffic management center (TMC) environment. The TMC of FDOT District 5 was selected as the demonstration site. Three decision support functions were implemented for the I-4 corridor managed by FDOT District 5. These are “normal day” traffic pattern and parameter identification, incident impact estimation, and historical detector data “play back” using the Remote Traffic Microwave Sensor (RTMS) simulator.

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Executive Summary

As part of completed Florida Department of Transportation (FDOT) research projects (FDOT Research BDK80 977-02, FDOT Research BDK80 977-03, and FDOT Research BDK80 977-11), decision support tools were developed to allow for better analysis and visualization of historical traffic and incident data to support the planning and operation of incident management and traffic management centers (TMCs). The goal of this demonstration project is to implement the use of these decision support tools at a traffic management center in Florida and demonstrate the benefits of these tools in a traffic management center (TMC) environment. The TMC of FDOT District 5 was selected as the demonstration site.

In this project, three decision support functions were implemented for the I-4 corridor managed by FDOT District 5. These functions are “normal day” traffic pattern and parameter identification, incident impact estimation, and historical detector data “play back” using the Remote Traffic Microwave Sensor (RTMS) simulator. To accomplish the first two tasks, a previously developed tool referred to as ITS Data Capture and Performance Measurement (ITSDCAP) was utilized to fuse ITS detector data and incident data for the I-4 corridor and perform the required analysis. A Web-based version of ITSDCAP was further developed to make this tool more convenient to use. Case studies of the tool’s application were conducted for a critical section of the I-4 corridor.

The recurrent day-to-day bottleneck locations and impacts within this study section were identified by the traffic pattern analysis. The normal days were clustered out to allow the estimation of the corresponding mobility, safety, and reliability performance for these days and the variation of these measures by time of day and day of week.

This study also assessed incident impacts on traffic operations in terms of queue length, incident delay, the potential for secondary incidents, and energy and environmental impacts, and also provided a method for calculating an incident severity index based on these impacts. Two methods were used to assess incident impacts on travel time. The first is based on speed

measurements from a traffic detector, referred to in this study as the “data-based method.” The second is based on detector volume measurement, but also uses queuing analysis equations. Differences were identified between the results of the incident impact analyses based on the two methods. In both cases, the analyses of incident impacts show significant impacts on mobility and that the main reason for unreliability for this corridor are incidents that cause severe crashes. When the days associated with these incident days were removed from the database and reliability was recalculated, the reliability indices indicate a good performance. Thus, investment in incident management strategies is expected to yield significant benefits.

Playback of historical incident data for training and impact demonstration purposes includes the following: The Remote Traffic Microwave Sensor (RTMS) simulator developed in the previous work will be combined with real-world data to “play back” historical detector data utilizing the SunGuide software displays, which can be used to train TMC operators to improve their operations during incident conditions. Virtual RTMS detectors were coded in the SunGuide system and connected to the RTMS simulator to display the historical detector data. In addition, an interface was created to display incident impacts through time progression. This can be used in traffic incident management team meetings to demonstrate the importance of incident management, either with or without video.

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List of Selected Acronyms and Abbreviations

Acronyms and abbreviations used in the report are listed below.

AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
CCTV	Closed-circuit Television
DMS	Dynamic Message Sign
EB	Eastbound
FDOT	Florida Department of Transportation
HAR	Highway Advisory Radio
HC	Hydrocarbon
ITS	Intelligent Transportation System
LPR	License Plate Reader
MD	Midday
RITIS	Regional Integrated Transportation Information System
RTMS	Remote Traffic Microwave Sensor
RWIS	Road Weather Information System
STEWARD	Statewide Transportation Engineering Warehouse for Archived Regional Data
TMC	Traffic Management Center
TSS	Traffic Sensor System
WB	Westbound

1 Introduction

1.1 Background

Incident management is consistently shown to be one of the most effective intelligent transportation system strategies, with benefit-to-cost ratios exceeding 10:1 in many cases. Thus, transportation agencies consider increasing the effectiveness of incident management strategies a high priority. Decision support tools were developed in previous FDOT research project to allow for better analysis and visualization of historical traffic and incident data in support of incident management and traffic management centers (TMCs). The two FDOT research projects are as follows:

- Decision Support Tools to Support the Operations of Traffic Management Centers (FDOT Research BDK80 977-02), and
- Traffic Management Simulation Development (FDOT Research BDK80 977-03).

The goal of the first project, "Decision Support Tools to Support the Operation of Traffic Management Centers," was to develop decision support tools to support Traffic Management Center (TMC) operations based on collected intelligent transportation system (ITS) data. Several decision support modules were developed in that project, including different travel time estimation methods based on point traffic detectors, traffic diversion estimation using both detector data and incident data, determination of the time lag between incident occurrence and the time that it is recorded in the SunGuide database, and incident severity index classification based on primary incident attributes and incident impacts.

The second project, "Traffic Management Simulation Development," aimed at exploring the development of methods and tools for the use of microscopic traffic simulation models to support TMC software implementation, operation, and testing. It also investigated the use of ITS data to support the development and calibration of simulation models. More specifically, this second project developed the following software utilities:

- Software utilities that can use the existing SunGuide databases and other available information for the preparation and calibration of microscopic simulation tools.
- Software utilities that support the testing of ITS Data Warehouse processes by producing traffic sensor system (TSS) data, travel time data, and other measures, as needed, in the SunGuide archive format based on simulation outputs.
- Software utilities that allow the exchange of data between the SunGuide software and virtual detectors in a simulation environment, for use in the SunGuide subsystem testing and operation evaluation.

Additional and refined decision support functionalities were integrated in a data analysis environment developed in a third FDOT research project, “Integrated Environment for Performance Measurements and Assessment of Intelligent Transportation Systems Operations” (FDOT Research BDK80 977-11) (Hadi et al., 2012). A product of this project is a tool referred to as the ITS Data Capture and Performance Management Tool (ITSDCAP). This tool can capture and fuse data from multiple sources, including ITS data warehouse (RIITS or STEWARD), traffic detectors and AVI/AVL from the SunGuide software archives, the SunGuide software incident management database, the Florida Highway Patrol (FHP) incident database, INRIX (private sector data provider) data, work zone (construction) database, “511” calls and website hits, dynamic toll pricing data for managed lanes (I-95 Express), FDOT crash database, and FDOT planning statistics office data. The tool filters, imputes, and fuses the data and calculates various mobility, reliability, safety, and environmental impacts. It also contains modules that support data mining, traffic modeling, and ITS benefit-cost analysis.

1.2 Project Objectives

The goal of this project is to demonstrate the use of the decision support tools developed as part of the FDOT research projects mentioned above. In this project, the TMC of FDOT District 5 was selected as the demonstration site. The specific products to be implemented as part of this demonstration include:

- ***Traffic pattern identification and performance measure estimation*****:** This estimation includes the identification of normal day traffic patterns and the estimation of the corresponding mobility, safety and reliability performance measures.
- ***Incident impact estimation tool*****:** Incident impacts on traffic operations in terms of queue length, incident delay, the potential for secondary incidents, energy and environmental impacts, and an incident severity index.
- ***Playback of historical incident data for training and impact demonstration purposes*****:** The Traffic Microwave Sensor (RTMS) simulator developed in the previous project will be combined with real-world data to "play back" historical detector data utilizing the SunGuide software displays, which can be used to train TMC operators to improve their operations during incident conditions. In addition, an interface was created to display incident impacts through time progression. This can be used in traffic incident management team meetings to demonstrate the importance of incident management.

1.3 Overview of Project Tasks and Document Organization

The first task of this project was to identify the study corridor and capture related incident data from FDOT District 5 SunGuide software and traffic data from the STEWARD data warehouse. The data quality of these two types of data was further examined. This task is described in Chapter 2.

The second task of this project was to implement the traffic pattern identification tool to cluster the days into the classification of "normal" days and "unusual" days, based on the collected traffic and incident data. The performance measures in terms of speed, volume, travel time, congestion index, and travel time reliability were estimated, allowing the user to have a complete picture of traffic patterns, and easily identify bottleneck locations. The results of this task are documented in Chapter 3.

The procedures used to implement the incident impact estimation tool are documented in Chapter 4. A detailed description is provided of the calculation methods of incident statistics, queue length, incident delay, secondary incident probability, increase in fuel consumption and emissions, and incident severity index. Case studies were conducted to illustrate the incident impacts in FDOT District 5.

The playback of incident impacts is documented in Chapter 5. The preliminary step in this process was to update the SunGuide database at Florida International University (FIU) by integrating FDOT District 5 detector and travel link information, and then connect to the RTMS simulator to play back the historical detector data. In addition, the interface created to display incident impacts as time progresses is presented.

1.4 References

Hadi, M., C. Zhan, Y. Xiao, and H. Qiang. Decision Support Tools to Support the Operations of Traffic Management Centers (TMC). Final report BDK80 977-02, Prepared for the Florida Department of Transportation, January, 2011.

Hadi, M., C. Zhan, and P. Alvarez. Traffic Management Simulation Development. Final report BDK80 977-03, Prepared for the Florida Department of Transportation, January, 2011.

Hadi, M., Y. Xiao, C. Zhan, P. Alvarez. Integrated Environment for Performance Measurements and Assessment of Intelligent Transportation Systems Operations. Final report BDK80 977-11, Prepared for the Florida Department of Transportation, June, 2012.

2 Data Capture

2.1 Study Corridor

Based on discussions with FDOT District 5 ITS personnel, the section between Milepost 84 and Milepost 94 along the I-4 corridor in Orlando, Florida was selected as the study corridor. Figure 2-1 shows the location and geometry of this study corridor.

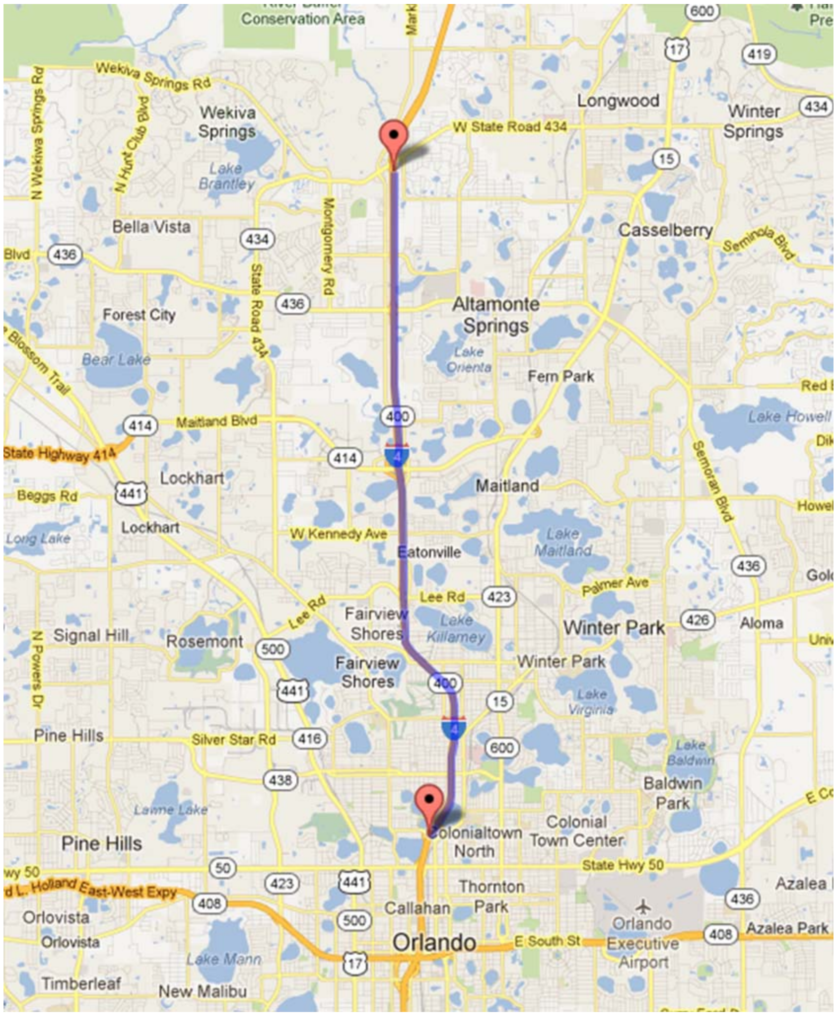


Figure 2-1 Selected I-4 Corridor

2.2 Captured Data

In order to perform the tasks of this project, traffic detector and incident data need to be collected and fused for the I-4 segment selected as the study corridor. In this project, these two types of data are captured and integrated using the ITSDCAP tool. The following section is a brief description of the two types of captured data.

2.2.1 Traffic Detector Data

The traffic detector data collected between January 1, 2011 and February 29, 2012 were retrieved from the Statewide Transportation Engineering Warehouse for Archived Regional Data (STEWARD). The STEWARD data warehouse was developed as a proof of concept prototype for the collection and use of ITS data in Florida (Courage and Lee, 2008 and 2009). It retrieved the 20-second raw traffic sensor system (TSS) measurements of speed, volume count and occupancy from district traffic management centers, and archived the data at the of 5-, 15-, and 60-minute aggregation levels. Figure 2-2 illustrates the locations of traffic detectors along the study corridor, and Figure 2-3 presents an example of STEWARD data. Volume, speed, and occupancy data were downloaded from STEWARD at the 5-minute aggregation level and used for the purpose of this study.

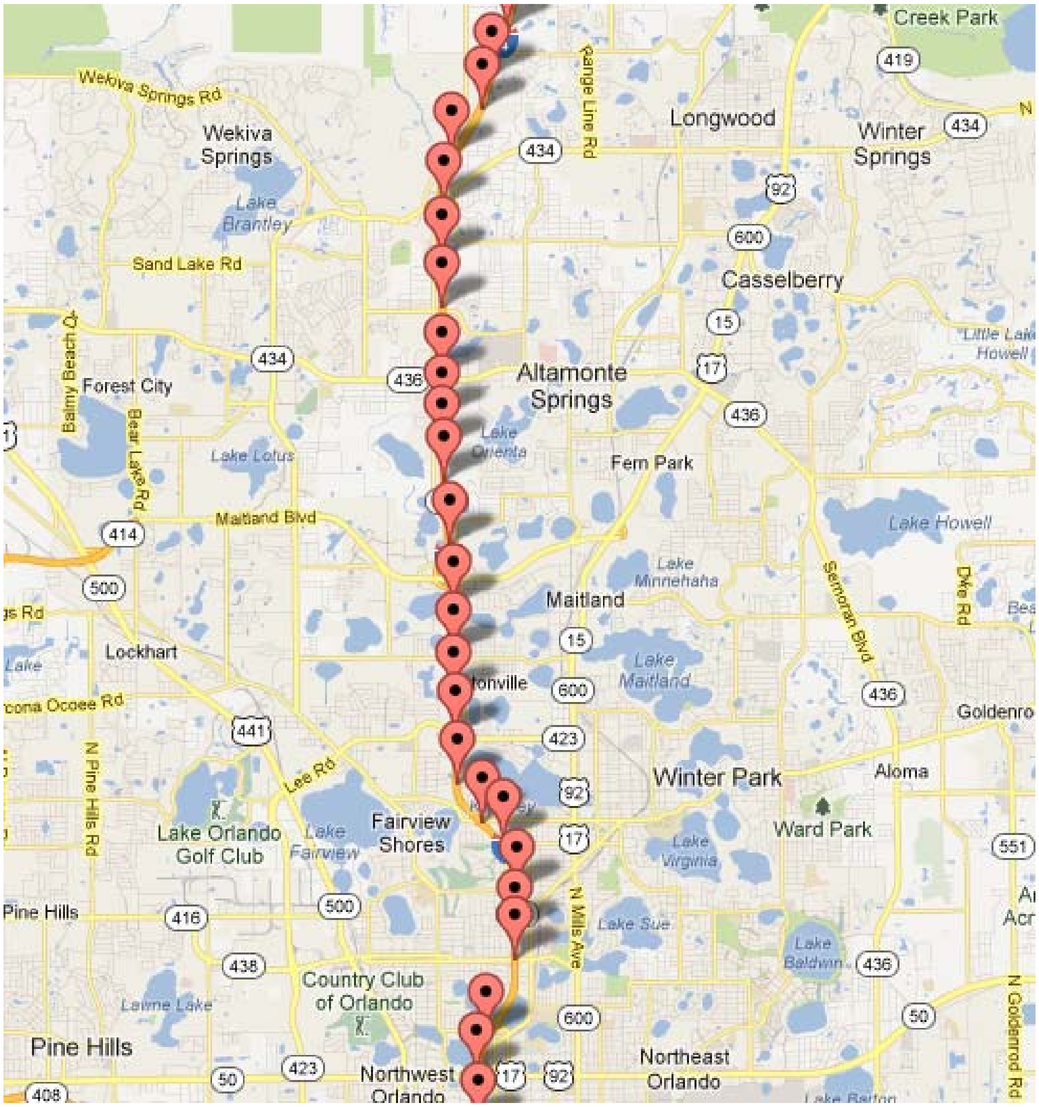
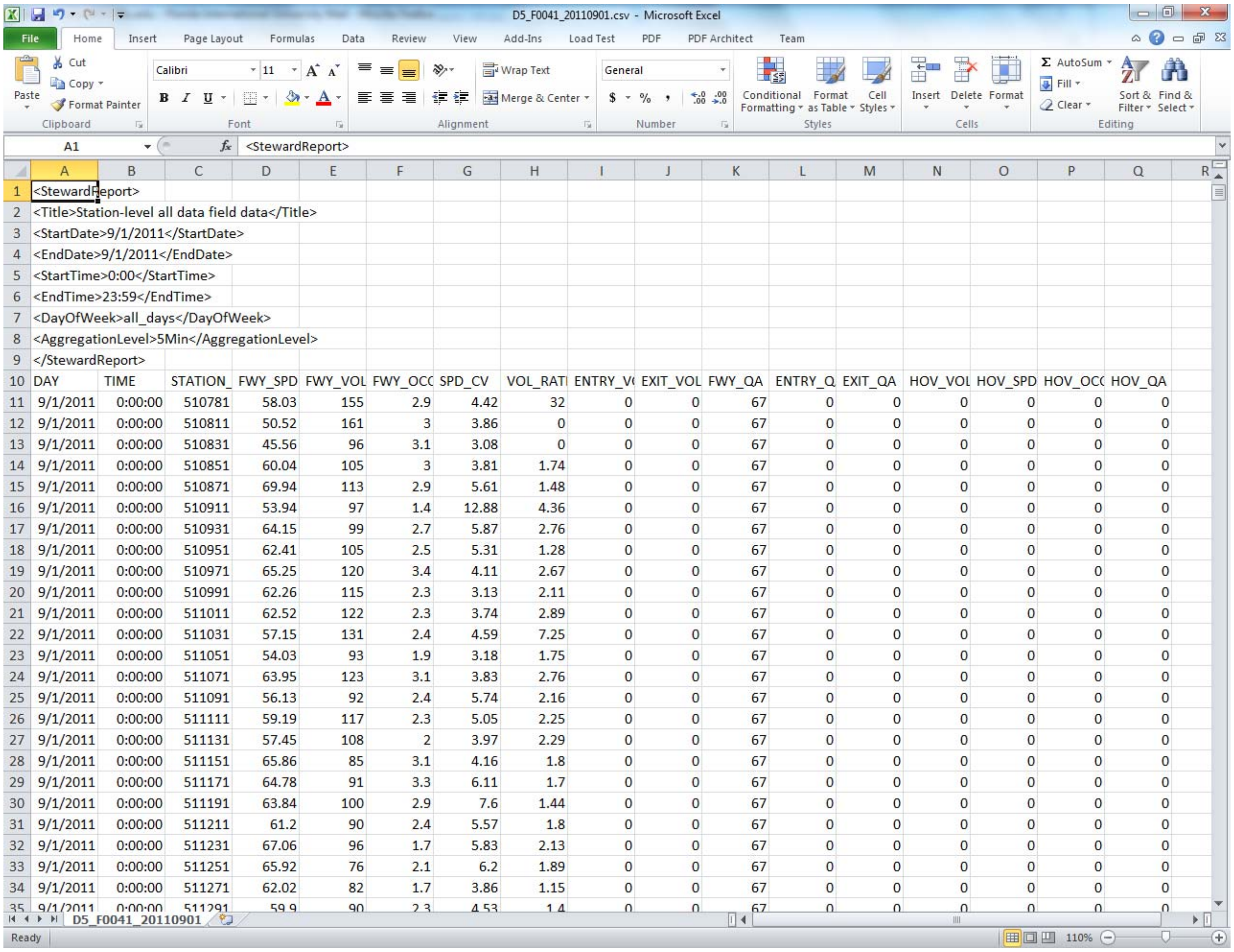


Figure 2-2 Traffic Detector Locations



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
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2	<Title>Station-level all data field data</Title>																
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4	<EndDate>9/1/2011</EndDate>																
5	<StartTime>0:00</StartTime>																
6	<EndTime>23:59</EndTime>																
7	<DayOfWeek>all_days</DayOfWeek>																
8	<AggregationLevel>5Min</AggregationLevel>																
9	</StewardReport>																
10	DAY	TIME	STATION_	FWY_SPD	FWY_VOL	FWY_OCC	SPD_CV	VOL_RATI	ENTRY_V	EXIT_VOL	FWY_QA	ENTRY_Q	EXIT_QA	HOV_VOL	HOV_SPD	HOV_OCC	HOV_QA
11	9/1/2011	0:00:00	510781	58.03	155	2.9	4.42	32	0	0	67	0	0	0	0	0	0
12	9/1/2011	0:00:00	510811	50.52	161	3	3.86	0	0	0	67	0	0	0	0	0	0
13	9/1/2011	0:00:00	510831	45.56	96	3.1	3.08	0	0	0	67	0	0	0	0	0	0
14	9/1/2011	0:00:00	510851	60.04	105	3	3.81	1.74	0	0	67	0	0	0	0	0	0
15	9/1/2011	0:00:00	510871	69.94	113	2.9	5.61	1.48	0	0	67	0	0	0	0	0	0
16	9/1/2011	0:00:00	510911	53.94	97	1.4	12.88	4.36	0	0	67	0	0	0	0	0	0
17	9/1/2011	0:00:00	510931	64.15	99	2.7	5.87	2.76	0	0	67	0	0	0	0	0	0
18	9/1/2011	0:00:00	510951	62.41	105	2.5	5.31	1.28	0	0	67	0	0	0	0	0	0
19	9/1/2011	0:00:00	510971	65.25	120	3.4	4.11	2.67	0	0	67	0	0	0	0	0	0
20	9/1/2011	0:00:00	510991	62.26	115	2.3	3.13	2.11	0	0	67	0	0	0	0	0	0
21	9/1/2011	0:00:00	511011	62.52	122	2.3	3.74	2.89	0	0	67	0	0	0	0	0	0
22	9/1/2011	0:00:00	511031	57.15	131	2.4	4.59	7.25	0	0	67	0	0	0	0	0	0
23	9/1/2011	0:00:00	511051	54.03	93	1.9	3.18	1.75	0	0	67	0	0	0	0	0	0
24	9/1/2011	0:00:00	511071	63.95	123	3.1	3.83	2.76	0	0	67	0	0	0	0	0	0
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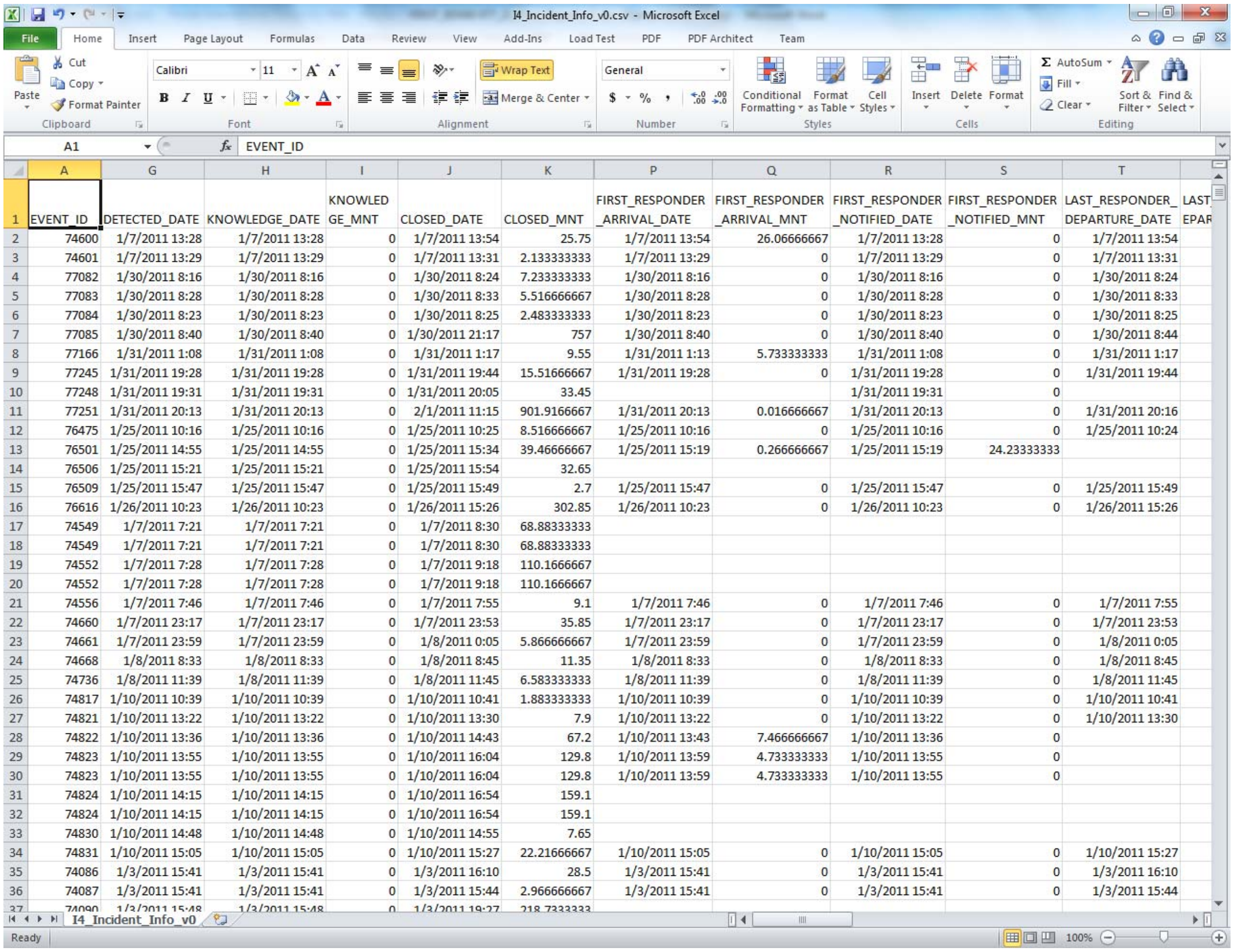
27	9/1/2011	0:00:00	511131	57.45	108	2	3.97	2.29	0	0	67	0	0	0	0	0	0
28	9/1/2011	0:00:00	511151	65.86	85	3.1	4.16	1.8	0	0	67	0	0	0	0	0	0
29	9/1/2011	0:00:00	511171	64.78	91	3.3	6.11	1.7	0	0	67	0	0	0	0	0	0
30	9/1/2011	0:00:00	511191	63.84	100	2.9	7.6	1.44	0	0	67	0	0	0	0	0	0
31	9/1/2011	0:00:00	511211	61.2	90	2.4	5.57	1.8	0	0	67	0	0	0	0	0	0
32	9/1/2011	0:00:00	511231	67.06	96	1.7	5.83	2.13	0	0	67	0	0	0	0	0	0
33	9/1/2011	0:00:00	511251	65.92	76	2.1	6.2	1.89	0	0	67	0	0	0	0	0	0
34	9/1/2011	0:00:00	511271	62.02	82	1.7	3.86	1.15	0	0	67	0	0	0	0	0	0
35	9/1/2011	0:00:00	511291	59.9	90	2.3	4.53	1.4	0	0	67	0	0	0	0	0	0

Figure 2-3 Example of STEWARD Data

2.2.2 Incident Data

Incident data for the study corridor were obtained from the FDOT District 5 SunGuide Event Database. For each SunGuide incident record, the stored information includes incident timestamps (detection, notification, arrivals, and departures), incident ID, responding agencies, event details, chronicles of the event, and environmental information. The detection timestamp is the time when an incident is reported to the TMC and inputted in the SunGuide system. The notification timestamps are recorded per responding agency and refer to the time when such responding agencies are notified. The arrival and departure timestamps are also recorded per responding agency and refer to the time when such agencies arrive and depart from the incident site. Figure 2-4 presents an example of extracted incident information.



	A	G	H	I	J	K	P	Q	R	S	T	
1	EVENT_ID	DETECTED_DATE	KNOWLEDGE_DATE	KNOWLEDGE_MNT	CLOSED_DATE	CLOSED_MNT	FIRST_RESPONDER_ARRIVAL_DATE	FIRST_RESPONDER_ARRIVAL_MNT	FIRST_RESPONDER_NOTIFIED_DATE	FIRST_RESPONDER_NOTIFIED_MNT	LAST_RESPONDER_DEPARTURE_DATE	LAST EPAR
2	74600	1/7/2011 13:28	1/7/2011 13:28	0	1/7/2011 13:54	25.75	1/7/2011 13:54	26.06666667	1/7/2011 13:28	0	1/7/2011 13:54	
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5	77083	1/30/2011 8:28	1/30/2011 8:28	0	1/30/2011 8:33	5.516666667	1/30/2011 8:28	0	1/30/2011 8:28	0	1/30/2011 8:33	
6	77084	1/30/2011 8:23	1/30/2011 8:23	0	1/30/2011 8:25	2.483333333	1/30/2011 8:23	0	1/30/2011 8:23	0	1/30/2011 8:25	
7	77085	1/30/2011 8:40	1/30/2011 8:40	0	1/30/2011 21:17	757	1/30/2011 8:40	0	1/30/2011 8:40	0	1/30/2011 8:44	
8	77166	1/31/2011 1:08	1/31/2011 1:08	0	1/31/2011 1:17	9.55	1/31/2011 1:13	5.733333333	1/31/2011 1:08	0	1/31/2011 1:17	
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29	74823	1/10/2011 13:55	1/10/2011 13:55	0	1/10/2011 16:04	129.8	1/10/2011 13:59	4.733333333	1/10/2011 13:55	0		
30	74823	1/10/2011 13:55	1/10/2011 13:55	0	1/10/2011 16:04	129.8	1/10/2011 13:59	4.733333333	1/10/2011 13:55	0		
31	74824	1/10/2011 14:15	1/10/2011 14:15	0	1/10/2011 16:54	159.1						
32	74824	1/10/2011 14:15	1/10/2011 14:15	0	1/10/2011 16:54	159.1						
33	74830	1/10/2011 14:48	1/10/2011 14:48	0	1/10/2011 14:55	7.65						
34	74831	1/10/2011 15:05	1/10/2011 15:05	0	1/10/2011 15:27	22.21666667	1/10/2011 15:05	0	1/10/2011 15:05	0	1/10/2011 15:27	
35	74086	1/3/2011 15:41	1/3/2011 15:41	0	1/3/2011 16:10	28.5	1/3/2011 15:41	0	1/3/2011 15:41	0	1/3/2011 16:10	
36	74087	1/3/2011 15:41	1/3/2011 15:41	0	1/3/2011 15:44	2.966666667	1/3/2011 15:41	0	1/3/2011 15:41	0	1/3/2011 15:44	
37	74090	1/3/2011 15:48	1/3/2011 15:48	0	1/3/2011 19:27	218.7333333						

Figure 2-4 Example of Incident Information

2.3 References

Courage, K.G. and S. Lee. Development of a Central Data Warehouse for Statewide ITS and Transportation Data in Florida: Phase II Proof of Concept. A Report Developed for the Florida Department of Transportation by the University of Florida, Tallahassee, FL, 2008.

Courage, K.G. and S. Lee. Development of a Central Data Warehouse for Statewide ITS and Transportation Data in Florida: Phase III Final Report. A Report Developed for the Florida Department of Transportation by the University of Florida, Tallahassee, FL, 2009.

3 Traffic Pattern Identification and Performance Measurements

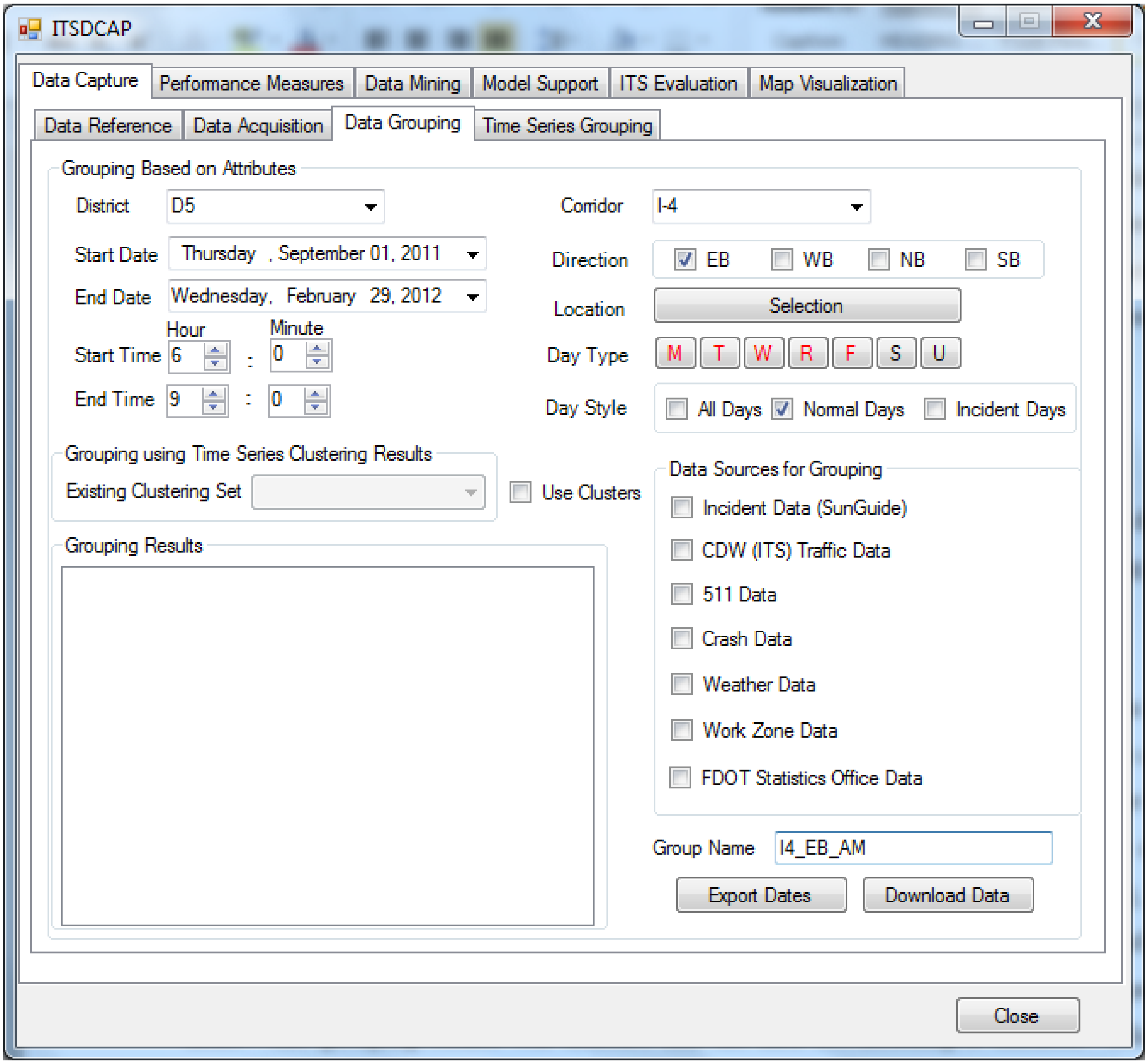
Identifying traffic patterns and estimating the corresponding performance measures are critical to identifying bottleneck locations and monitoring transportation system performances to determine the need for improvements, including capacity additions or implementing advanced strategies, such as ramp metering and managed lanes. For this purpose, ITSDCAP is applied in order to identify the recurrent bottleneck locations and the performance measures along the I-4 study segment.

This section first provides a brief review of traffic pattern identification procedures and performance measure estimation methods used in the ITDSCAP tool, and then presents the case study results.

3.1 Traffic Pattern Identification

Two types of data grouping methods have been used by the research team to identify traffic patterns. The first data grouping method differentiates traffic patterns based on user-specified criteria. The criteria can be a combination of parameters such as user-specified data sources for grouping, time period, roadway segment, day of week, and day type (incident-free or incident days). The second data grouping method classifies user-specified days into different groups according to their similarities utilizing a statistical method referred to as the k-means clustering analysis. This is an iterative partitioning algorithm that attempts to minimize the sum of squared distances between all points and cluster centroid while maximizing the distance between clusters. These two methods can be applied separately or in combination. The details of these two methods can be found in Hadi et al. (2012).

The two data grouping methods mentioned above have been integrated into the ITSDCAP tool. Figure 3-1 presents the original desktop ITSDCAP interface for the criteria-based data grouping, and Figure 3-2 presents the interface for clustering analysis-based data grouping. In this demonstration project, the ITSDCAP tool was used to allow the traffic pattern analysis for the I-4 corridor in FDOT District 5.



District D5

Start Date Thursday , September 01, 2011

End Date Wednesday, February 29, 2012

Start Time 6 : 0 (Hour : Minute)

End Time 9 : 0

Corridor I-4

Direction ☑ EB ☐ WB ☐ NB ☐ SB

Day Type M T W R F S U

Day Style ☐ All Days ☑ Normal Days ☐ Incident Days

Existing Clustering Set

☐ Use Clusters

☐ Incident Data (SunGuide)

☐ CDW (ITS) Traffic Data

☐ 511 Data

☐ Crash Data

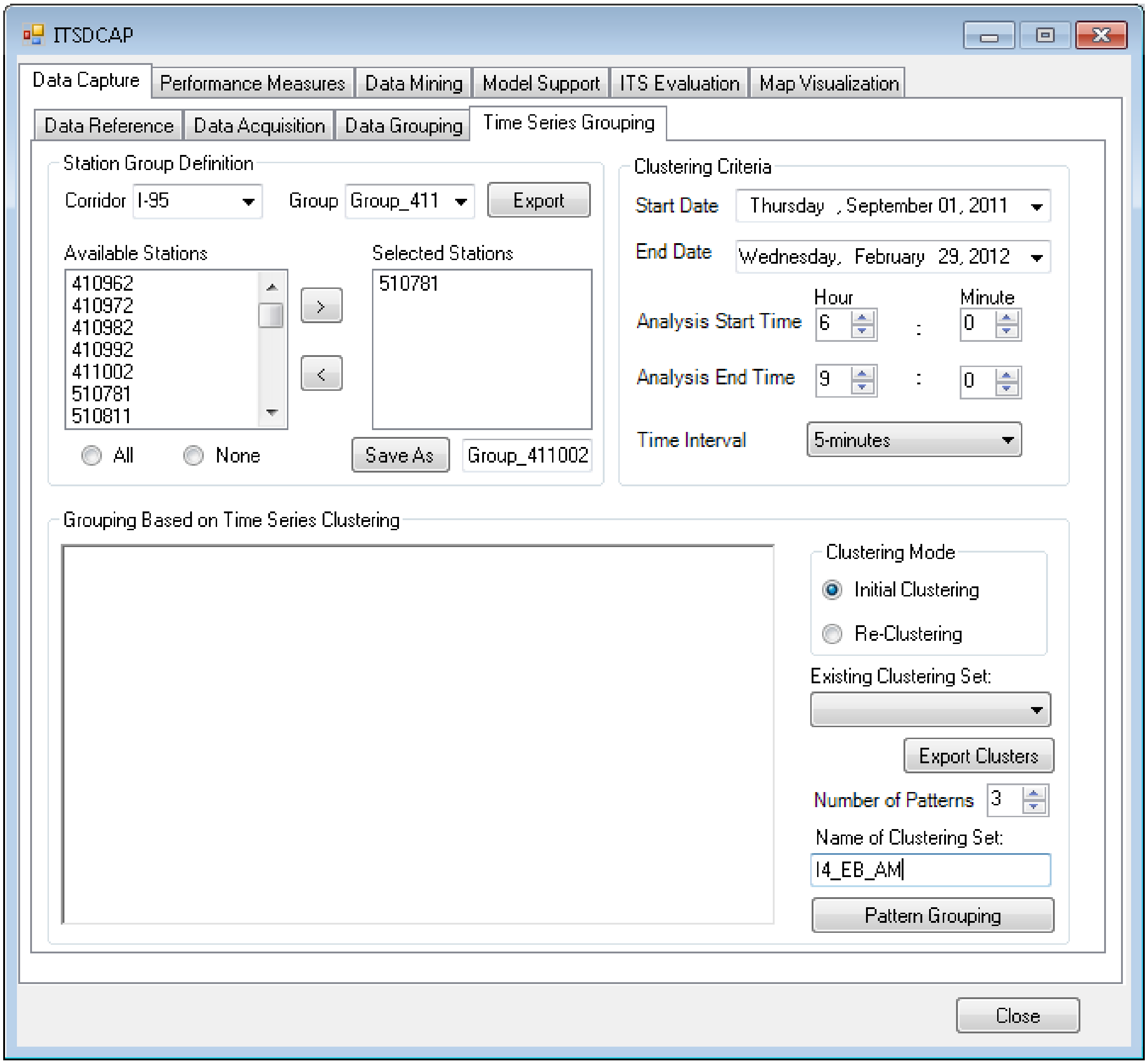
☐ Weather Data

☐ Work Zone Data

☐ FDOT Statistics Office Data

Group Name I4_EB_AM

Figure 3-1 ITSDCAP Interface for Criteria-Based Data Grouping



Corridor: I-95
Group: Group_411

Available Stations:
410962
410972
410982
410992
411002
510781
510811

Selected Stations:
510781

○ All ○ None

Save As: Group_411002

Start Date: Thursday , September 01, 2011
End Date: Wednesday, February 29, 2012
Analysis Start Time: Hour 6 : Minute 0
Analysis End Time: 9 : 0
Time Interval: 5-minutes

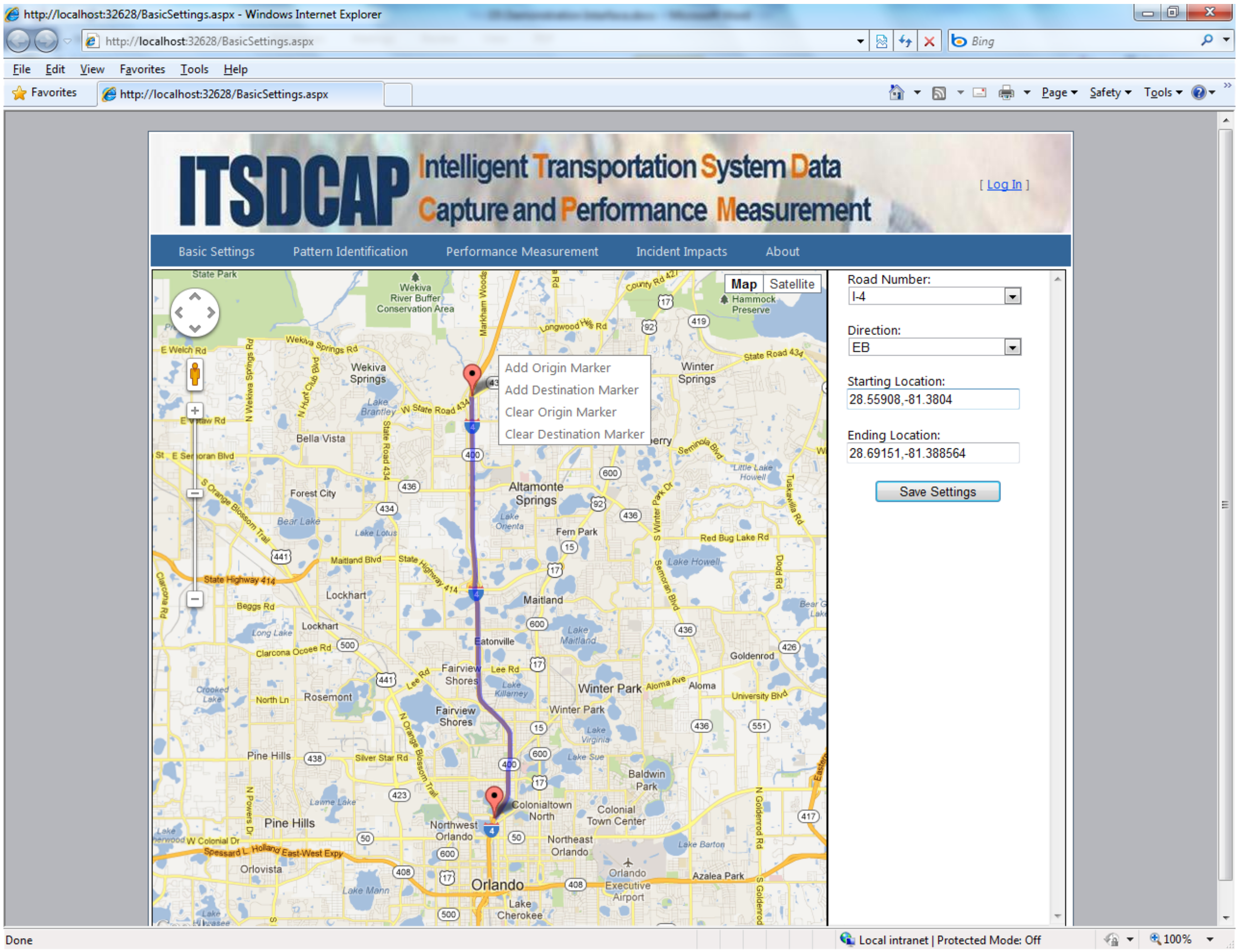
Clustering Mode:
● Initial Clustering
○ Re-Clustering

Existing Clustering Set:

Number of Patterns: 3
Name of Clustering Set: I4_EB_AM

Figure 3-2 ITSDCAP Interface for Clustering Analysis-Based Data Grouping

Note that the original ITSDCAP tool is a desktop application. It requires installation when it is used in different computers. To overcome such shortcomings, a Web-based version of ITSDCAP was developed in this demonstration project. The Web-based version currently only includes the traffic pattern identification and incident impact analysis functions that are required by this project. Figure 3-3 shows the location selection page of this Web-based ITSDCAP tool. In this webpage, the users can select their study corridor and direction. They can also specify the start and end locations by either clicking on the map or inputting the latitude and longitude values in the textboxes.



Road Number: I-4

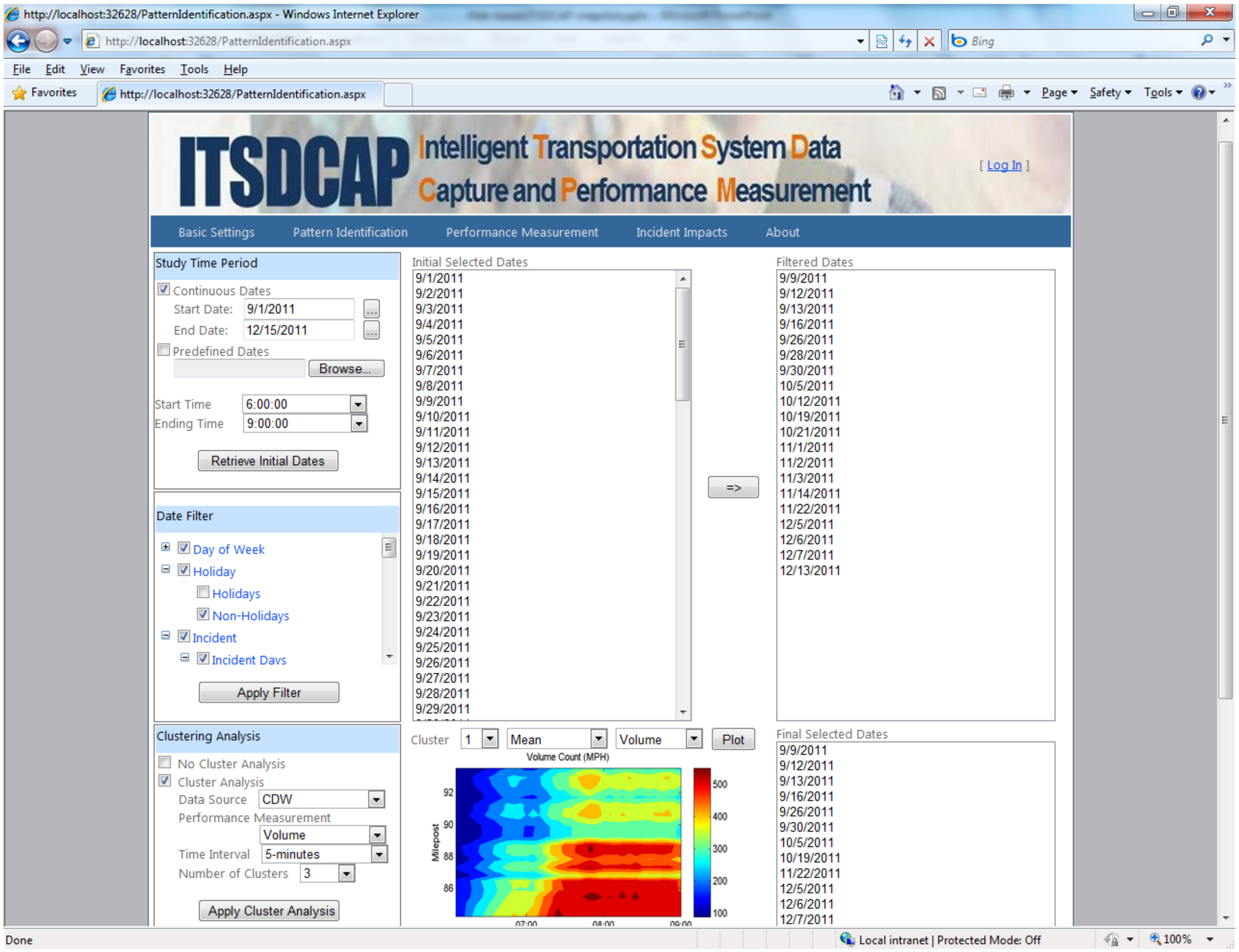
Direction: EB

Starting Location: 28.55908,-81.3804

Ending Location: 28.69151,-81.388564

Figure 3-3 Location Selection Page in Web-based ITSDCAP Tool

Figure 3-4 illustrates the pattern identification interface in the Web-based ITSDCAP tool. As shown in this figure, the user can either specify a continuous study period or upload a text file with predefined continuous or discrete dates. The next optional step is to filter the dates based on certain criteria, for example, day of week, holiday or non-holiday, incident type, lane blockage, and so on. This part is equivalent to the criteria-based data grouping method in the original ITSDCAP tool, as described above. For the filtered dates, the user has an option to further conduct a k-means clustering analysis. The analysis can be based on time series of volume counts, speed, or occupancy. The resulting performance measures of each cluster (speed, volume, and occupancy) can be visualized through the contour plot, as shown in Figure 3-4. These cluster performance measures, in terms of mean, minimum, maximum, median, 95th, 90th, 80th, 20th, 10th, and 5th percentiles, can also be compared to those measures on individual days, as illustrated in Figures 3-5 and 3-6. The final selected dates can be downloaded by clicking the “Download” button.



Study Time Period

☑ Continuous Dates
Start Date: 9/1/2011
End Date: 12/15/2011
☐ Predefined Dates
Start Time 6:00:00
Ending Time 9:00:00

Date Filter

☑ Day of Week
☑ Holiday
  ☐ Holidays
  ☑ Non-Holidays
☑ Incident
  ☑ Incident Davs

Clustering Analysis

☐ No Cluster Analysis
☑ Cluster Analysis
Data Source CDW
Performance Measurement Volume
Time Interval 5-minutes
Number of Clusters 3

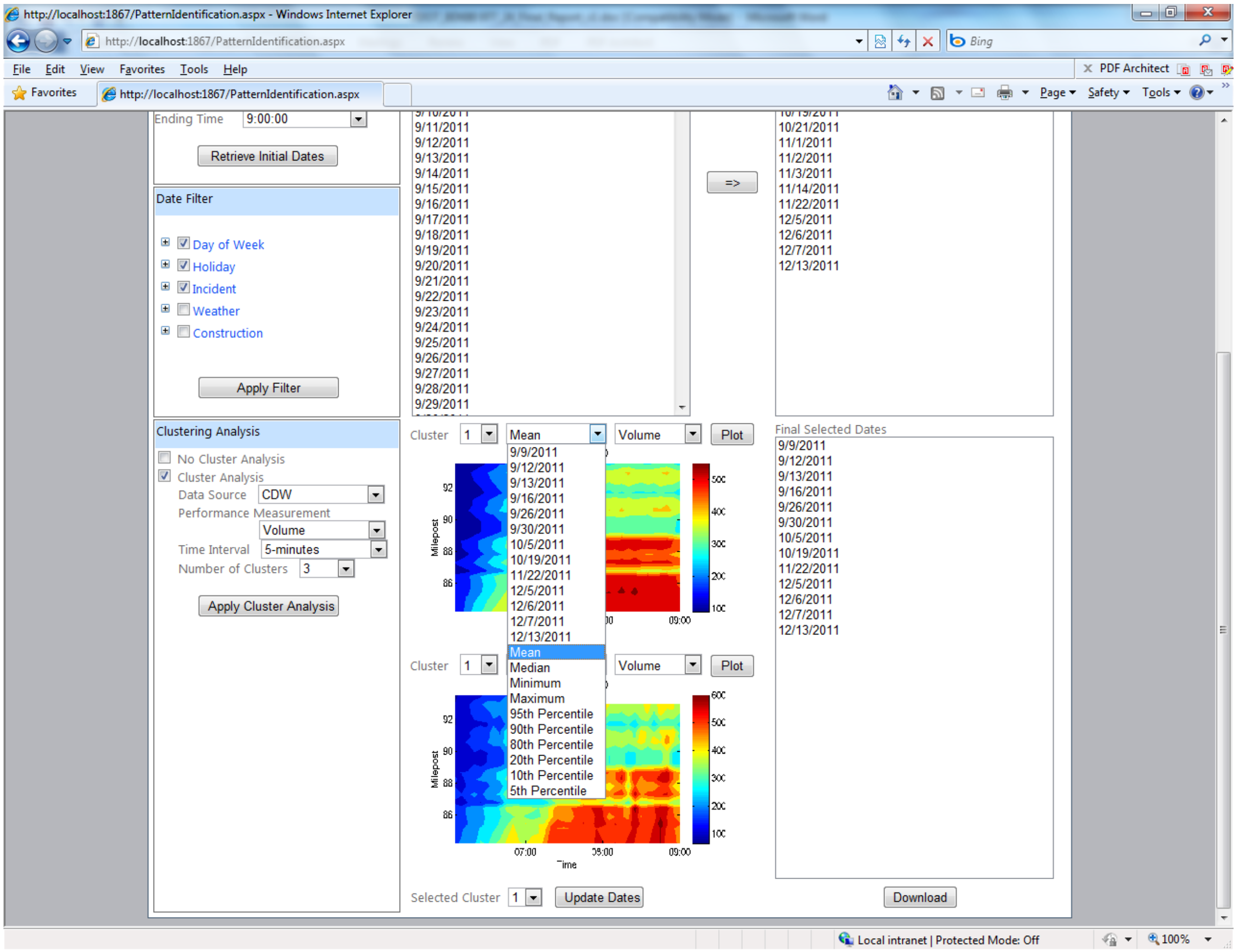
Initial Selected Dates
9/1/2011
9/2/2011
9/3/2011
9/4/2011
9/5/2011
9/6/2011
9/7/2011
9/8/2011
9/9/2011
9/10/2011
9/11/2011
9/12/2011
9/13/2011
9/14/2011
9/15/2011
9/16/2011
9/17/2011
9/18/2011
9/19/2011
9/20/2011
9/21/2011
9/22/2011
9/23/2011
9/24/2011
9/25/2011
9/26/2011
9/27/2011
9/28/2011
9/29/2011

Filtered Dates
9/9/2011
9/12/2011
9/13/2011
9/16/2011
9/26/2011
9/28/2011
9/30/2011
10/5/2011
10/12/2011
10/19/2011
10/21/2011
11/1/2011
11/2/2011
11/3/2011
11/14/2011
11/22/2011
12/5/2011
12/6/2011
12/7/2011
12/13/2011

Cluster 1 Mean Volume

Final Selected Dates
9/9/2011
9/12/2011
9/13/2011
9/16/2011
9/26/2011
9/30/2011
10/5/2011
10/19/2011
11/22/2011
12/5/2011
12/6/2011
12/7/2011

Figure 3-4 Pattern Identification Page in Web-based ITSDCAP Tool



Ending Time 9:00:00

Date Filter

- ☑ Day of Week
- ☑ Holiday
- ☑ Incident
- ☐ Weather
- ☐ Construction

Clustering Analysis

- ☐ No Cluster Analysis
- ☑ Cluster Analysis

Data Source: CDW
Performance Measurement: Volume
Time Interval: 5-minutes
Number of Clusters: 3

9/11/2011
9/12/2011
9/13/2011
9/14/2011
9/15/2011
9/16/2011
9/17/2011
9/18/2011
9/19/2011
9/20/2011
9/21/2011
9/22/2011
9/23/2011
9/24/2011
9/25/2011
9/26/2011
9/27/2011
9/28/2011
9/29/2011

10/21/2011
11/1/2011
11/2/2011
11/3/2011
11/14/2011
11/22/2011
12/5/2011
12/6/2011
12/7/2011
12/13/2011

Cluster 1 | Mean | Volume

9/9/2011
9/12/2011
9/13/2011
9/16/2011
9/26/2011
9/30/2011
10/5/2011
10/19/2011
11/22/2011
12/5/2011
12/6/2011
12/7/2011
12/13/2011

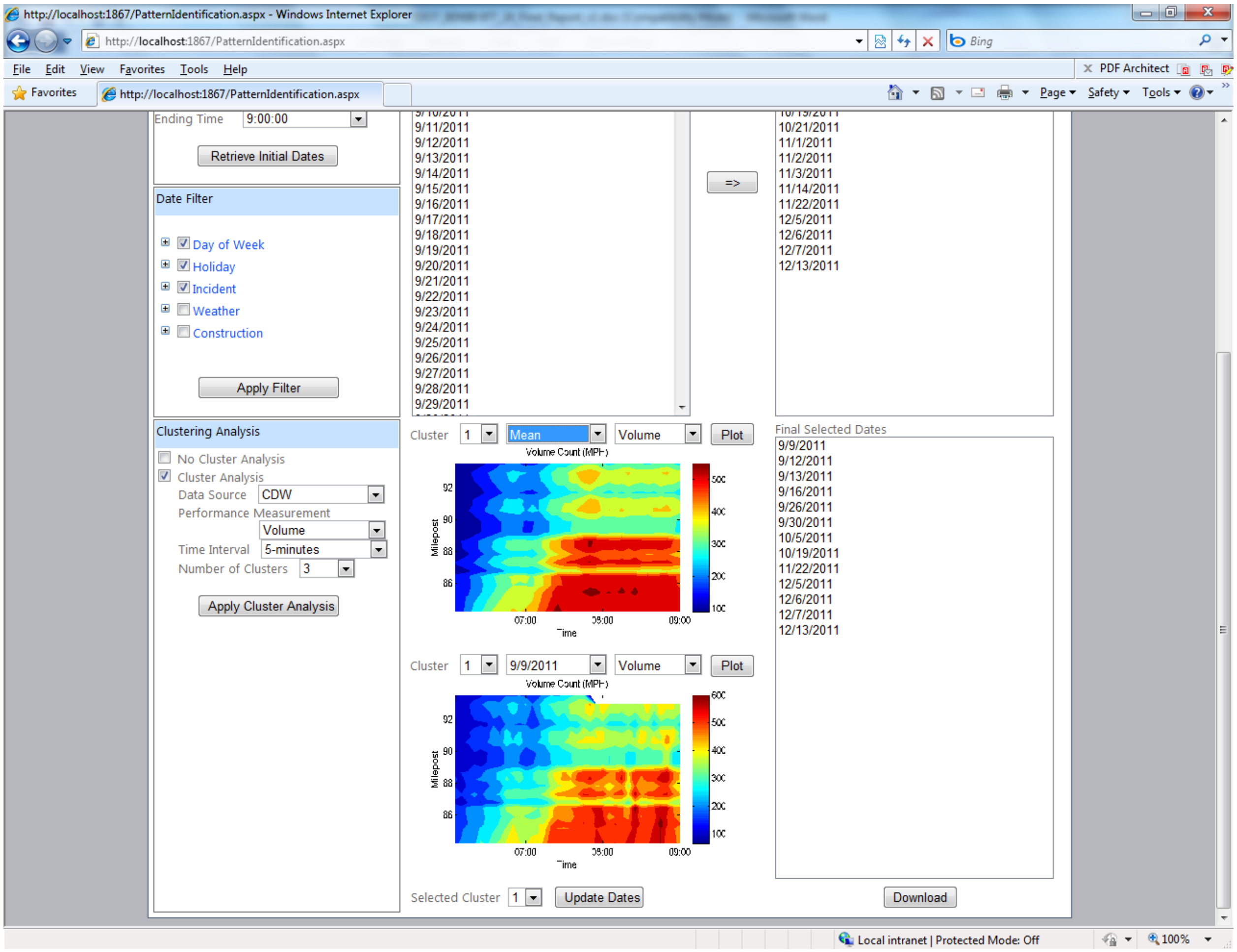
Mean
Median
Minimum
Maximum
95th Percentile
90th Percentile
80th Percentile
20th Percentile
10th Percentile
5th Percentile

Cluster 1 | Volume

Final Selected Dates
9/9/2011
9/12/2011
9/13/2011
9/16/2011
9/26/2011
9/30/2011
10/5/2011
10/19/2011
11/22/2011
12/5/2011
12/6/2011
12/7/2011
12/13/2011

Selected Cluster 1

Figure 3-5 Cluster Performance Measure Selection in Web-based ITSDCAP Tool



Ending Time 9:00:00

- ☑ Day of Week
- ☑ Holiday
- ☑ Incident
- ☐ Weather
- ☐ Construction

☐ No Cluster Analysis
☑ Cluster Analysis
Data Source: CDW
Performance Measurement: Volume
Time Interval: 5-minutes
Number of Clusters: 3

9/11/2011
9/12/2011
9/13/2011
9/14/2011
9/15/2011
9/16/2011
9/17/2011
9/18/2011
9/19/2011
9/20/2011
9/21/2011
9/22/2011
9/23/2011
9/24/2011
9/25/2011
9/26/2011
9/27/2011
9/28/2011
9/29/2011

10/21/2011
11/1/2011
11/2/2011
11/3/2011
11/14/2011
11/22/2011
12/5/2011
12/6/2011
12/7/2011
12/13/2011

Cluster 1 Mean Volume

Cluster 1 9/9/2011 Volume

Selected Cluster 1

Final Selected Dates
9/9/2011
9/12/2011
9/13/2011
9/16/2011
9/26/2011
9/30/2011
10/5/2011
10/19/2011
11/22/2011
12/5/2011
12/6/2011
12/7/2011
12/13/2011

Figure 3-6 Clustering Analysis Results Visualization

3.2 Performance Measure Estimation

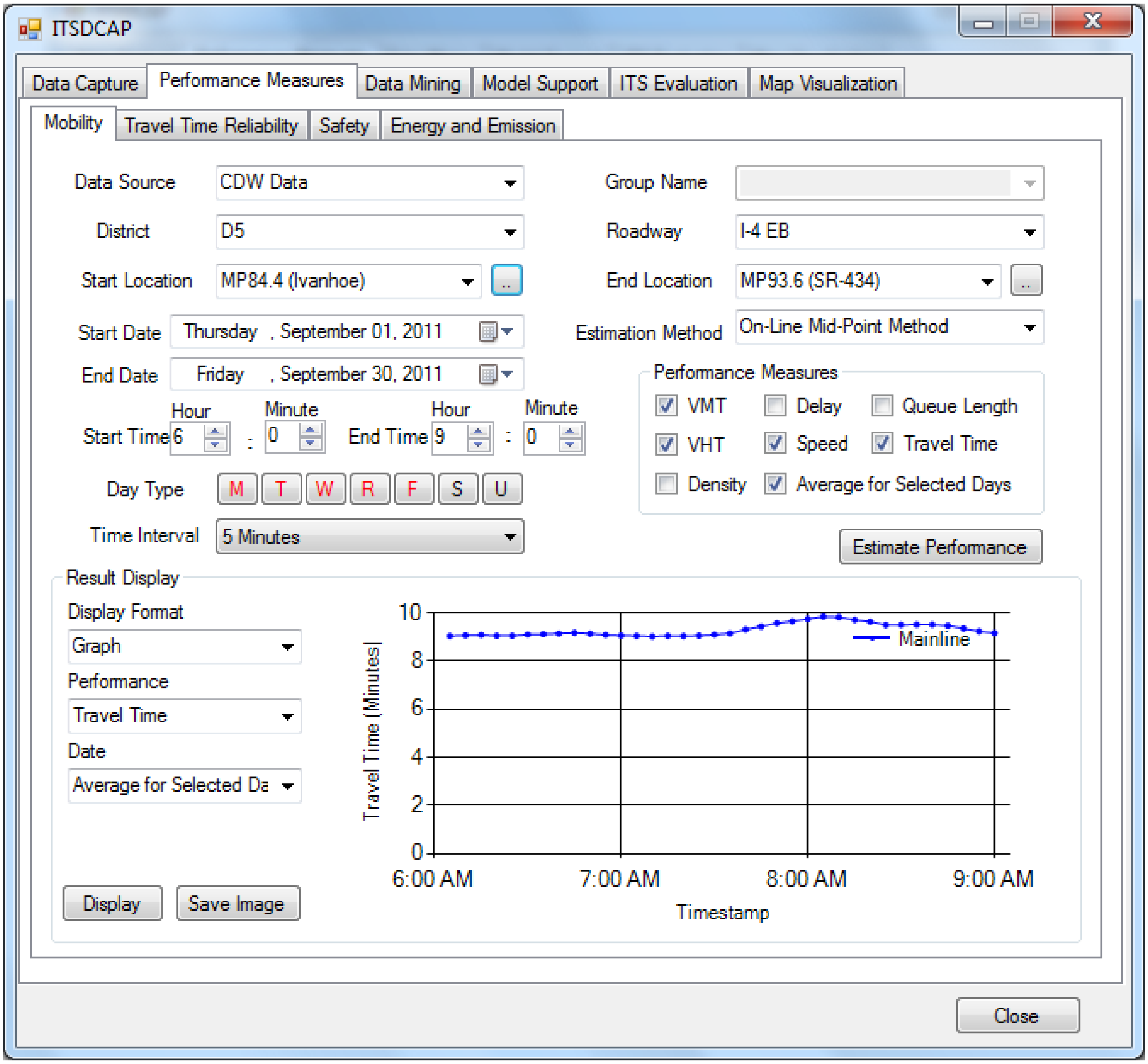
In addition to the speed, volume, and occupancy measures mentioned above, other performance measures can also be estimated for identified groups of days through the ITSDCAP tool.

3.2.1 Mobility

Figures 3-7 presents the user interface in the desktop version of ITSDCAP for mobility performance measure calculations. It is seen in this figure that mobility measures can be estimated for user-specified time period and locations. The time period can be a continuous period of time or discrete days that meet specific criteria, such as normal days or days with incidents or specific patterns based on clustering results. The selection of the segment for mobility measure estimation can be accomplished through the use of GIS maps by clicking the buttons next to the start and end location textboxes, as shown in Figure 3-8. Figure 3-7 displays the seven mobility measures that can be estimated, as listed below:

- Speed
- Density
- Queue length/location
- Travel Time
- Delay
- Vehicle-Mile Traveled (VMT)
- Vehicle-Hour Traveled (VHT).

For the details of the estimation method for each of these mobility measures, readers are referred to Hadi et al. (2012). The estimation results can be visualized in either a table or graph format. A chart plot is provided for most of the measures. A contour plot is also provided for speed and density visualization to show the variations in space and time.



Data Source: CDW Data

District: D5

Start Location: MP84.4 (Ivanhoe)

Start Date: Thursday , September 01, 2011

End Date: Friday , September 30, 2011

Start Time: Hour 6 : Minute 0

End Time: Hour 9 : Minute 0

Day Type: M T W R F S U

Time Interval: 5 Minutes

Group Name:

Roadway: I-4 EB

End Location: MP93.6 (SR-434)

Estimation Method: On-Line Mid-Point Method

Performance Measures

☑ VMT ☐ Delay ☐ Queue Length

☑ VHT ☑ Speed ☑ Travel Time

☐ Density ☑ Average for Selected Days

Result Display

Display Format: Graph

Performance: Travel Time

Date: Average for Selected Da

Figure 3-7 Mobility Performance Measure Calculation Interface in ITSDCAP

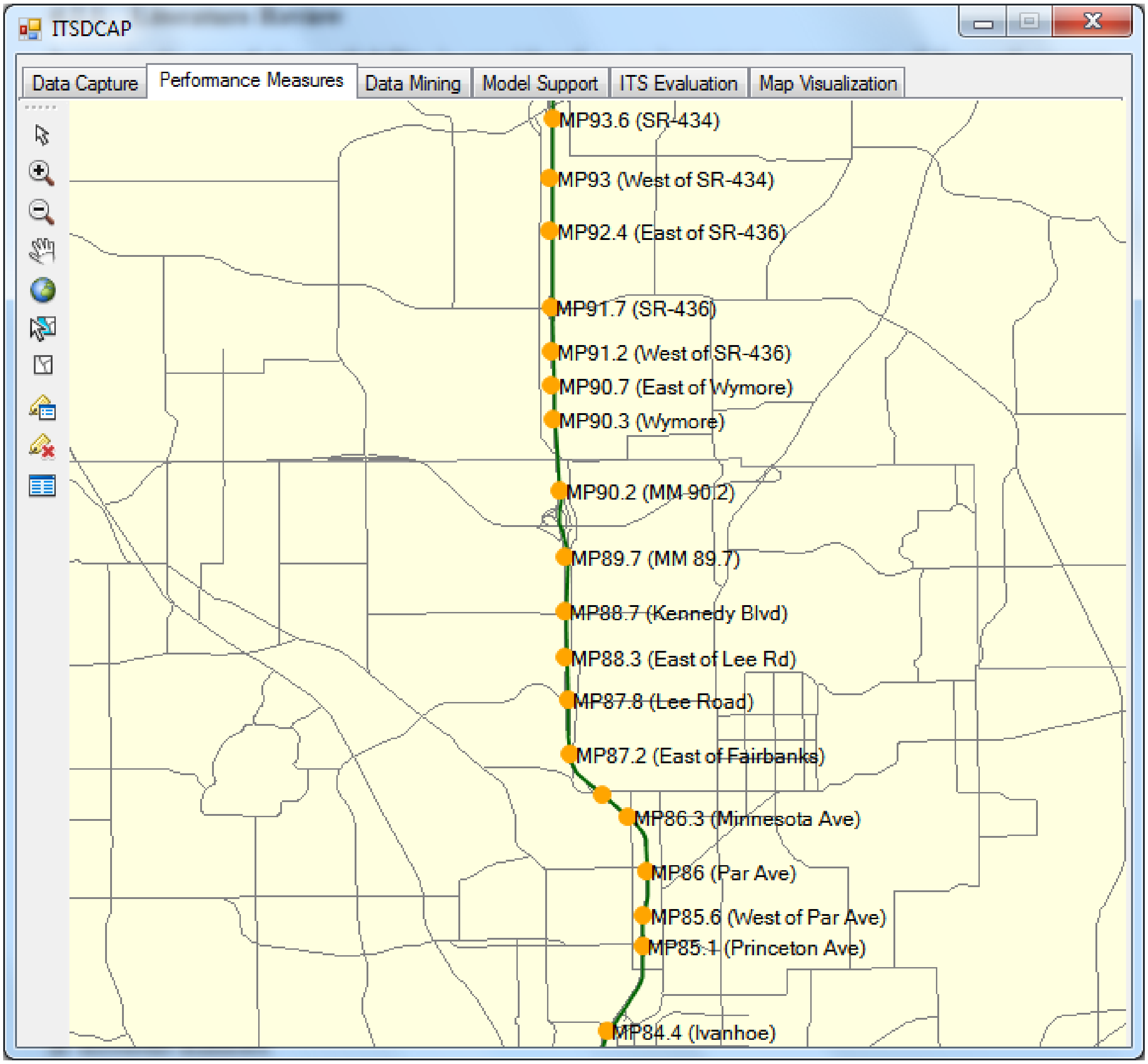


Figure 3-8 Study Corridor Selection Interface in ITSDCAP

3.2.2 Travel Time Reliability

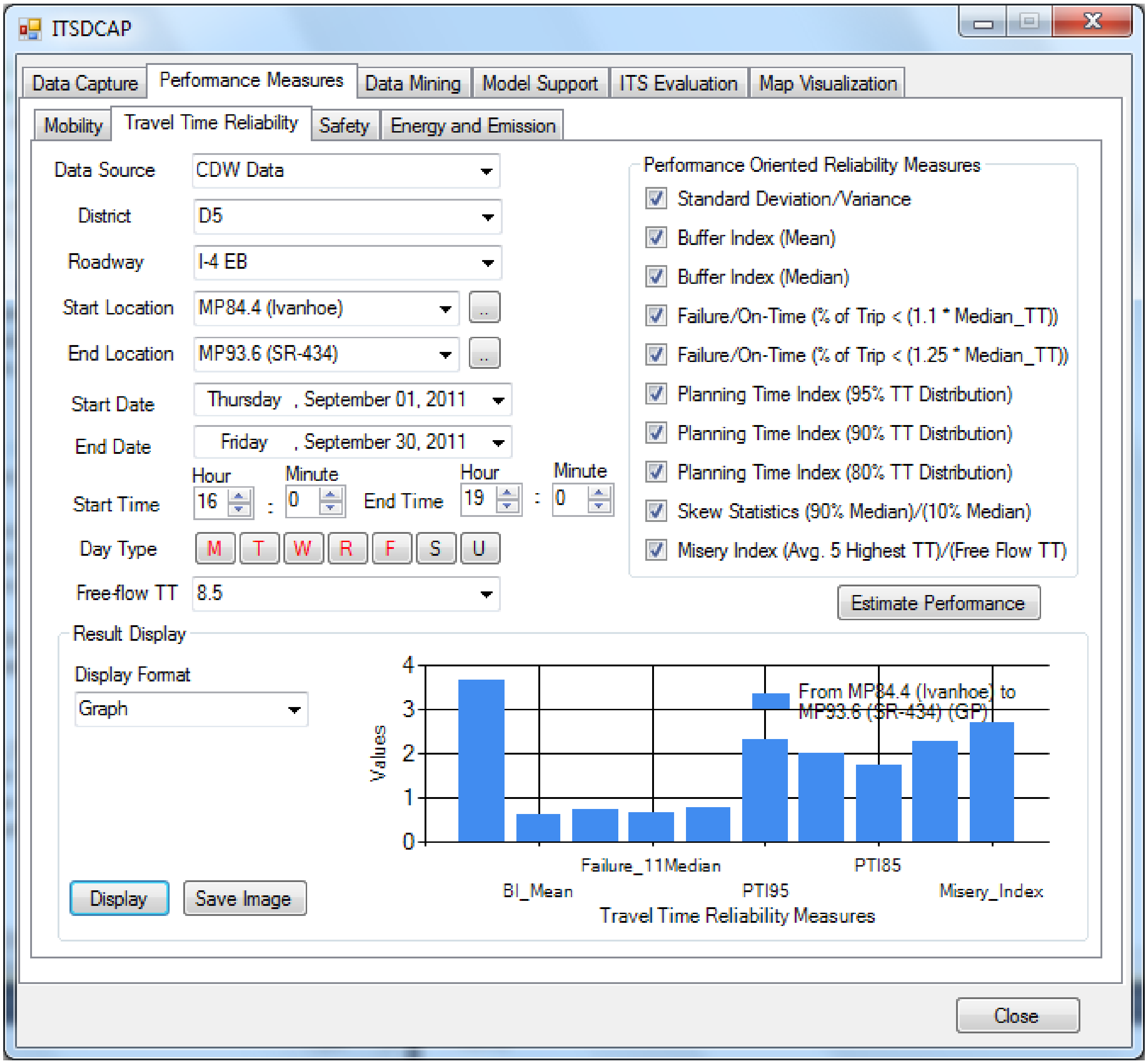
Figure 3-9 presents a snapshot of the user interface for travel time reliability measures in the ITSDCAP tool. As in the case of the mobility measure interface, this travel time reliability measure interface allows users to specify their study time period, roadway segment, and day of week. The following travel time reliability metrics can be calculated using the ITSDCAP tool:

- Standard deviation/variance
- Buffer index based on mean or median free-flow travel time
- Failure/on-time performance based on the threshold of 1.1 or 1.25 times the median travel time
- Planning time index based on 95th, 90th, or 80th percentile
- Skew statistics
- Misery index

Table 3-1 provides the definition of each of the aforementioned travel time reliability measures. The user can request the reliability measure estimation by clicking the button "Estimate Performance." When the analysis is finished, the results in tabular or graphical formats can be displayed in the "Result Display" panel.

Table 3-1 Definitions of Travel Time Reliability Measures

Reliability Performance Metric	**Definition**
Buffer Index (BI)	The difference between the 95th percentile travel time and the average travel time, normalized by the average travel time.
Failure/On-Time Performance	Percent of trips with travel times less than: • 1.1* median travel time • 1.25* median travel time
95th Percentile Travel Time Index	95th percentile of the travel time index distribution
90th Percentile Travel Time Index	95th percentile of the travel time index distribution
80th Percentile Travel Time Index	80th percentile of the travel time index distribution
Skew Statistics	The ratio of 90th percentile travel time minus the median travel time divided by the median travel time minus the 10th travel time percentile
Misery Index	The average of the highest five percent of travel times divided by the free-flow travel time.



Data Source: CDW Data
District: D5
Roadway: I-4 EB
Start Location: MP84.4 (Ivanhoe)
End Location: MP93.6 (SR-434)
Start Date: Thursday, September 01, 2011
End Date: Friday, September 30, 2011
Start Time: Hour 16 : Minute 0
End Time: Hour 19 : Minute 0
Day Type: M T W R F S U
Free-flow TT: 8.5
Display Format: Graph

Performance Oriented Reliability Measures
- ☑ Standard Deviation/Variance
- ☑ Buffer Index (Mean)
- ☑ Buffer Index (Median)
- ☑ Failure/On-Time (% of Trip < (1.1 * Median_TT))
- ☑ Failure/On-Time (% of Trip < (1.25 * Median_TT))
- ☑ Planning Time Index (95% TT Distribution)
- ☑ Planning Time Index (90% TT Distribution)
- ☑ Planning Time Index (80% TT Distribution)
- ☑ Skew Statistics (90% Median)/(10% Median)
- ☑ Misery Index (Avg. 5 Highest TT)/(Free Flow TT)

Figure 3-9 Reliability Performance Measure Calculation Interface in ITSDCAP

3.2.3 Traffic Safety

The frequency of crashes along the I-4 study corridor segment was also examined in this case study. Two sources of crash data were used: (1) crash data retrieved from the Crash Analysis Reporting (CAR) system dated between July 1, 2010 and December 31, 2010, and (2) crash data retrieved from the D5 SunGuide incident database dated between September 1, 2011 and February 29, 2012. The crash data was not available for time periods later than the one used in this study because of the time latency in making this data available in the CAR system. Because the data from the two different sources were collected for two different periods, a direct comparison is not possible.

In the SunGuide incident database, the incident location is reported as the latitude and longitude of the closest incident reference point, while the nearest milepost to the crash is used in the CAR system to report crash locations. In order to utilize a common reference for the two sources of crash data, the crash locations from the CAR system are converted to the mile posts of the corresponding incident reference points.

3.3 Case Study Results

The modified ITSDCAP tool was applied to the case study of this project to analyze the normal day traffic patterns along the I-4 study corridor between Milepost 84.4 and Milepost 93.6 in Orlando, Florida. The study time period was between September 1, 2011, and February 29, 2012. This section includes the traffic pattern analysis results for this study corridor.

3.3.1 Average Speed and Volume

The space-time contour map of the average speed under normal day traffic conditions along the I-4 eastbound study corridor is displayed in Figure 3-10. The weekdays are divided into three groups: Monday, Tuesday/Wednesday/Thursday, and Friday, taking into consideration that the traffic patterns are usually different on Mondays and Fridays, compared to the remaining weekdays. Figure 3-10 shows that under normal days, the traffic is almost at a free flow during the AM peak period along the eastbound I-4 corridor segment, but is very congested between 5:00 pm and 6:30 pm during the PM peak period. The recurrent (day-to-day) bottleneck locations can be identified as Milepost 87.2, east of West Fairbanks Avenue, and Milepost 90.2, before Wymore Road. Note that for Fridays, the congestion starts about one hour earlier than the other days. Figure 3-11 displays the space-time contour map of the average speed under normal day traffic conditions for the westbound direction of the I-4 corridor. This figure shows that a queue starts west of SR-834 (about Milepost 91.2) and propagates upstream during the normal AM peak period. It can also be seen that traffic congestion is more severe on Mondays. During the PM peak period, the traffic along the study corridor also experiences congestion due to the queue spillback from Downtown Orlando. Contrary to the AM peak period, the most congested day is Friday, specifically during the PM peak period.

The corresponding average volume under normal day traffic conditions around bottleneck locations are shown in the figures in Appendix A. These figures indicate that average volume trends are consistent between different days of the week, except Fridays, where the trend in the PM peak period is significantly different.

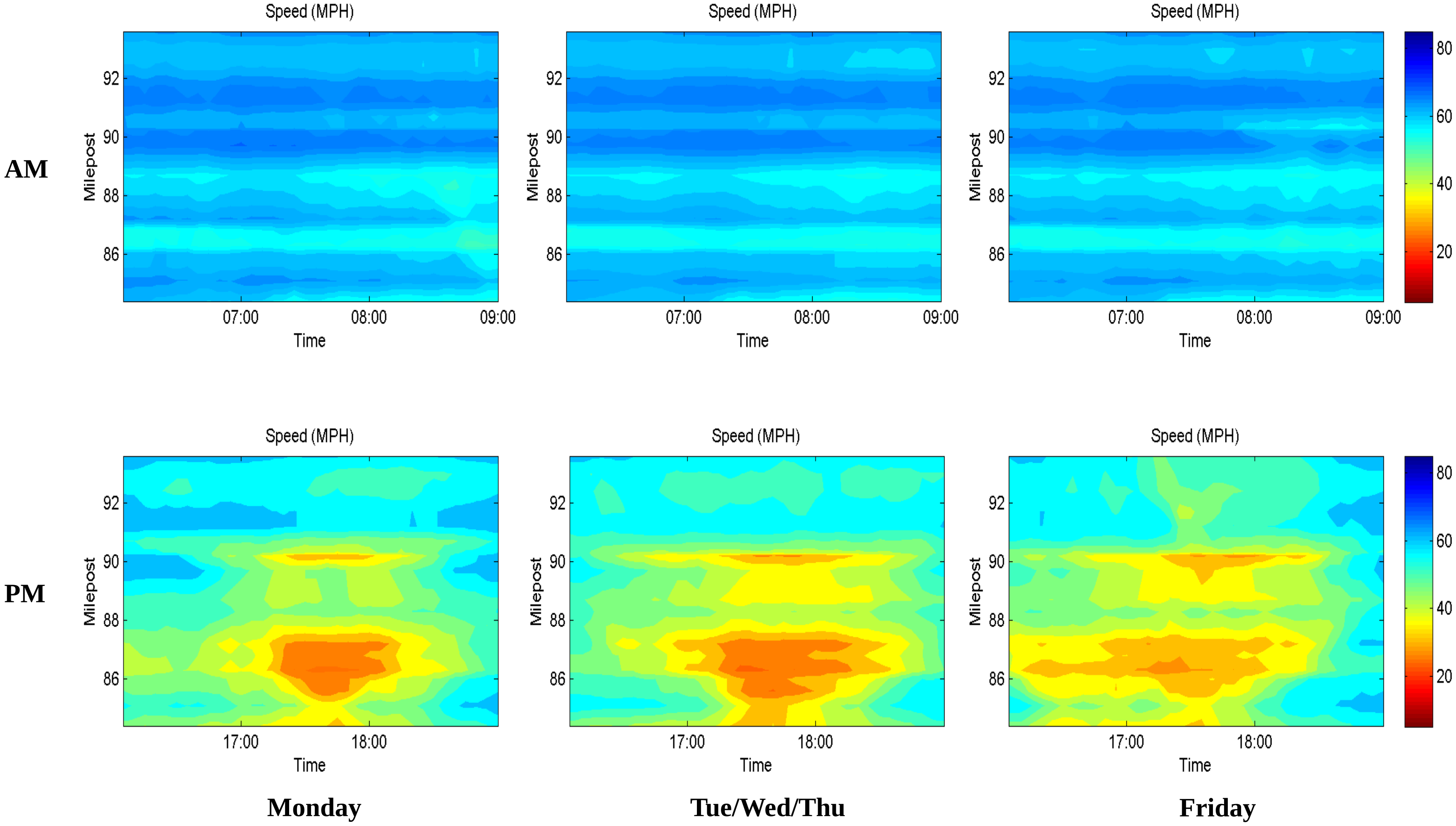


Figure 3-10 Average Speed under Normal Traffic Conditions for I-4 EB Study Corridor

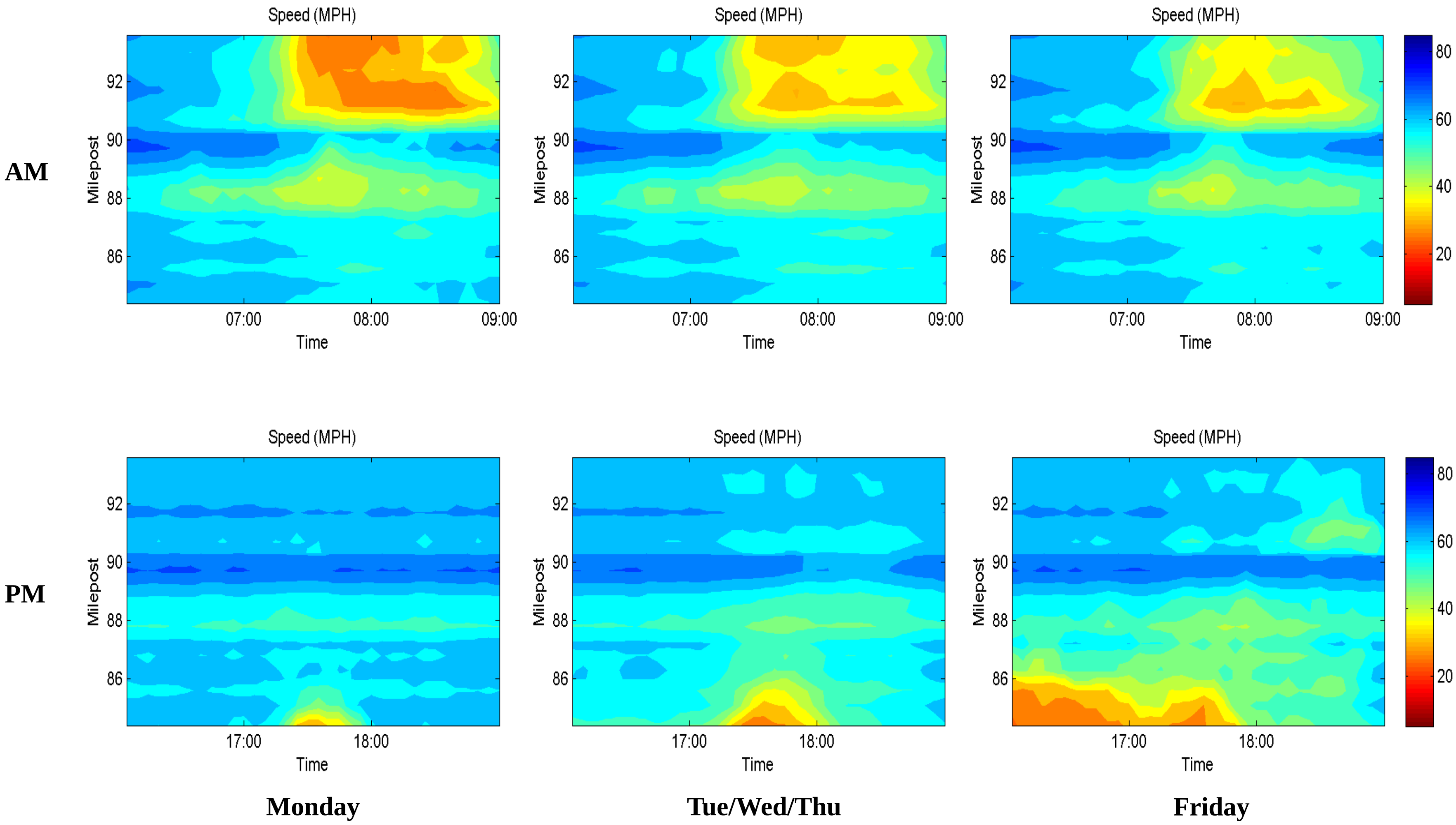
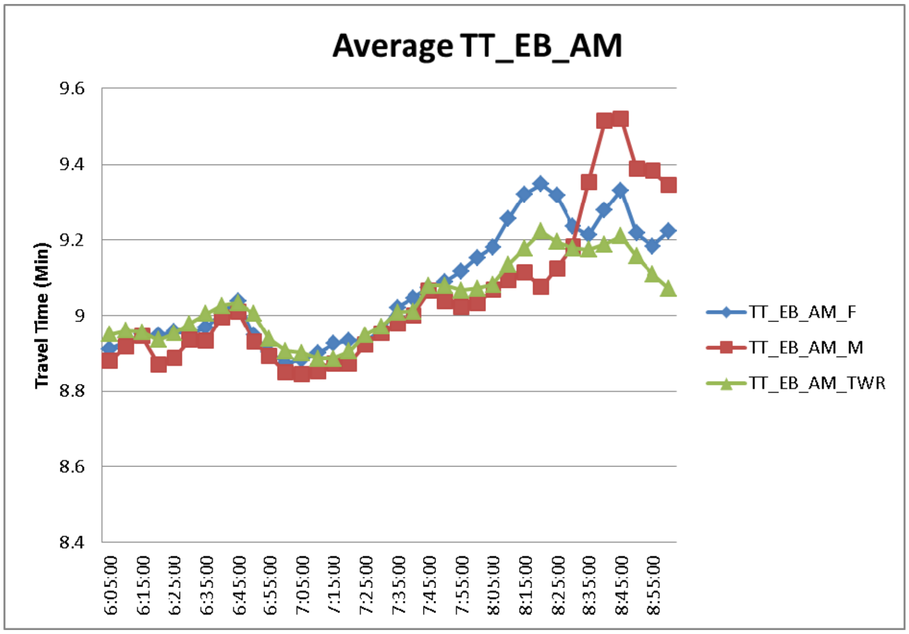


Figure 3-11 Average Speed under Normal Traffic Conditions for I-4 WB Study Corridor

3.3.2 Travel Time

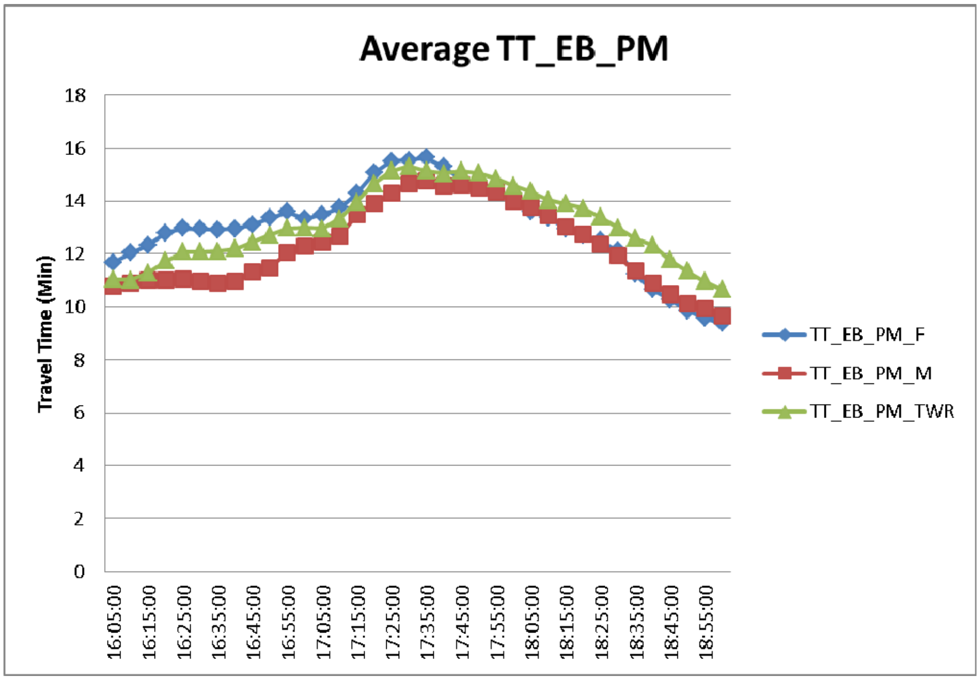
The normal day travel time results for the I-4 study corridor are presented in Figure 3-12. Figure 3-12(a) shows that during the AM peak period, the travel times along the I-4 eastbound segment follow similar patterns for different days of the week before 7:45 AM, but after that, the travel time pattern varies. The travel time between 7:45 AM and 9:00 AM on Fridays are slightly higher than those on Tuesdays/Wednesdays/Thursdays. The highest travel time can be observed around 8:45 AM on Mondays. Figure 3-12(b) indicates that vehicles experience higher travel time between 4:00 PM and 5:45 PM on Fridays, and higher travel time between 5:45 PM and 7:00 PM on Tuesdays/Wednesdays/Thursdays along the I-4 eastbound segment, further confirming the earlier peaking of traffic congestion on Fridays compared to the rest of the week.

Figures 3-12(c) and 3-12(d) display the travel time under normal conditions for the I-4 westbound segment. It can be seen from Figure 3-12(c) that the day of week only slightly affects the travel time trend during the AM peak period, and the travel times on Mondays are slightly higher than the other days. However, during the PM peak period, there is a considerable variation in the travel time patterns on different days of the week. Again, the increase in travel time on Fridays starts much earlier than the other days.

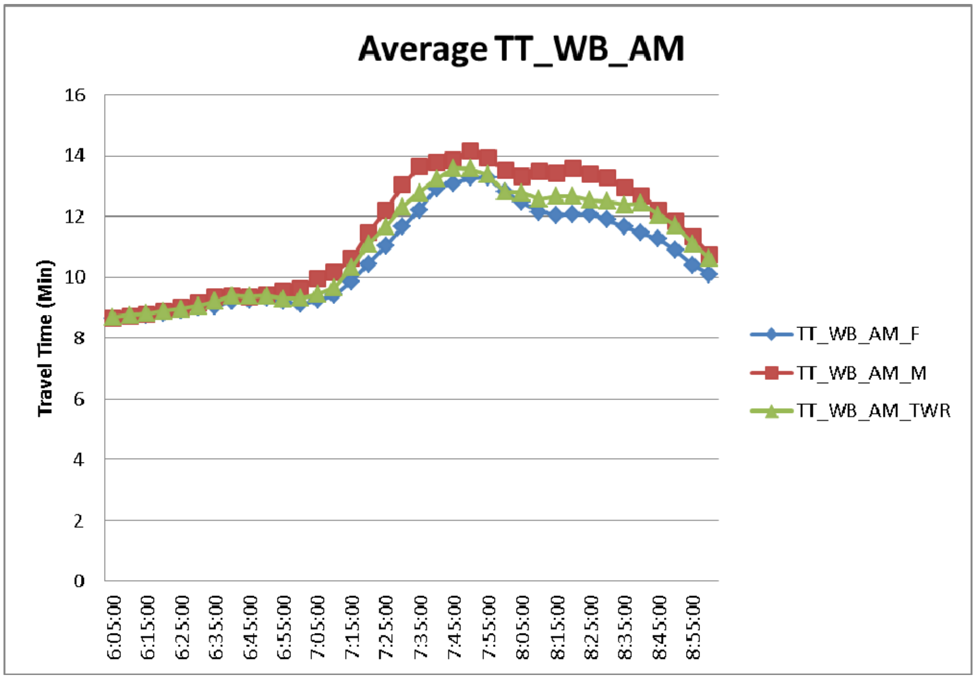


(a) EB, AM Peak Period

Figure 3-12 Travel Time under Normal Traffic Conditions for the I-4 Study Corridor

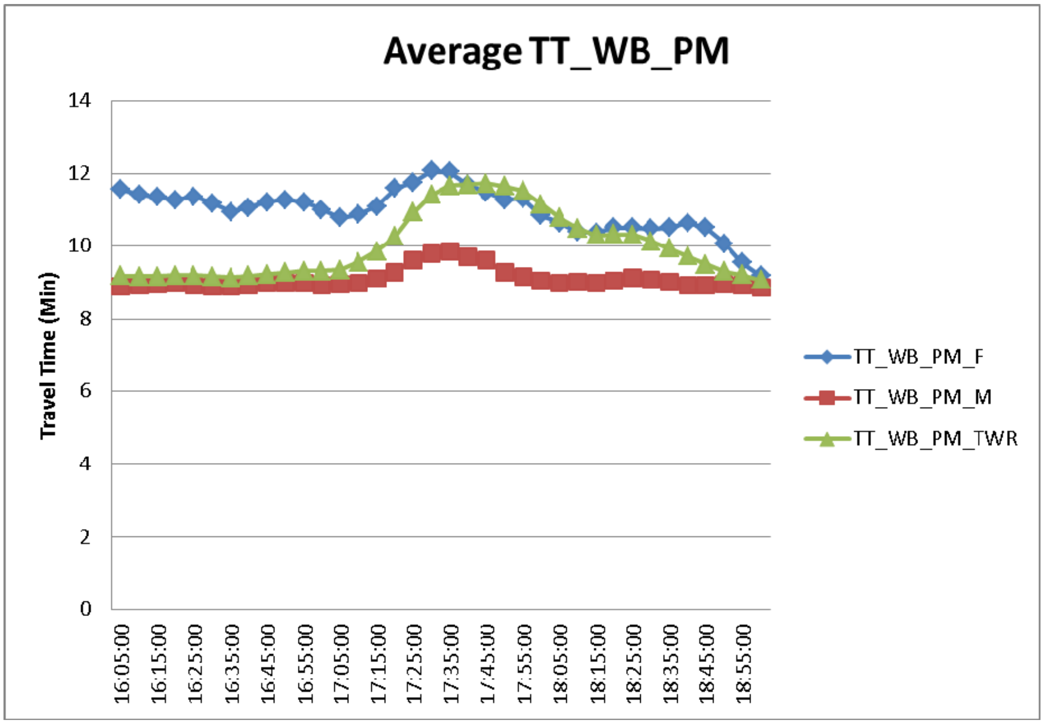


(b) EB, PM Peak Period



(c) WB, AM Peak Period

Figure 3-12 Travel Time under Normal Traffic Conditions for the I-4 Study Corridor (Continued)



(d) WB, PM Peak Period

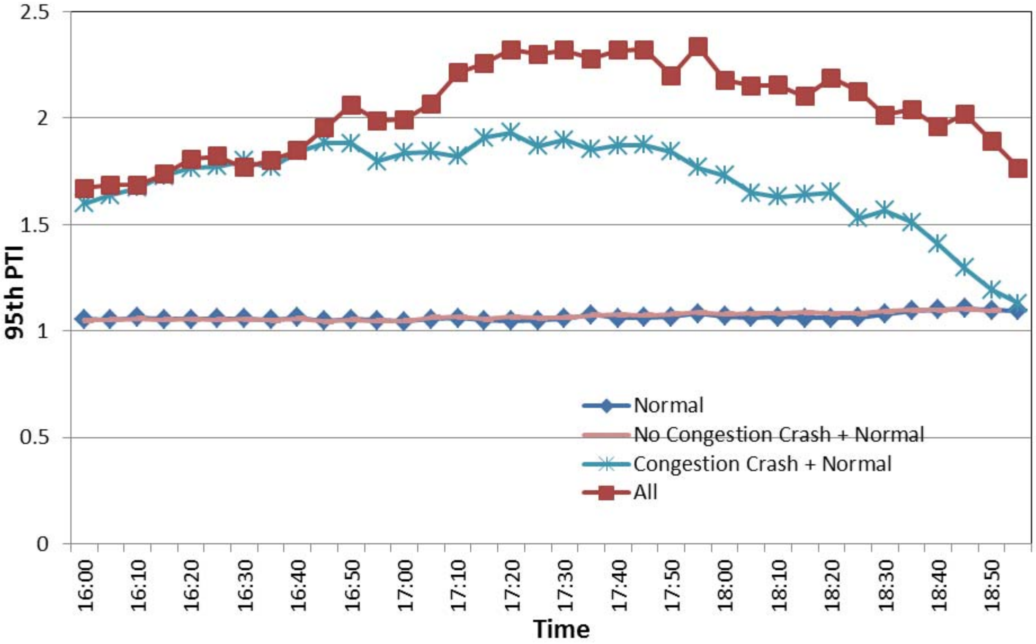
Figure 3-12 Travel Time under Normal Traffic Conditions for the I-4 Study Corridor (Continued)

3.3.3 Travel Time Reliability

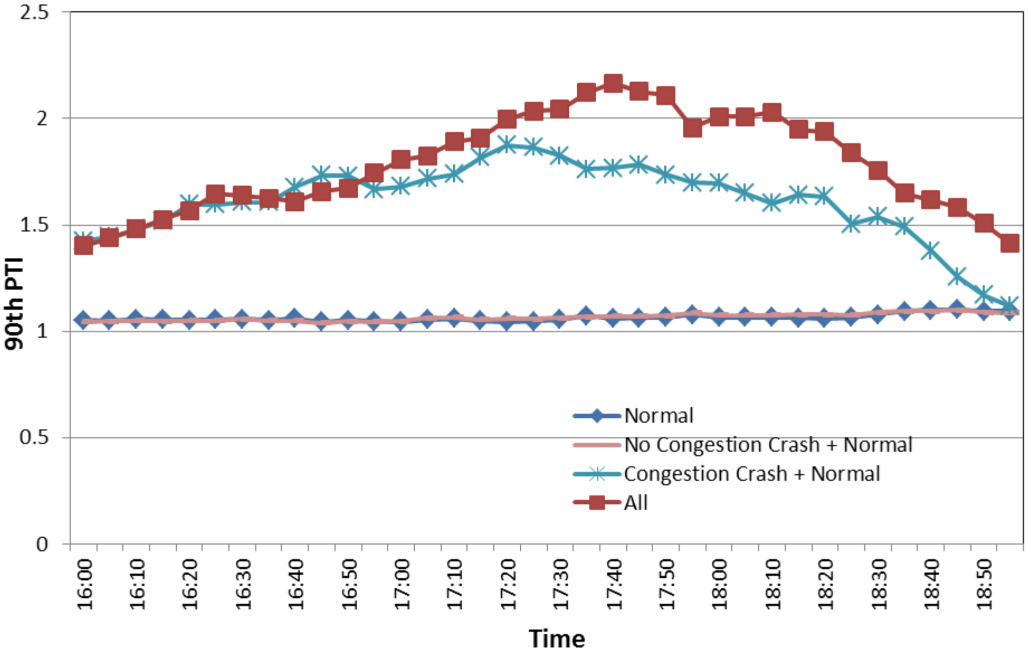
The travel time reliability and the impacts of events on travel time reliability for the I-4 study corridor were investigated for the case study. The days between September 1, 2011 and February 29, 2012 were divided into different groups based on event occurrence. For example, this includes a normal day group without any events, a group with normal days and a specific event type, a group with two event types, and so on. Various travel time reliability metrics (as described in Section 3.2.2) were calculated for each group. The results for the 95th, 90th, and 85th travel time (planning) time index (TTI or PTI) are discussed in this section.

Figures 3-13(a) through 3-13(c) display travel time reliability measures for the I-4 eastbound segment during the PM peak period, and Figures 3-14(a) through 3-14(c) display the corresponding results for the I-4 westbound segment during the AM peak period. As shown in Figure 3-13(a), the 95th planning time index is close to 1 for the normal day group (that is, without events). When the days with crashes not flagged as the cause for congestion by the operators (referred to as no congestion crashes in the figure) are included in the group (in addition to normal days), the 95th planning time index barely changes. However, the 95th planning time index greatly increases when the days with severe crashes that cause congestion, flagged as such by TMC operators, are taken into consideration and included. When including other types of events (disabled vehicles, debris on road, flat tires, etc.) into the analysis, the 95th planning time index increases further. The value can reach as high as 2.3, which means that in the worst 5% of travel instances, it will take more than two times the normal day travel time for the vehicles to finish the same journey. Similar trends for the 90th and 85th planning time index are shown in Figures 3-13(b) and 3-13(c).

The curves in Figures 3-14(a) through 3-14(c) for the I-4 westbound segment show similar results: crashes not flagged as the cause of congestion by the operators, exhibiting a negligible impact on travel time reliability, and those flagged to cause congestion and have a significant impact in the values of planning time index.

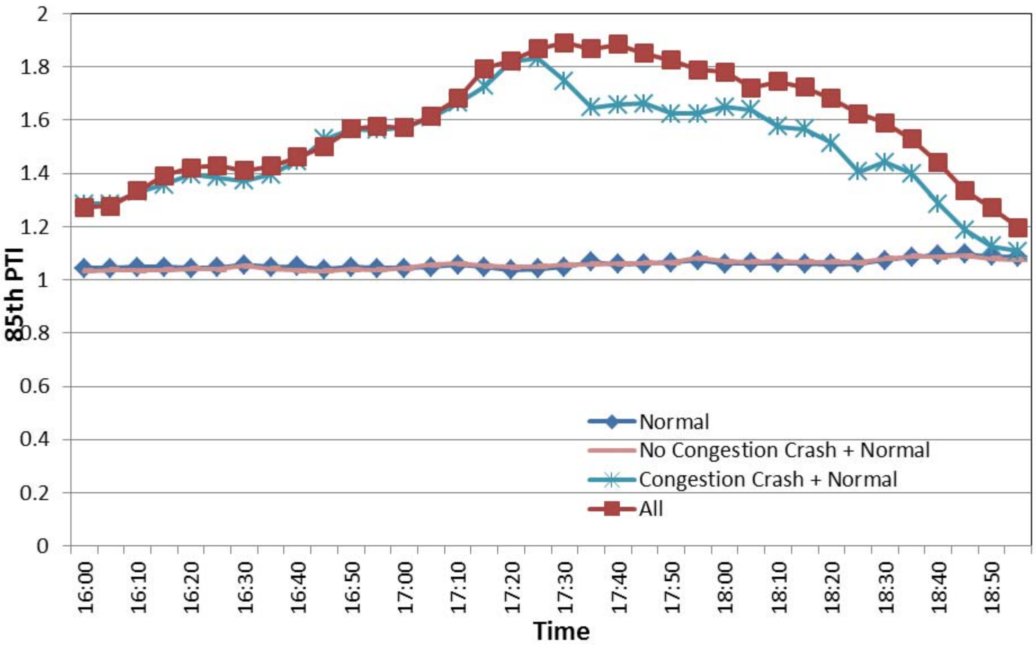


(a) 95th Planning Time Index



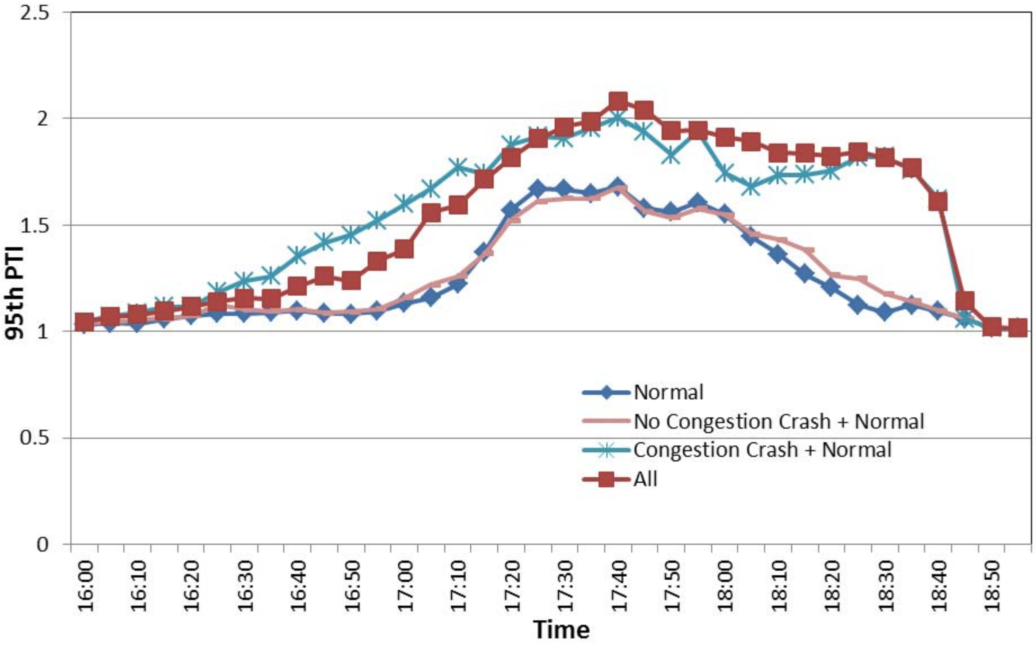
(b) 90th Planning Time Index

Figure 3-13 Impact of Event Type on Travel Time Reliability for the I-4 EB Segment



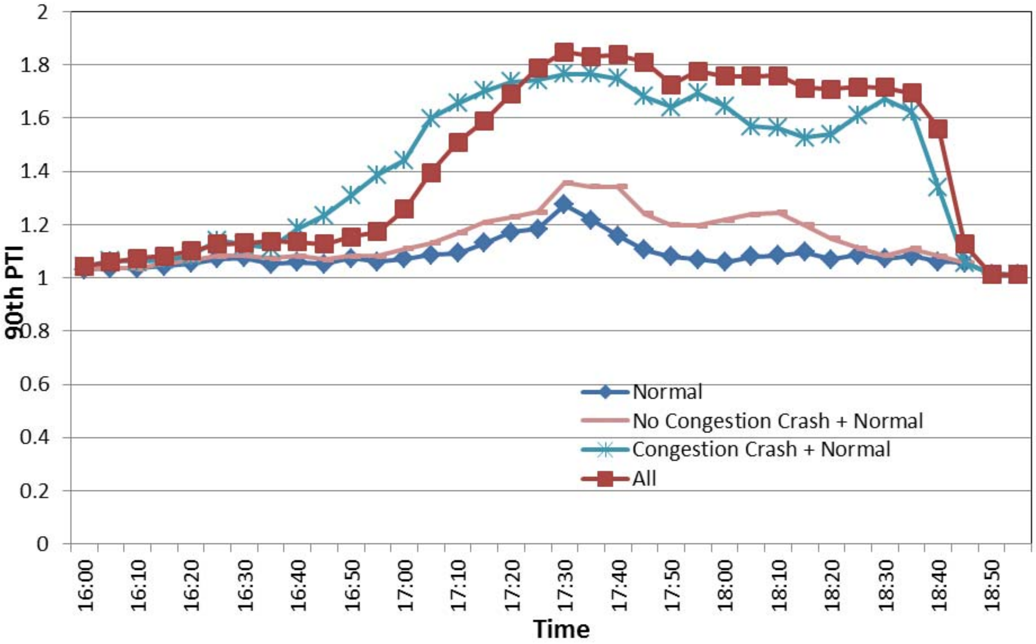
(c) 85th Planning Time Index

Figure 3-13 Impact of Event Type on Travel Time Reliability for the I-4 EB Segment (Continued)

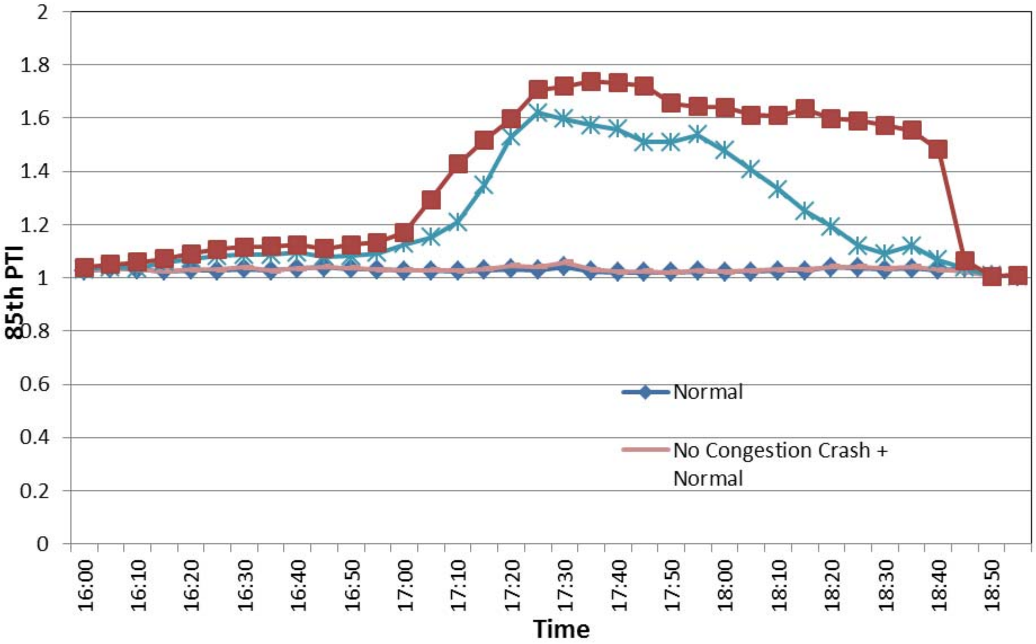


(a) 95th Planning Time Index

Figure 3-14 Impact of Event Type on Travel Time Reliability for the I-4 WB Segment



(b) 90th Planning Time Index

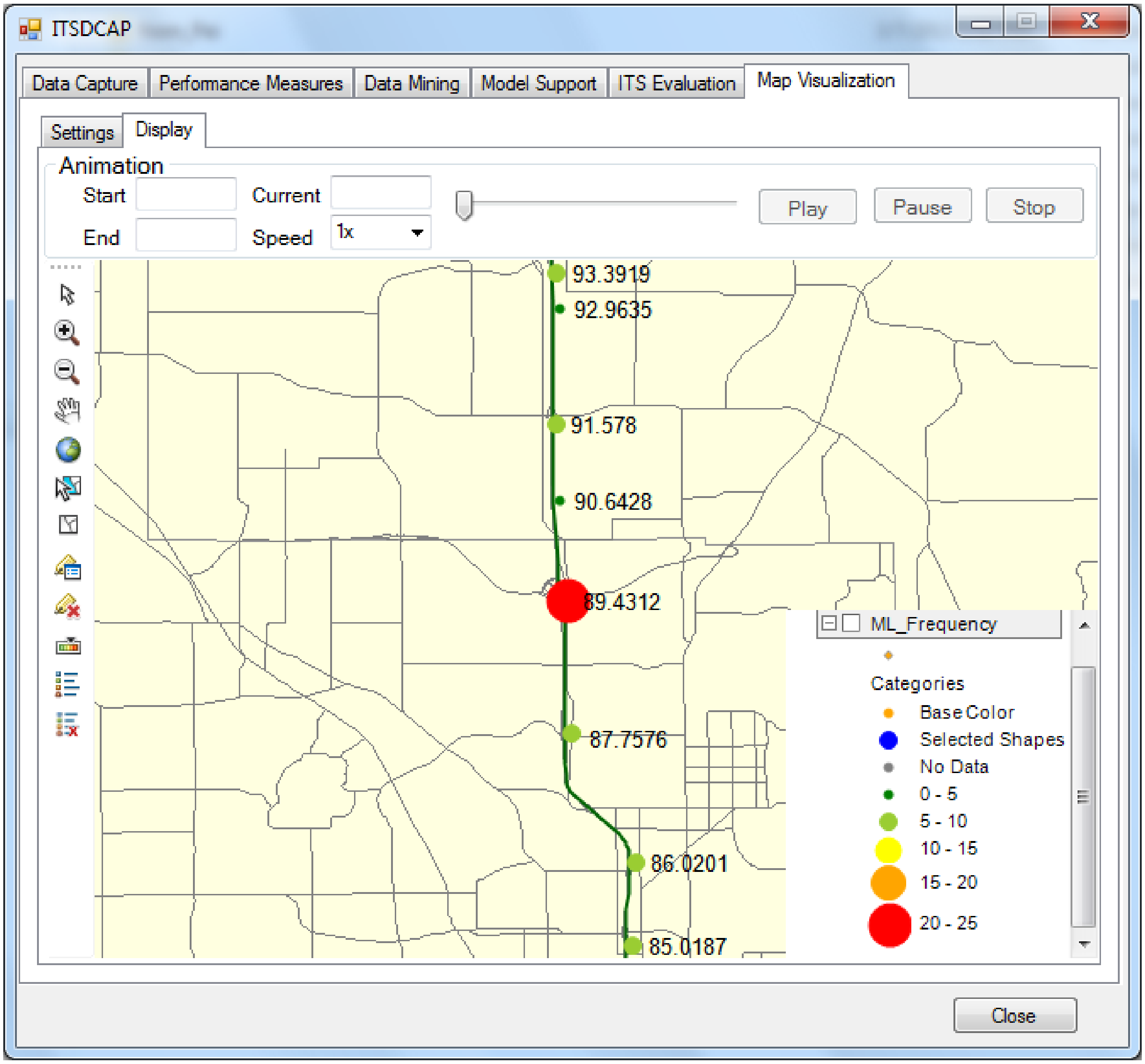


(c) 85th Planning Time Index

Figure 3-14 Impact of Event Type on Travel Time Reliability for the I-4 WB Segment (Continued)

3.3.4 Traffic Safety

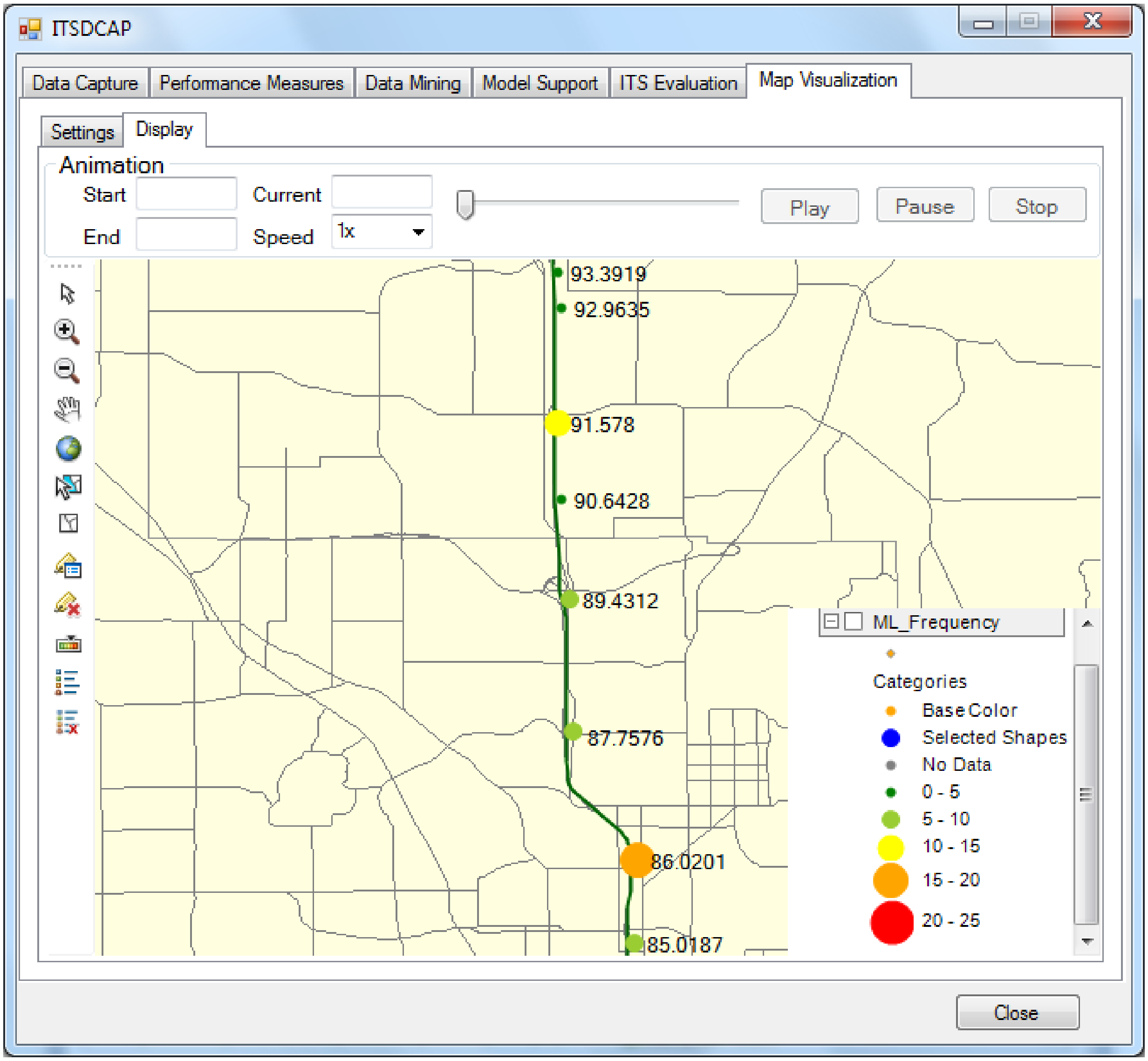
Figure 3-15 presents the spatial distribution of crash frequency based on both the SunGuide incident database and the CAR system data for the eastbound I-4 study corridor. Figure 3-16 shows the corresponding results for the westbound I-4 study corridor. It is seen from these two figures that the crash frequency distribution varies with the crash data sources. However, as mentioned earlier, the two data sources are derived from two different dates. Thus, they cannot be directly compared. Nevertheless, such differences are to be expected due to the fact that the CAR system only reports the crashes that result in a fatality, an injury, or a property-damage-only (PDO) higher than $1,000, while the incident database reports all of the events that occur along the corridor.



Speed 1x

(a) Incident Database

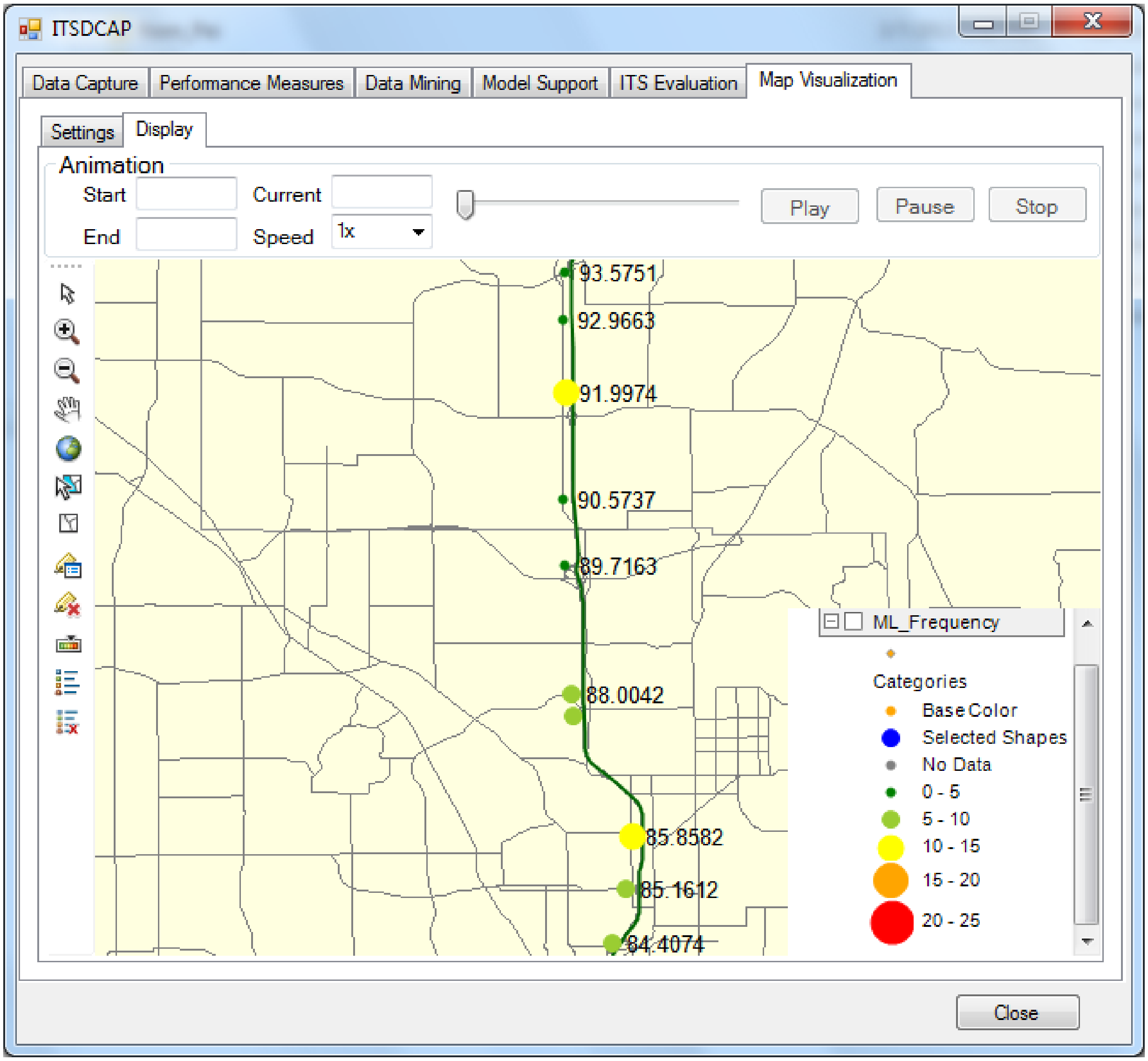
Figure 3-15 Crash Frequency for I-4 EB Segment



Speed 1x

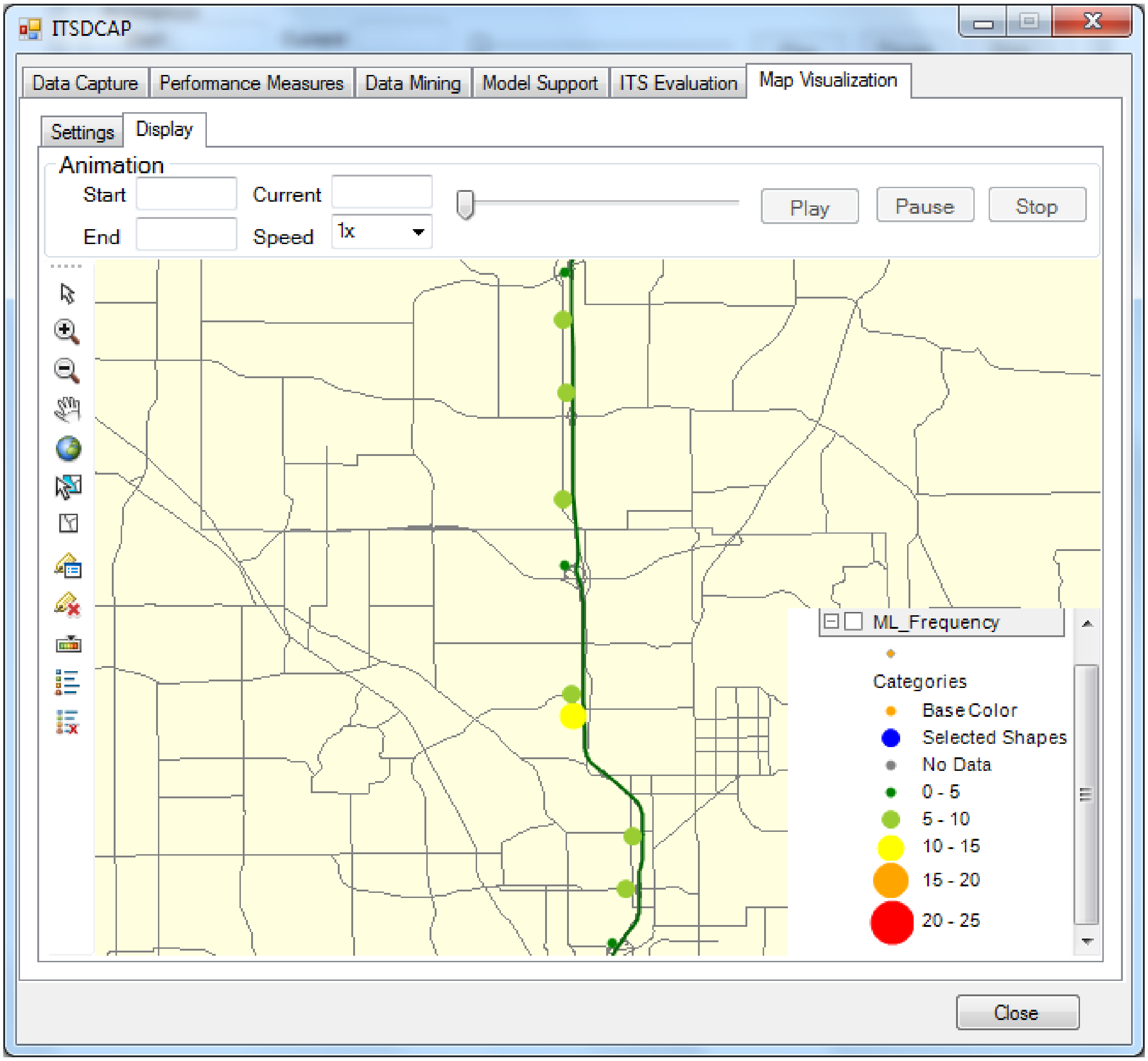
(b) CAR System

Figure 3-15 Crash Frequency for I-4 EB Segment (Continued)



(a) Incident Database

Figure 3-16 Crash Frequency for I-4 WB Segment



(b) CAR System

Figure 3-16 Crash Frequency for I-4 WB Segment (Continued)

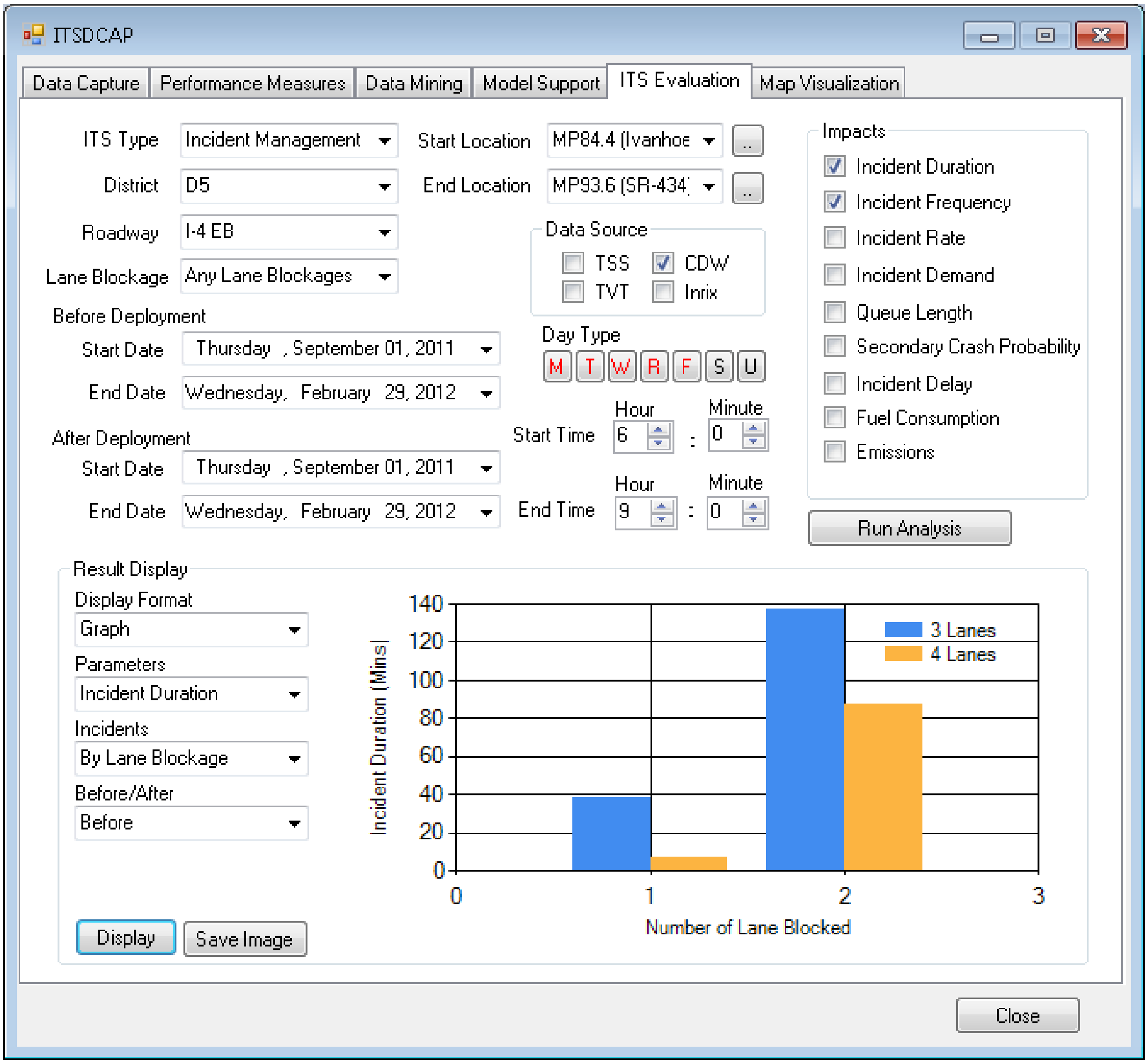
3.4 References

Hadi, M., Y. Xiao, C. Zhan, P. Alvarez. Integrated Environment for Performance Measurements and Assessment of Intelligent Transportation Systems Operations. Final report BDK80 #977-11, Prepared for the Florida Department of Transportation, June, 2012.

4 Incident Impacts

4.1 Incident Impacts Estimation in ITSDCAP Tool

Incident impact estimation is a function in the ITS Evaluation Module of the ITSDCAP tool, as shown in Figure 4-1. This function assesses incident impacts on mobility, secondary accidents probability, fuel consumption, and emissions. This section reviews the evaluation methodology used in ITSDCAP to calculate these impacts.



ITS Type: Incident Management
District: D5
Roadway: I-4 EB
Lane Blockage: Any Lane Blockages
Start Location: MP84.4 (Ivanhoe
End Location: MP93.6 (SR-434)

Data Source
☐ TSS ☑ CDW
☐ TVT ☐ Inrix

Before Deployment
Start Date: Thursday , September 01, 2011
End Date: Wednesday, February 29, 2012

After Deployment
Start Date: Thursday , September 01, 2011
End Date: Wednesday, February 29, 2012

Day Type: M T W R F S U

Start Time: Hour 6 : Minute 0
End Time: Hour 9 : Minute 0

Impacts
☑ Incident Duration
☑ Incident Frequency
☐ Incident Rate
☐ Incident Demand
☐ Queue Length
☐ Secondary Crash Probability
☐ Incident Delay
☐ Fuel Consumption
☐ Emissions

Result Display
Display Format: Graph
Parameters: Incident Duration
Incidents: By Lane Blockage
Before/After: Before

Figure 4-1 Incident Impact Estimation Interface in ITSDCAP

4.1.1 Incident Duration and Frequency

Incident frequency (or incident rate in incidents per million vehicle miles of travel) and average incident durations, both by blockage type, are essential parameters for calculating incident impacts. In ITSDCAP, the incident frequency and average incident duration parameters are calculated based on the incident data archived by traffic management centers in Florida. These parameters are summarized by time, location, and blockage type, and can be visualized to give users a picture of the temporal and spatial distribution of incidents.

4.1.2 Traffic Demands

Travel demand is a required parameter to estimate the impacts of incidents on mobility using queuing analysis. The average travel demands are estimated based on the ITS detector data in ITSDCAP. The traffic demand for a normal day traffic pattern is obtained by first eliminating the days with incidents, construction, special events, and holidays/weekends, and then clustering out other unusual days using the k-means clustering algorithm, as described in the previous section of this report.

4.1.3 Mobility Measures

Two analysis methods can be used to estimate the mobility impacts in ITSDCAP. The first is the deterministic queuing analysis; the second is the direct measurements based on captured detector data. In cases where mobility measures cannot be directly assessed based on the captured data, a deterministic queuing analysis can be used to estimate these measures. However, the values of demands, capacity drops, and incident durations that are used in the queuing analysis are based on the data captured by the ITSDCAP tool. If sufficient data are available, mobility measures can be directly measured based on the captured data by comparing the incident day’s vehicle-hour traveled with the normal day’s vehicle-hour traveled for the timestamps with incident conditions, including the incident recovery time period.

The queue length during the incident can be estimated based on detector measurements, using one of three methods that examine congestion levels at each detection station. These methods are a speed threshold-based method, occupancy threshold-based method, and clustering analysis-based method. The speed-threshold method identifies the station to be within the queue, as long as the measured speed at the detector station is less than a predefined speed threshold. The second method uses the occupancy threshold instead of the speed-threshold for this determination. The third method is based on cluster centroids identified based on *k*-mean clustering analyses (Xiao, 2011). Once the congestion level is identified for each detector station, the spatial distribution of congestion levels is used to determine the queue length. The queue length is estimated for each incident and used in the calculation of average values for all incidents of the same lane blockage types, segment, time of day, and duration category.

4.1.4 Probability of Secondary Incidents

Another important impact of incidents is the potential for secondary incidents. The logistic regression model developed by Zhan et al. (2009) was used to assess the potential for secondary incidents. Equation 4-1 shows the derived expression for the secondary crash likelihood.

$$\begin{aligned}\mathrm{Pr\,ob}(\mathit{SecondaryCrash}) = \exp(&-6.100 + 0.462 \times \ln(\mathrm{LaneBlockage}) + 0.170 \times \mathrm{QueueLength}\\ &+ 0.702 \times \mathrm{PM} + 0.959 \times \mathrm{Midday}\\ &+ 1.397 \times \mathrm{AM} + 0.451 \times \mathrm{Accident})\end{aligned} \tag{4-1}$$

where LaneBlockage represents the total length of lane blockage in minutes, and QueueLength denotes the maximum queue length in miles caused by the incident. All of the other variables in Equation 2 are self-explanatory binary variables with a value of 0 or 1.

4.1.5 Fuel Consumption and Emissions

In the ITSDCAP tool, the fuel consumption and emission impacts of incidents are calculated based on the method used by Skabardonis and Mauch (2005). The equation for fuel consumption and pollutant emission calculation is as follows:

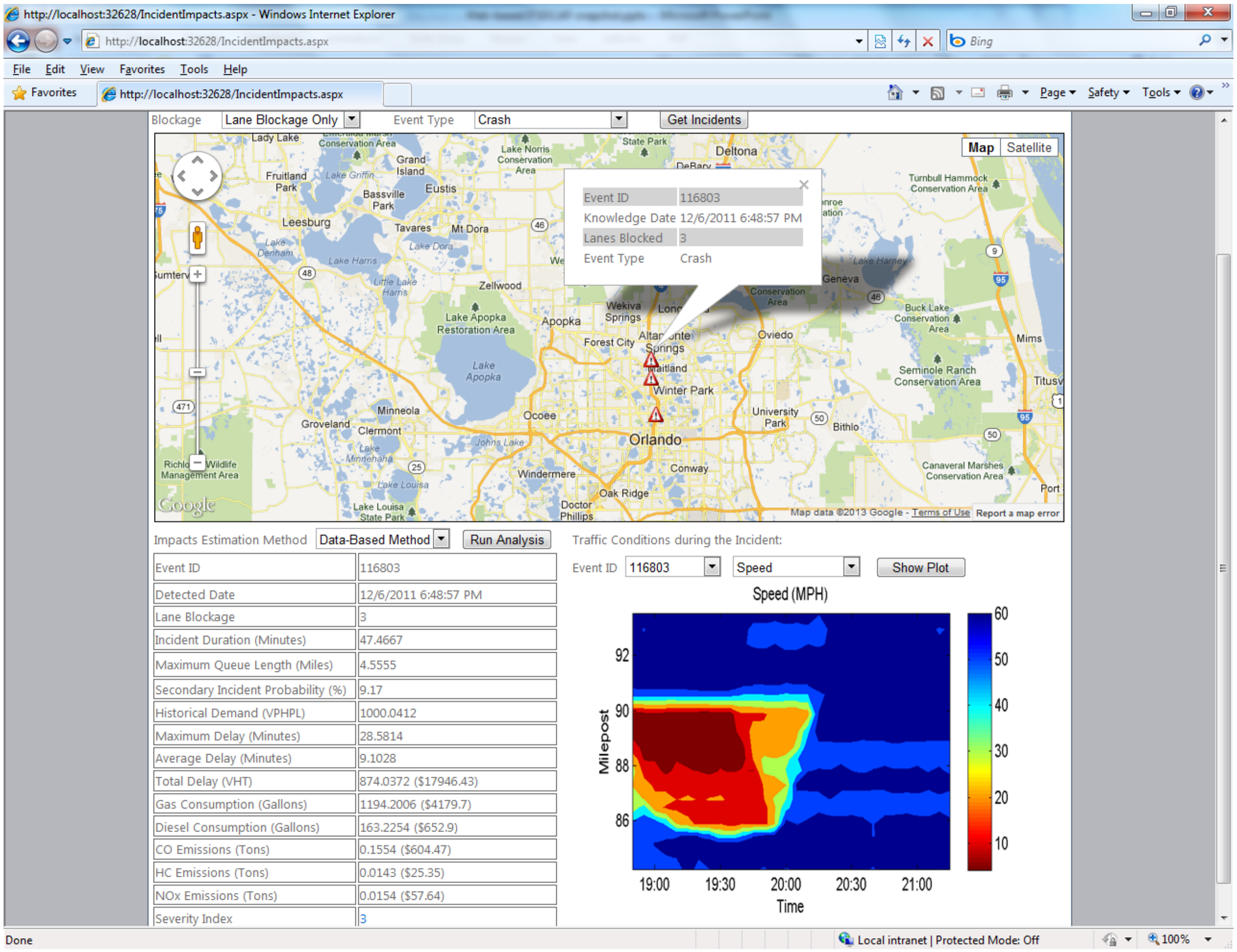
$$F_i = D \times e_{si} \tag{4-2}$$

where the variable F_i represents either the fuel consumption or CO, HC, NOx emissions. The symbol D is the incident-induced delays, and e_{si} is the fuel consumption rate or emission rate at speed *s*. The advantage of this method is that it can better capture the fuel consumption and emissions under the stop-and-go conditions caused by incidents. .

4.2 Web-based ITSDCAP Tool

As is the case with the traffic pattern identification function, the incident impact estimation was integrated into the Web-based ITSDCAP tool, allowing for a more convenient use of the tool. In the Web-based ITSDCAP tool, the selection of the roadway segment and study time period for the incident impact analysis follows the procedures described in Section 3.1. Figure 4-2 presents the interface of the Web-based version of ITSDCAP for incident impact estimation. As shown in this figure, the user can filter the incidents by inputting the lane blockage type and event type.
The user can perform the incident impacts for an individual incident or for a subgroup of incidents at a given location. When the button “Get Incidents” is clicked, the locations of incidents that satisfy user-specified criteria will be displayed on the Google Map. To obtain the incident impacts at a given location, the user will left-click an incident marker, whereupon an information window will pop up and display the incident information, such as event ID, detected date, number of lanes blocked, and event type. When the user right-clicks an incident marker, another pop-up menu will be displayed, allowing the user to select the estimation method for the incident’s impacts. The estimation method can be either a data-based method or use a queuing analysis, as described above. The estimated incident impact results are listed in the table below the map. The traffic conditions during the incident under investigation can also be simultaneously visualized through the contour plot, as shown in Figure 4-3.

In addition to the impacts of individual incidents, the Web-based ITSDCAP tool can also be applied to study the overall impacts of a subgroup of incidents of a given type. As shown in Figure 4-4, this can be accomplished by clicking the button “Run Analysis.” When analysis is finished, the corresponding results will be displayed on the webpage.



Blockage: Lane Blockage Only
Event Type: Crash

Event ID	116803
Knowledge Date	12/6/2011 6:48:57 PM
Lanes Blocked	3
Event Type	Crash

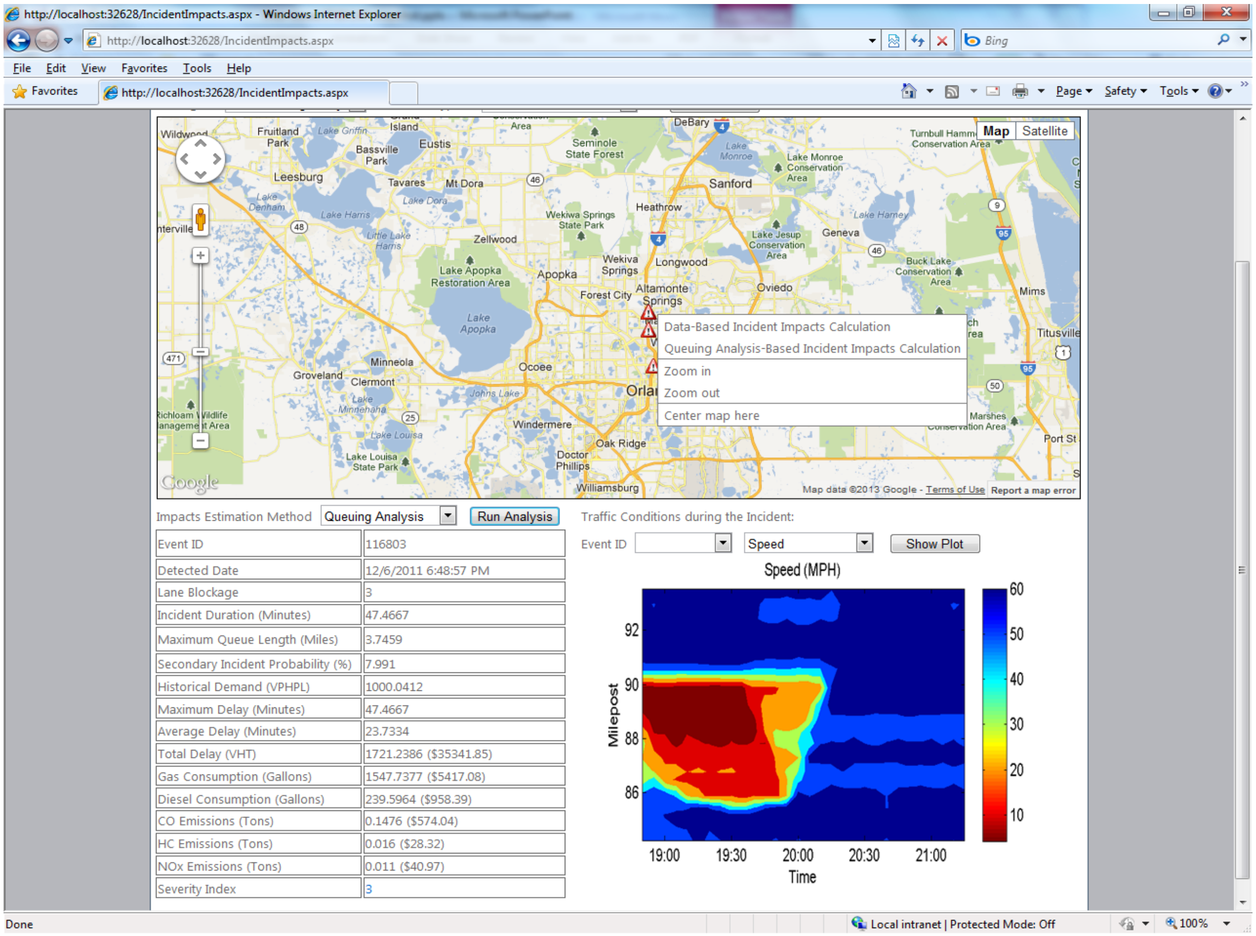
Impacts Estimation Method: Data-Based Method

Event ID	116803
Detected Date	12/6/2011 6:48:57 PM
Lane Blockage	3
Incident Duration (Minutes)	47.4667
Maximum Queue Length (Miles)	4.5555
Secondary Incident Probability (%)	9.17
Historical Demand (VPHPL)	1000.0412
Maximum Delay (Minutes)	28.5814
Average Delay (Minutes)	9.1028
Total Delay (VHT)	874.0372 ($17946.43)
Gas Consumption (Gallons)	1194.2006 ($4179.7)
Diesel Consumption (Gallons)	163.2254 ($652.9)
CO Emissions (Tons)	0.1554 ($604.47)
HC Emissions (Tons)	0.0143 ($25.35)
NOx Emissions (Tons)	0.0154 ($57.64)
Severity Index	3

Traffic Conditions during the Incident:

Event ID: 116803
Speed

Figure 4-2 Incident Impact Estimation Interface in Web-based ITSDCAP



Impacts Estimation Method: Queuing Analysis

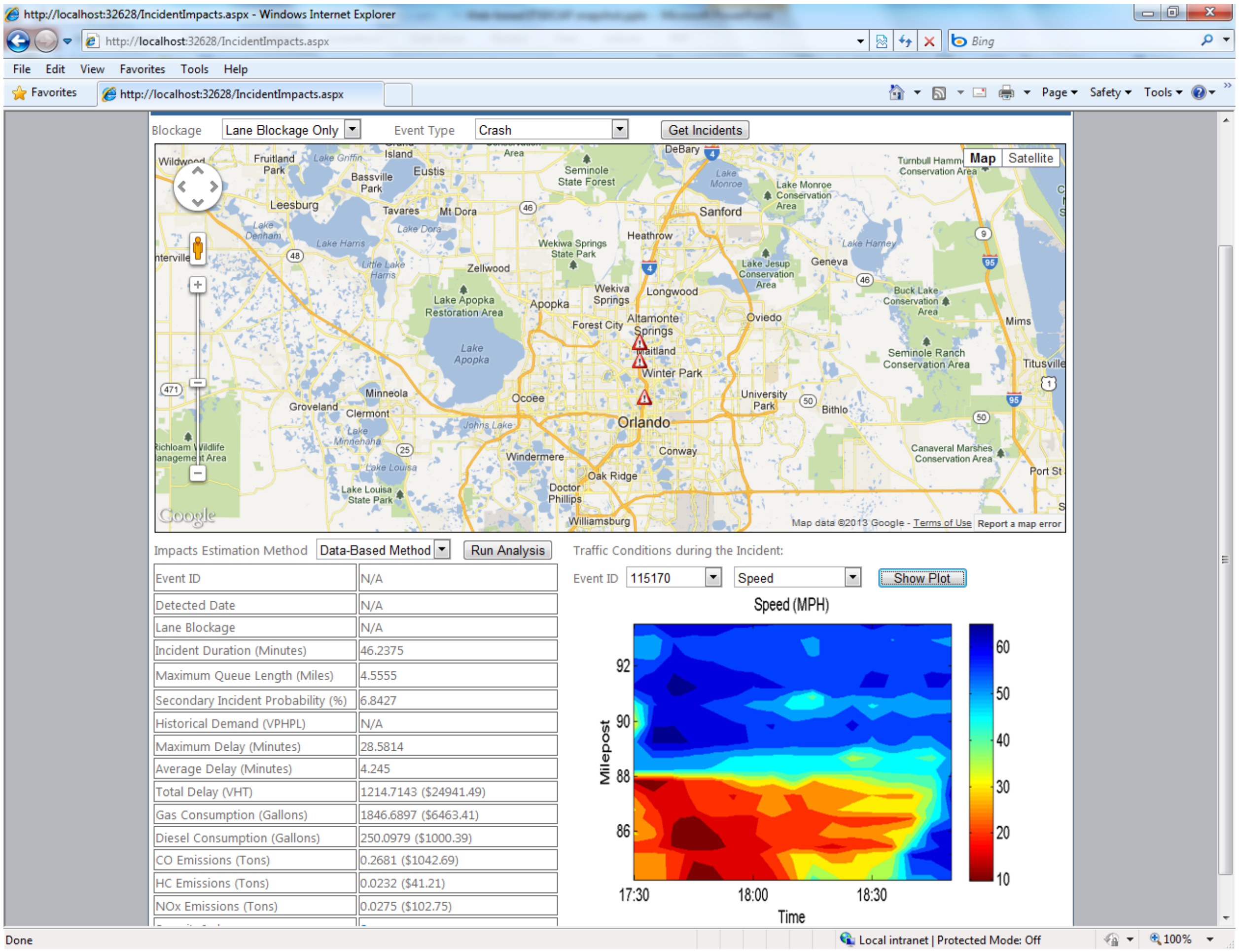
Event ID	116803
Detected Date	12/6/2011 6:48:57 PM
Lane Blockage	3
Incident Duration (Minutes)	47.4667
Maximum Queue Length (Miles)	3.7459
Secondary Incident Probability (%)	7.991
Historical Demand (VPHPL)	1000.0412
Maximum Delay (Minutes)	47.4667
Average Delay (Minutes)	23.7334
Total Delay (VHT)	1721.2386 ($35341.85)
Gas Consumption (Gallons)	1547.7377 ($5417.08)
Diesel Consumption (Gallons)	239.5964 ($958.39)
CO Emissions (Tons)	0.1476 ($574.04)
HC Emissions (Tons)	0.016 ($28.32)
NOx Emissions (Tons)	0.011 ($40.97)
Severity Index	3

Traffic Conditions during the Incident:

Event ID:

Speed

Figure 4-3 Individual Incident Impact Estimation Menu in Web-based ITSDCAP



Blockage: Lane Blockage Only
Event Type: Crash

Impacts Estimation Method: Data-Based Method

Event ID	N/A
Detected Date	N/A
Lane Blockage	N/A
Incident Duration (Minutes)	46.2375
Maximum Queue Length (Miles)	4.5555
Secondary Incident Probability (%)	6.8427
Historical Demand (VPHPL)	N/A
Maximum Delay (Minutes)	28.5814
Average Delay (Minutes)	4.245
Total Delay (VHT)	1214.7143 ($24941.49)
Gas Consumption (Gallons)	1846.6897 ($6463.41)
Diesel Consumption (Gallons)	250.0979 ($1000.39)
CO Emissions (Tons)	0.2681 ($1042.69)
HC Emissions (Tons)	0.0232 ($41.21)
NOx Emissions (Tons)	0.0275 ($102.75)

Traffic Conditions during the Incident:
Event ID: 115170
Speed

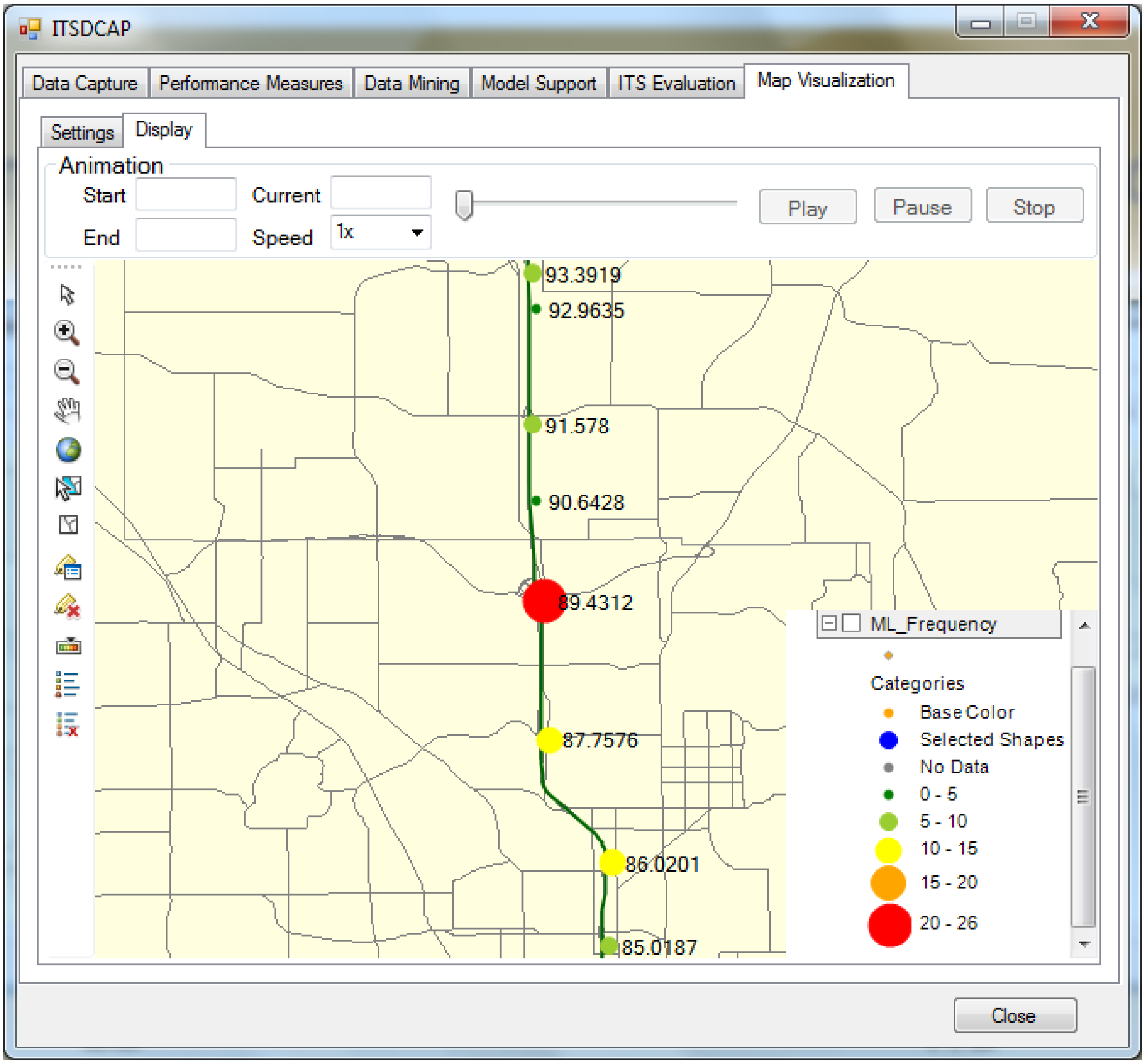
Figure 4-4 Impacts Estimation for a Group of Incidents in Web-based ITSDCAP

4.3 Case Study Results

The ITSDCAP tool was applied to investigate the incident impacts along the I-4 study corridor on weekdays between September 1, 2011 and February 29, 2012. This section presents the case study results.

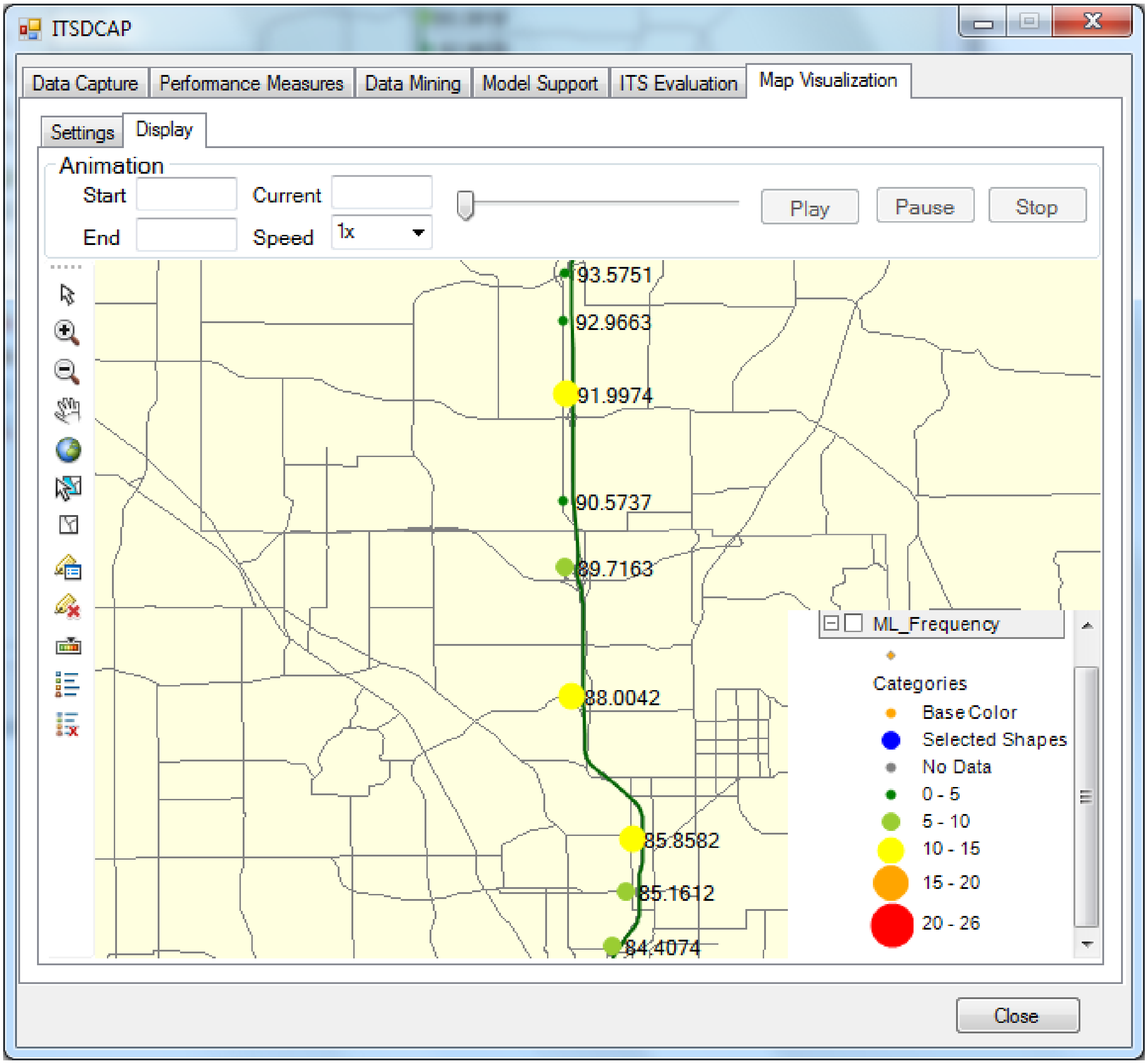
4.3.1 Incident Statistics

Figure 4-5 shows the spatial distribution of incident frequency along the study corridor. It is seen that for the eastbound direction of this corridor, the segment with the most frequent incidents is located at milepost 89.4, between West Kennedy Boulevard and Maitland Boulevard, with an incident number of more than 20 during the study time period. The roadway segment between milepost 86 and 88 also has a relatively high incident frequency in the eastbound direction, compared to other locations (10-15 incidents). For the westbound direction of this study corridor, the segments with a relatively high incident frequency (10-15 incidents) are located between milepost 85.8 and 88 (between East/West Par Street and West Fairbanks Avenue) and around the SR-436.



(a) I-4 EB

Figure 4-5 Incident Frequency along the I-4 Study Corridor

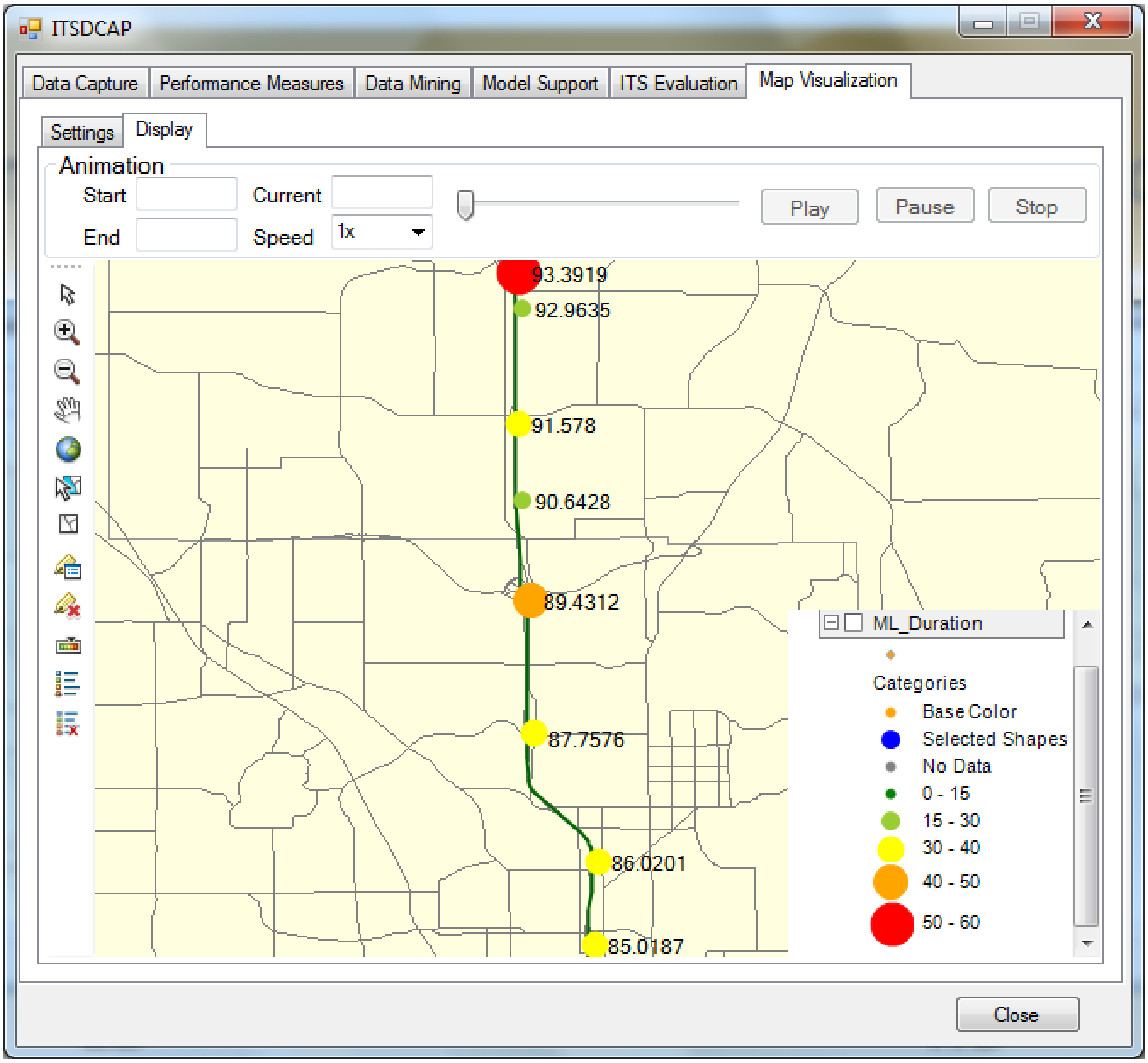


Speed 1x

(b) I-4 WB

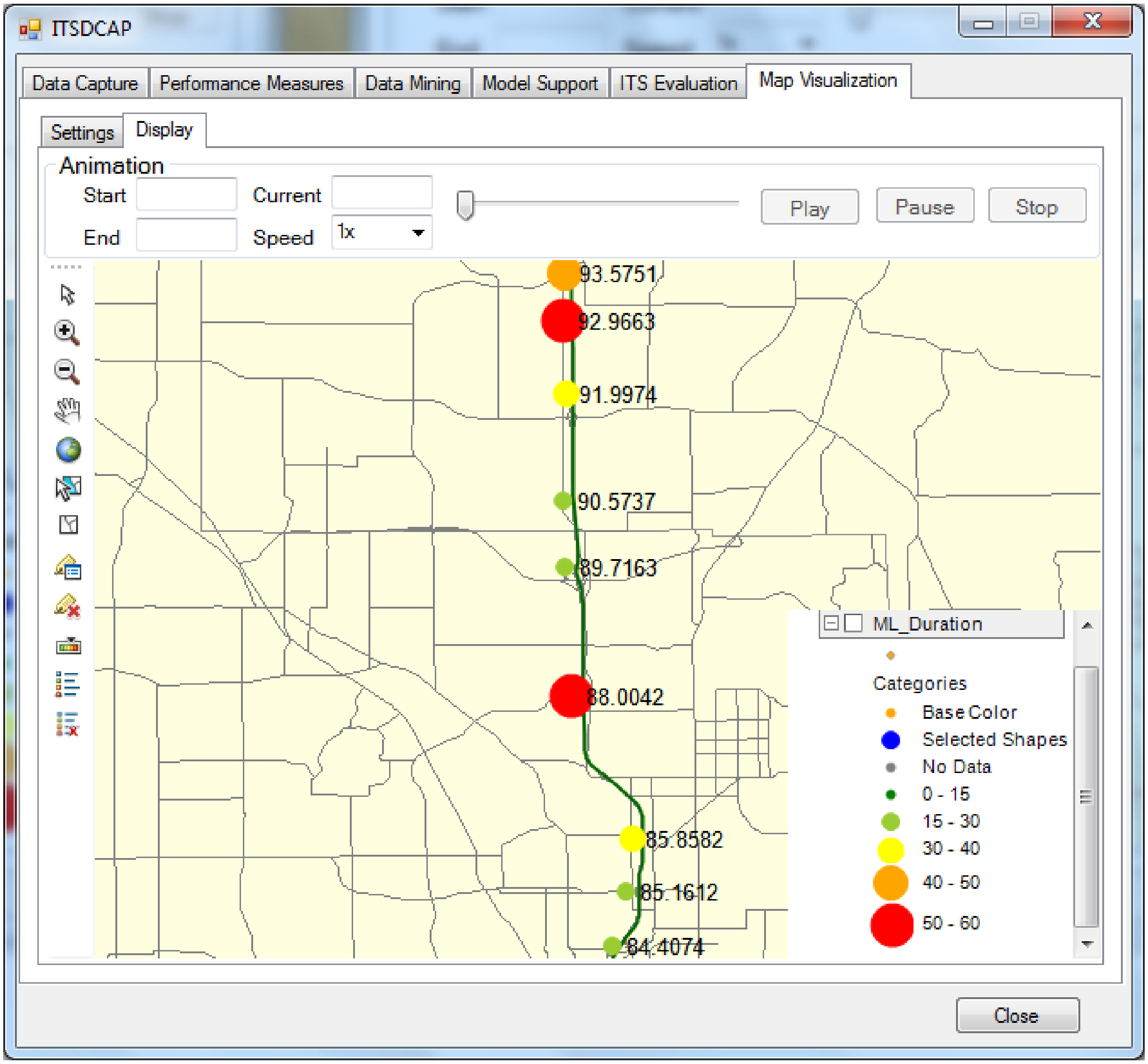
Figure 4-5 Incident Frequency along the I-4 Study Corridor (Continued)

Figure 4-6 shows the spatial distribution of average incident duration along the study corridor. This figure shows that the average incident duration is significantly different at different locations along the corridor. However, this variation could be due to the small sample size used in this study. Because of the small sample size, one incident with significantly higher incident duration than the durations of the other incidents at the location can have a significant impact on the average duration. In some cases, using the median rather than the average can produced better results.



(a) I-4 EB (Average Duration)

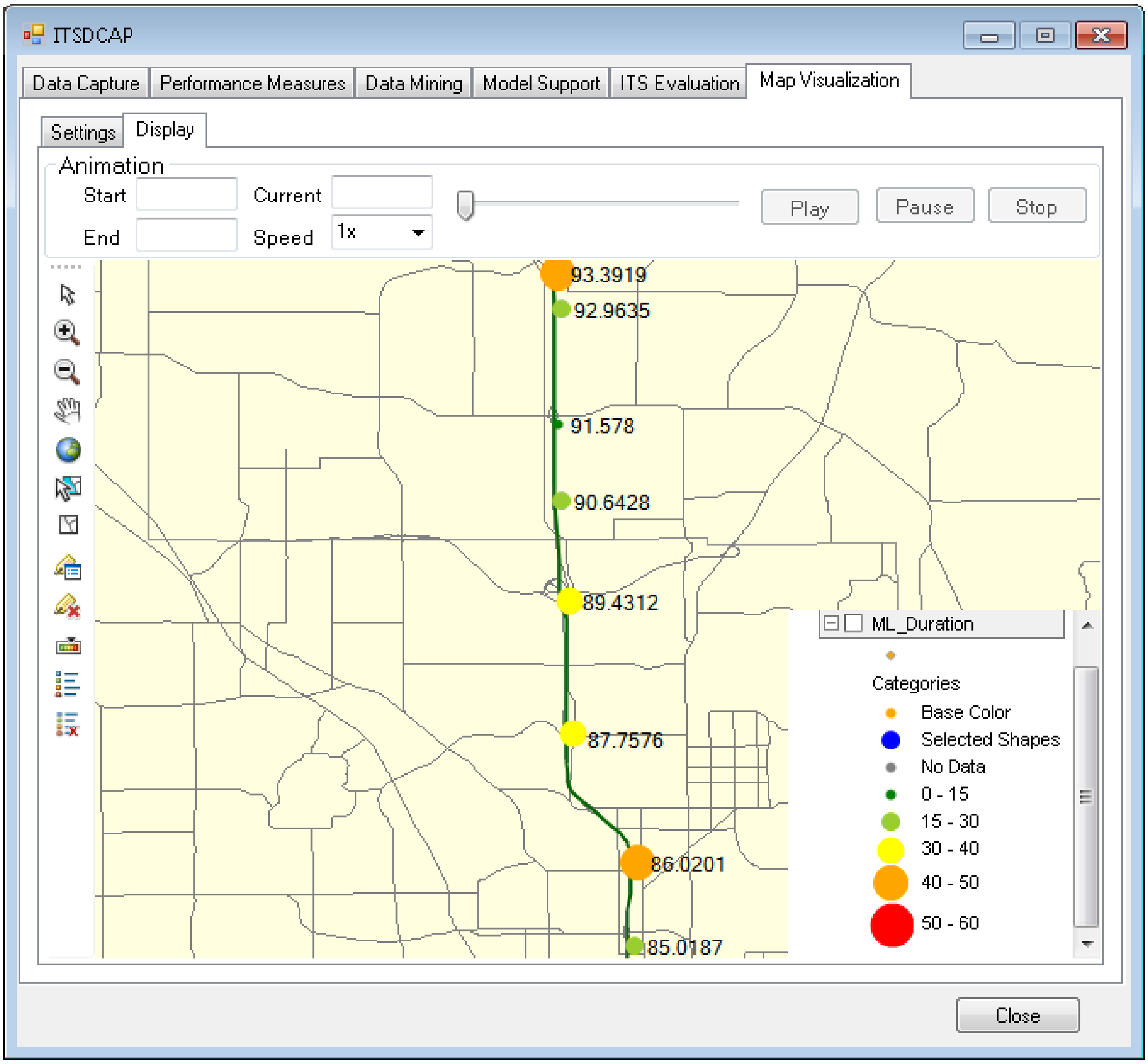
Figure 4-6 Incident Duration along the I-4 Study Corridor



Speed 1x

(b) I-4 WB (Average Duration)

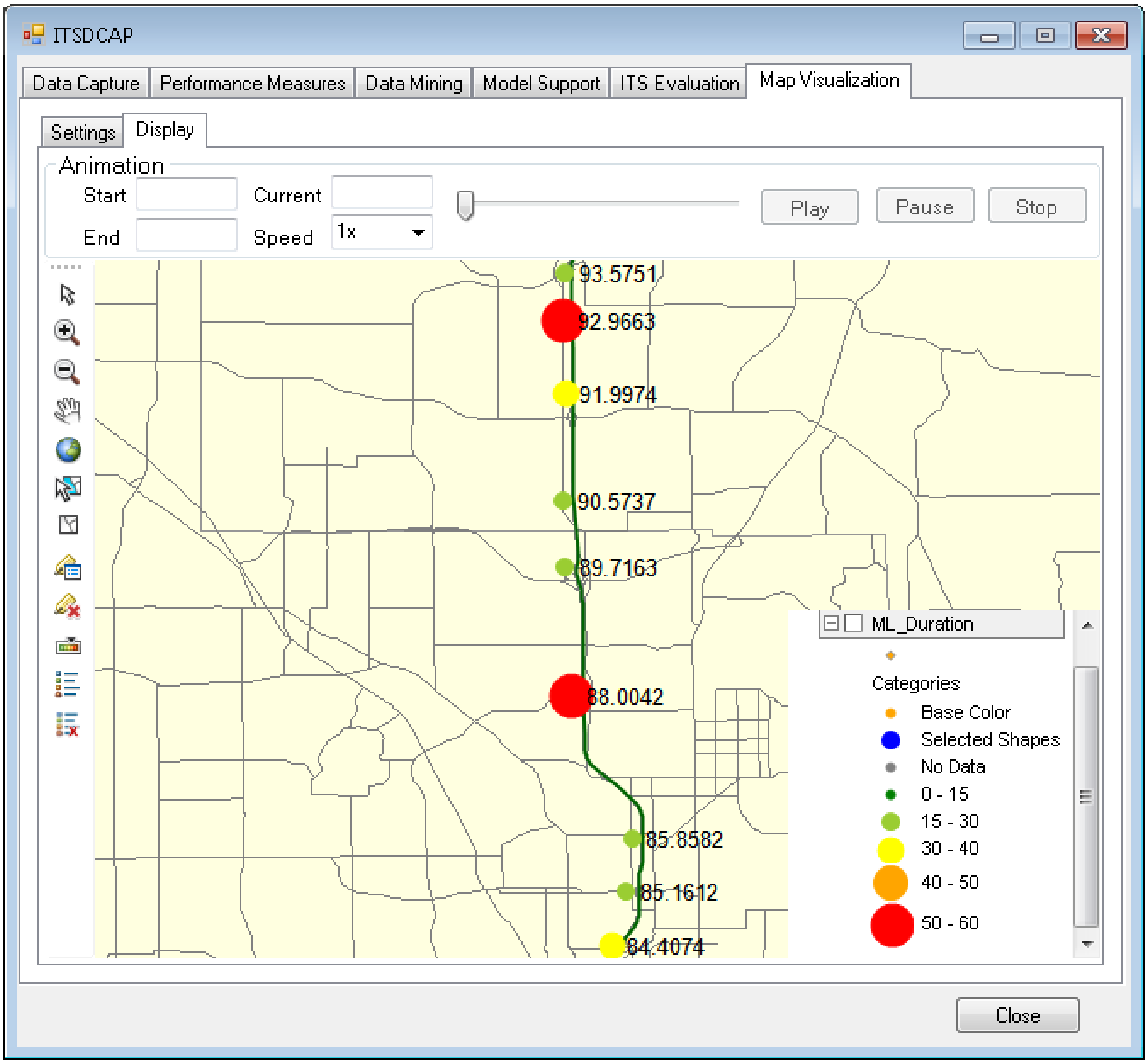
Figure 4-6 Incident Duration along the I-4 Study Corridor (Continued)



Speed 1x

(c) I-4 EB (Median Duration)

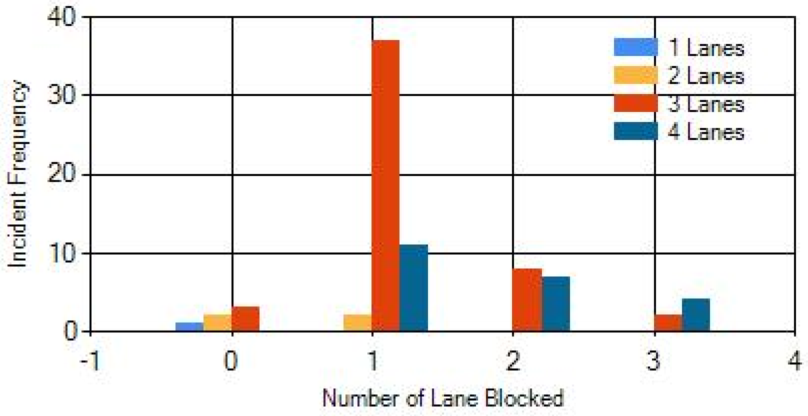
Figure 4-6 Incident Duration along the I-4 Study Corridor (Continued)



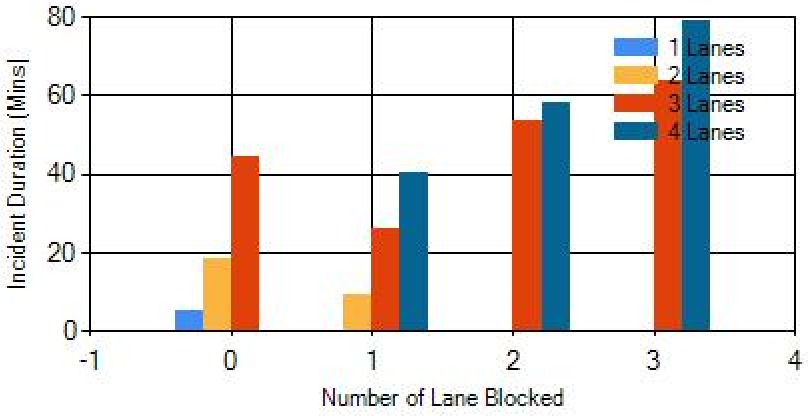
(d) I-4 WB (Median Duration)

Figure 4-6 Incident Duration along the I-4 Study Corridor (Continued)

Figure 4-7 presents another visualization of incident frequency and duration results by the number of lane blockages along the I-4 EB segment. This figure shows that the most frequent incidents are the one out of three lanes blockage incidents, and the average incident duration for this type of incident is about 25 minutes. Similar trends can also be observed for the I-4 WB segment, as shown in Figure 4-8.

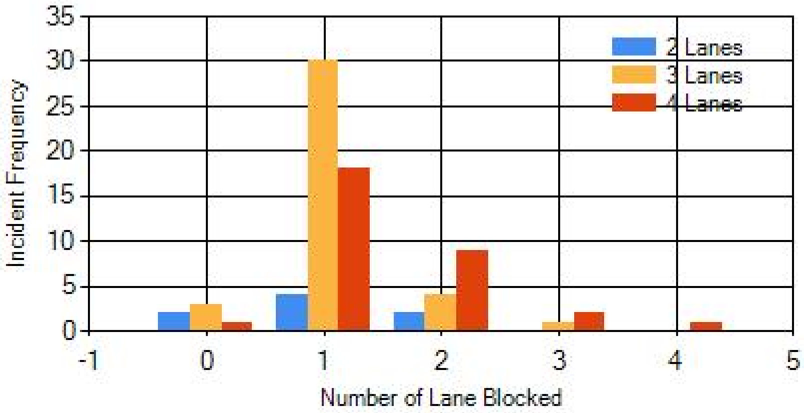


(a) Incident Frequency

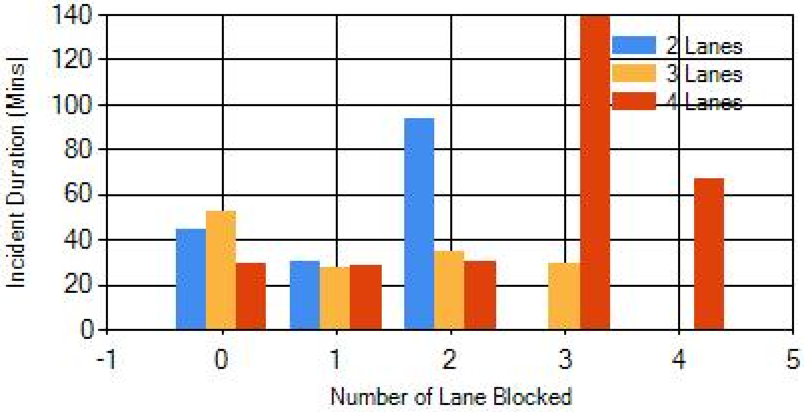


(b) Average Incident Duration

Figure 4-7 Incident Frequency and Average Incident Duration for Different Number of Lane Blockages along the I-4 EB Segment



(a) Incident Frequency

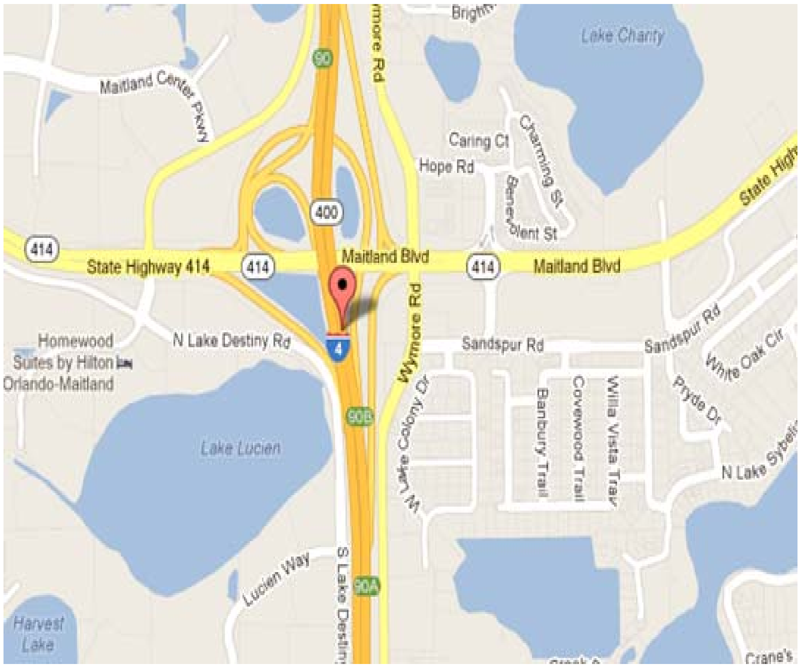


(b) Average Incident Duration

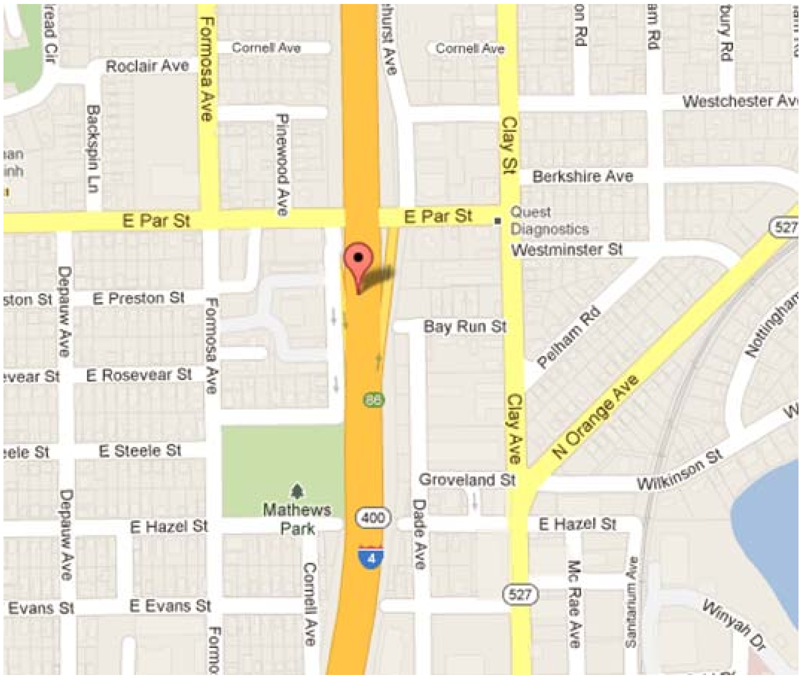
Figure 4-8 Incident Frequency and Average Incident Duration for Different Number of Lane Blockages along the I-4 WB Segment

4.3.2 Incident Impacts

For this case study, two locations (reference points) along the study corridor were identified for further analysis of incident impacts. One location is on the eastbound direction, and another is on the westbound direction, as shown in Figure 4-9. The impacts of one-lane blockage incidents at these two locations are discussed in this section.



(a) I-4 EB Reference Point (28.6295, -81.38583)



(b) I-4 WB Reference Point (28.58132, -81.37711)

Figure 4-9 Incident Reference Points Selected for Further Impact Analysis

Table 4-1 presents the results of the analysis of average incident duration, maximum queue length, and secondary incident probability for one-lane blockage incidents that occurred at the two incident reference points. In order to compare the results estimated from both the data-based method and queuing analysis, only those incidents with available detector data were included in the analysis. Therefore, the incident impacts were not analyzed for the PM peak period at the EB reference point due to missing detector data. The average incident duration listed in this table varied from 2 minutes to about 30 minutes. For the eastbound incidents, the maximum queue length ranges from 1.15 miles to 4.5 miles based on real-world data, and from 0.11 mile to 3.29 miles based on queuing analysis. The corresponding secondary incident probability is about 4.4% - 13.61% based on real-world data, and about 3.37% - 11.1% based on queuing analysis. This indicates that in this case study, queuing analysis produces a slightly shorter queue length and lower probability of secondary incident, compared to the real-world data-based method. Similar conclusions can be reached based on the results for the westbound reference point, as shown in Table 4-1.

The results of incident delay, fuel consumption and emissions for one-lane blockage incidents that occurred at the eastbound and westbound reference points are presented in Table 4-2 and Table 4-3, respectively. A comparison of the results obtained from the data-based method to those from the queuing analysis shows that the incident impacts estimated from the queuing analysis are more severe than those obtained using the data-based method at the eastbound reference point. The opposite is observed at the westbound reference point. Such differences may be caused by the fact that the data-based method takes the background congestion (that is, recurrent congestion) into consideration when using historical travel time, while the queuing analysis does not capture such impacts and only estimates incident delays.

Table 4-1 Incident Duration, Maximum Queue Length and Secondary Incident Probability for One-Lane Blockage Incidents

Reference Point	Time Period	Total Number of Lanes	Number of Incidents	Incident Duration (Min.)	Data- Based Analysis		Queuing Analysis	
					Maximum Queue Length (Miles)	Secondary Incident Probability	Maximum Queue Length (Miles)	Secondary Incident Probability
EB	AM	3	1	16.92	1.7	7.02%	1.29	6.55%
		4	1	7.52	1.15	4.4%	0.11	3.68%
	MD*	3	3	37.7	2.45~4.5	4.59%-13.61%	0.64~3.29	3.37%-11.1%
WB	AM	4	1	12.62	2.25	4.29%	0.56	3.22 %
	MD	3	1	2.03	1.7	1.7 %	0.13	1.3 %
		4	3	30.23	0~2.7	2.36%~7.95 %	0.06~0.55	1.94 %~5.92%
	PM	3	1	7.58	1.7	2.42 %	0.47	1.96 %

Note: “MD” refers to Midday.

Table 4-2 Incident Delay, Fuel Consumption and Emissions for One-Lane Blockage Incidents at the EB Reference Point

Period	Impacts	Data-Based Analysis		Queuing Analysis	
		Values	Dollar Value	Values	Dollar Value
AM	Delay	127.35 (VHT)	$2,614.83	857.22 (VHT)	$17,601.04
	Gas Consumption	215.73 (Gallons)	$755.07	770.81 (Gallons)	$2,697.83
	Diesel Consumption	26.88 (Gallons)	$107.53	119.32 (Gallons)	$477.30
	CO Emission	0.046 (Tons)	$177.22	0.081 (Tons)	$315.01
	HC Emission	0.004 (Tons)	$7.59	0.0088 (Tons)	$15.61
	NOx Emission	0.004 (Tons)	$15.97	0.006 (Tons)	$22.39
MD	Delay	644.85 (VHT)	$13,240.51	3,339.77 (VHT)	$68,574.83
	Gas Consumption	971.64 (Gallons)	$3,400.75	3,003.12 (Gallons)	$10,510.92
	Diesel Consumption	132.42 (Gallons)	$529.68	464.90 (Gallons)	$1,859.58
	CO Emission	0.236 (Tons)	$918.05	0.316 (Tons)	$1,227.76
	HC Emission	0.027 (Tons)	$48.52	0.034 (Tons)	$60.67
	NOx Emission	0.018 (Tons)	$67.79	0.024 (Tons)	$87.68

Table 4-3 Incident Delay, Fuel Consumption and Emissions for One-Lane Blockage Incidents at the WB Reference Point

Period	**Impacts**	**Data-Based Analysis**		**Queuing Analysis**	
		Values	Dollar Value	Values	Dollar Value
AM	Delay	111.01 (VHT)	$2,011.08	126.37 (VHT)	$2,289.38
	Gas Consumption	164.29 (Gallons)	$575.01	114.38 (Gallons)	$400.33
	Diesel Consumption	9.10 (Gallons)	$36.43	7.92 (Gallons)	$31.66
	CO Emission	0.034 (Tons)	$131.42	0.012 (Tons)	$44.88
	HC Emission	0.003 (Tons)	$5.26	0.001 (Tons)	$2.11
	NOx Emission	0.003 (Tons)	$12.11	0.0008 (Tons)	$2.96
MD	Delay	665.57 (VHT)	$12,057.91	30.670 (VHT)	$5,556.57
	Gas Consumption	1,036.00 (Gallons)	$3,626.01	277.61 (Gallons)	$971.65
	Diesel Consumption	60.42 (Gallons)	$241.69	19.21 (Gallons)	$76.85
	CO Emission	0.265 (Tons)	$1,031.00	0.029 (Tons)	$112.78
	HC Emission	0.030 (Tons)	$54.06	0.003 (Tons)	$5.50
	NOx Emission	0.021 (Tons)	$79.89	0.002 (Tons)	$7.84

Table 4-3 Incident Delay, Fuel Consumption and Emissions for One-Lane Blockage Incidents at the WB Reference Point (Continued)

Period	Impacts	Data-Based Analysis		Queuing Analysis	
		Values	Dollar Value	Values	Dollar Value
PM	Delay	67.50 (9VHT)	$1,222.9217	62.38(VHT)	$1,130.18
	Gas Consumption	106.15 (Gallons)	$371.52	56.47 (Gallons)	$197.63
	Diesel Consumption	6.31 (Gallons)	$25.24	3.91 (Gallons)	$15.63
	CO Emission	0.024 (Tons)	$91.44	0.006 (Tons)	$22.97
	HC Emission	0.002 (Tons)	$3.74	0.0006 (Tons)	$1.13
	NOx Emission	0.002 (Tons)	$8.91	0.0004 (Tons)	$1.63

4.4 Comparison of Capacity versus Operation Improvements

An important potential application of the analyses in Chapters 3 and 4 is to be used in comparing the benefits and costs of capacity improvements versus those of providing more resources to support incident management. The annual benefits of eliminating or reducing the impacts of one or more recurrent bottlenecks can be calculated based on the analysis of Chapter 3. The annual benefits of reducing the incident duration by certain amounts can be also calculated utilizing an analysis similar to the one presented in Chapter 4. The estimated benefits for the two types of improvements can be compared with their estimated costs to support investment decisions.

4.5 References

Skabardonis A. and M. Mauch. *FSP* [Freeway Service Patrol] *Beat Evaluation and Predictor Models: Users Manual,* Research Report, No. UCB-ITS-RR-2005-XX, Institute of Transportation Studies, University of California-Berkeley, California, 2005.

Xiao, Y. Hybrid Approaches to Estimate Freeway Travel Times Using Point Traffic Detector Data. Ph.D. Dissertation, Florida International University, Miami, FL, 2011.

Zhan, C., A. Gan, and M. Hadi. Identify Secondary Crashes and Their Contributing Factors. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 2102, 2009, pp. 68-75.

5 SunGuide RTMS Simulator

5.1 Related SunGuide Software Information

The SunGuide TMC software is a set of ITS software that allows for the control of roadway devices, as well as information exchange across transportation agencies. The software represents a common software base that has been deployed by FDOT districts throughout the state of Florida. Figure 5-1 provides a graphical view of Release 5.0 of the SunGuide software.

SunGuide utilizes a tree-based application Data Bus that stores the real-time data in the memory of the server running it. The SunGuide Data Bus subsystem provides both a real-time exchange of data between the subsystems and clients of the SunGuide and a framework to which processes attach and exchange data with other subsystems. Depositing data to the bus is done in a structured, common format, and extracting data from the bus requires an appropriate privilege level. The primary advantage of this architecture is performance because Data Bus access is extremely fast, as opposed to having all of the real-time data moving through a long-term store such as relational database.

A subsystem in the SunGuide environment is a software process that implements a set of closely related functional requirements. A subsystem provides data to the Data Bus to make the data available to other SunGuide subsystems and interfaces. Examples of these subsystems are DMS, CCTV Control, Video Switching, Video Wall, Traffic Detection, HAR, RWIS, Safety Barriers, etc. When processes log into subsystems (e.g., the Graphical User Interface logs into the DMS subsystem), they become “clients” of the subsystem to which they log-on. As a client, they can subscribe for status data, which is typically retrieved from the Data Bus. They can also transmit command information if the subsystem supports this capability. These subsystems can be “clients” of other subsystems as well. The Data Bus process is the only process that connects directly to subsystems, as all other clients connect to subsystems through a connection to the Data Bus.

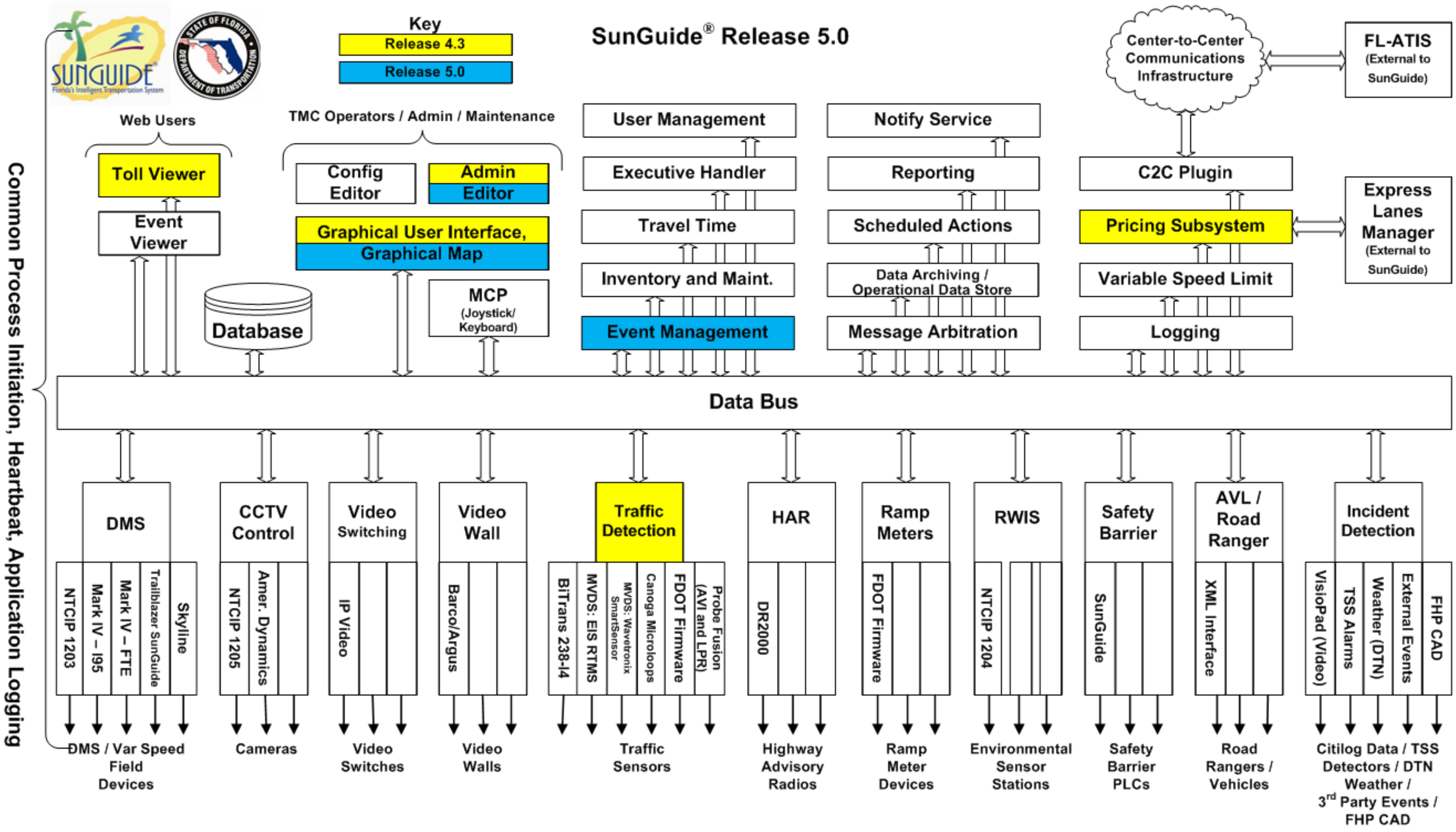


Figure 5-1 Graphical View of Version 5.0 of the SunGuide Software

The SunGuide requires the development of drivers associated with the aforementioned subsystems. A driver is utilized to implement a vendor-specific protocol or an ITS standard protocol. Drivers do not connect directly with the Data Bus; rather, each driver communicates with a subsystem. The details of the particular protocol being implemented are only important for the communication between the device and the driver. The subsystems do not communicate using these protocols, but rather by using standard XML messages. This approach allows a subsystem to be able to communicate with the devices of various vendors by developing a driver that communicates using the protocol of the vendor's device. The subsystem treats all devices in the same manner, independent of the protocol. The SunGuide architecture utilizes XML Interface Control Documents (ICDs) to provide the subsystems with a user-friendly interface.

The reason for the tool developed in this study is to make use of virtual traffic detectors to "play back" historical detector data for the purpose of operator training. This was done by interfacing with the SunGuide Transportation Sensor Subsystem (TSS), using the existing SunGuide device drivers. The SunGuide TSS acquires data from detection field devices (speed, volume, and occupancy) and communicates information between these detector device drivers and the SunGuide Data Bus. The TSS subsystem currently supports a number of device drivers, including BiTrans B238-I4, Remote Traffic Microwave Sensor (RTMS) by Electronic Integrated Systems (EIS), Smart Sensors by Wavetronix, 3M Canoga Microloops, FDOT Firmware, and Probe Fusion (AVL and LPR).

For the TSS subsystem, detector mapping information and roadway geometry are retrieved from the back-end Oracle database at startup. The user can add and map additional detectors, update or remove existing detectors, modify the polling cycles, or update the roadway geometry information, etc. The TSS subsystem can then send an addDetectorReq message to each driver containing the specified detectors. After receiving a response from the driver, the mapDetectorReq message is sent to map the zone numbers of the detector to links and lanes. Once a detector has been mapped to links and lanes, threshold values (e.g., for speed and/or occupancy) may be set for the links/lanes. After receiving the request from the TSS subsystem, the driver begins polling the detectors with the polling cycle specified in the addDetectorReq message. For each poll, the driver will send a linkUpdateMsg to the TSS subsystem, which contains detector data updates on speed, volume, and occupancy.

5.2 RTMS Simulator Program

As stated earlier, this study tool allows for the feeding of historical TSS data to the SunGuide software, to create a “play back” environment that supports operator training and possibly SunGuide updates diagnostics. The previous research established a bridge program (called “simulator”) between the virtual detectors and the SunGuide TSS subsystem. The connection is established between the historical TSS data and the SunGuide TSS subsystem, using existing device protocols with the implementation of the simulator programs. The protocol used is associated with the RTMS detector. The simulator reads the historical TSS output and communicates with the SunGuide TSS subsystem using existing product drivers. From the point-of-view of the SunGuide system, there is no difference in communicating and using the data of the virtual or historical data and real-world data from field devices. EIS Inc., the vendor of the RTMS detector, has developed a primitive RTMS simulator that can simulate one RTMS detector at a time. Thus, to reduce the requisite developmental effort, the primitive RTMS simulator was enhanced in the previous research conducted by the research team to allow the use of historical TSS output as “input” to the SunGuide TSS subsystem, and to allow support for the simultaneous simulation of multiple virtual detectors on one computer, using the multi-thread mechanism. With these enhancements, the simulator program supports simulating multiple detectors on the same computer and transmitting data to the SunGuide system. To improve performance and minimize data sharing or dead lock issues, the selected data files are pre-uploaded into a local Access database and an index created for quick data retrieval by the simulator program, as needed.

5.3 Using RTMS Simulator Program to "Play Back" Historical TSS Data

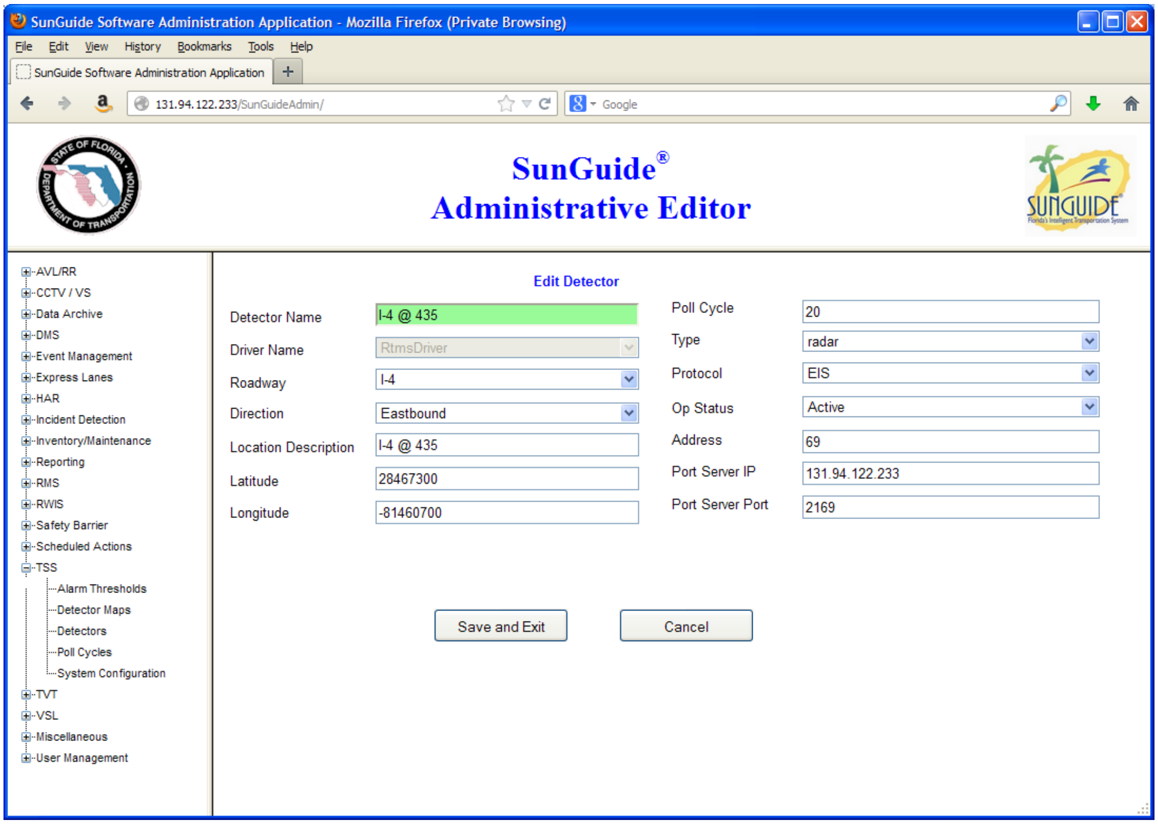
5.3.1 Pre-Requisite to Run the Simulator

The user must ensure that the Oracle client run-time libraries are installed on the computer that will run the simulators, as the program will need to directly retrieve detector configuration data from the SunGuide database.

5.3.2 Coding Virtual RTMS Detectors in SunGuide System

The user must then check that the virtual RTMS detectors are coded in the SunGuide system, with the IP address pointing to the computer that will run the RTMS simulator program, and check that the assigned port numbers are not conflicting with any other programs as well (as a general rule, port numbers below 255 are reserved for system usage).

Figure 5-2 shows the Administrator interface in the SunGuide system to specify the virtual RTMS detectors. The operators should specify “EIS” as the protocol type, and enter the IP address of the computer running the RTMS simulator program as the “Port Server IP.” The RTMS simulator program will automatically retrieve the information for all RTMS detectors that have a “Port Server IP” address pointing to the computer running the program.



Edit Detector

Detector Name	I-4 @ 435	Poll Cycle	20
Driver Name	RtmsDriver	Type	radar
Roadway	I-4	Protocol	EIS
Direction	Eastbound	Op Status	Active
Location Description	I-4 @ 435	Address	69
Latitude	28467300	Port Server IP	131.94.122.233
Longitude	-81460700	Port Server Port	2169

Figure 5-2 Administrator Interface in the SunGuide Software

5.3.3 Starting RTMS Simulator Program

The major interface of the RTMS simulator program is shown in Figure 5-3. There are two menu items that an end user can select from, “File” or “Help.” The “File” menu provides the items that are available for the simulator program, and the “Help” item provides license and copyright information.

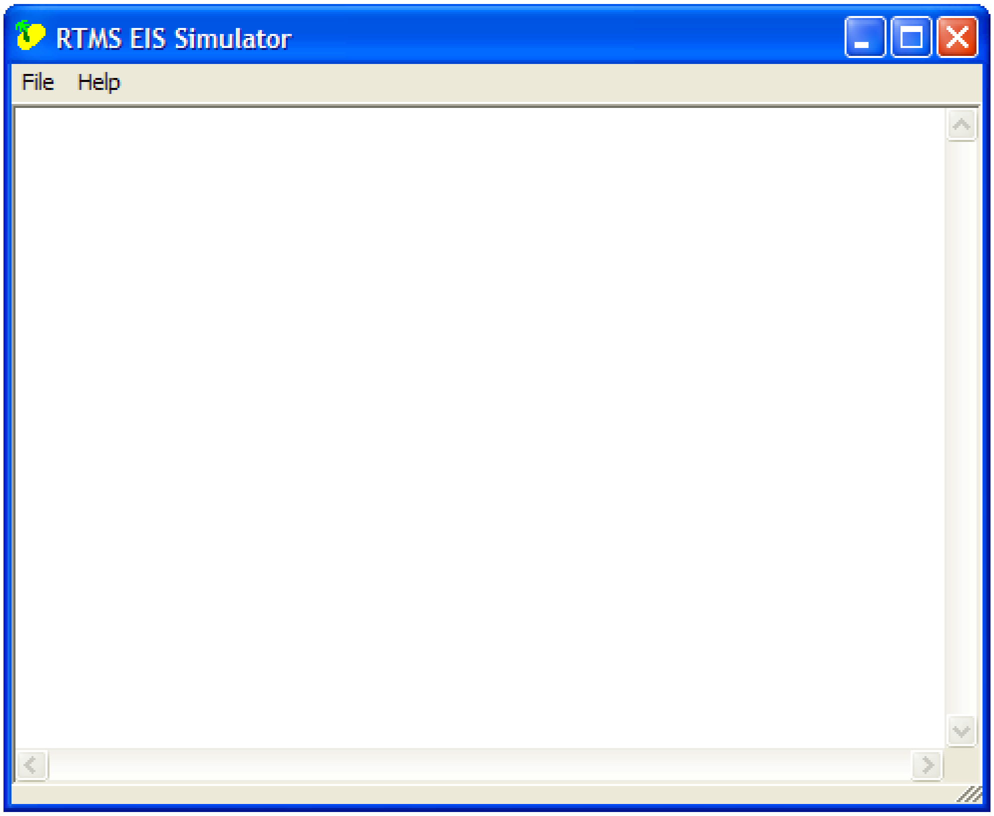


Figure 5-3 Startup Interface for RTMS Simulator

When an end user clicks on the “File” menu, six possible menu items are displayed, as shown in Figure 5-4. A user can choose to “Start Server,” “Stop Server,” “Configure Data,” “Debug Logging,” “Clear Display,” or “Exit.”

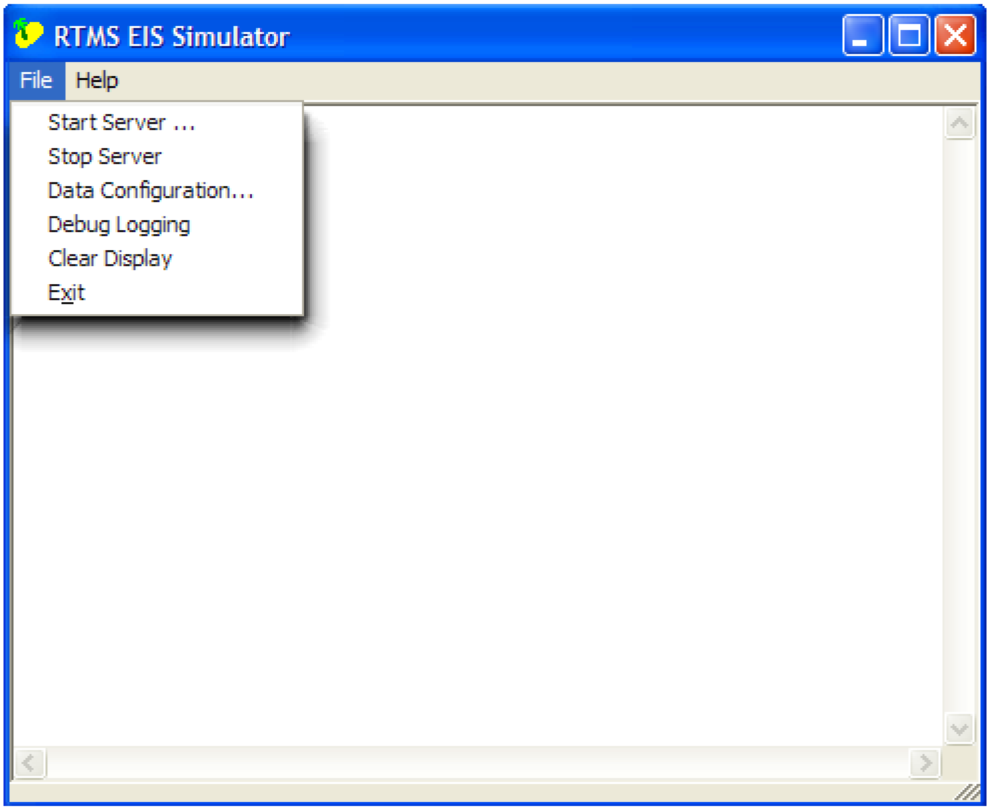


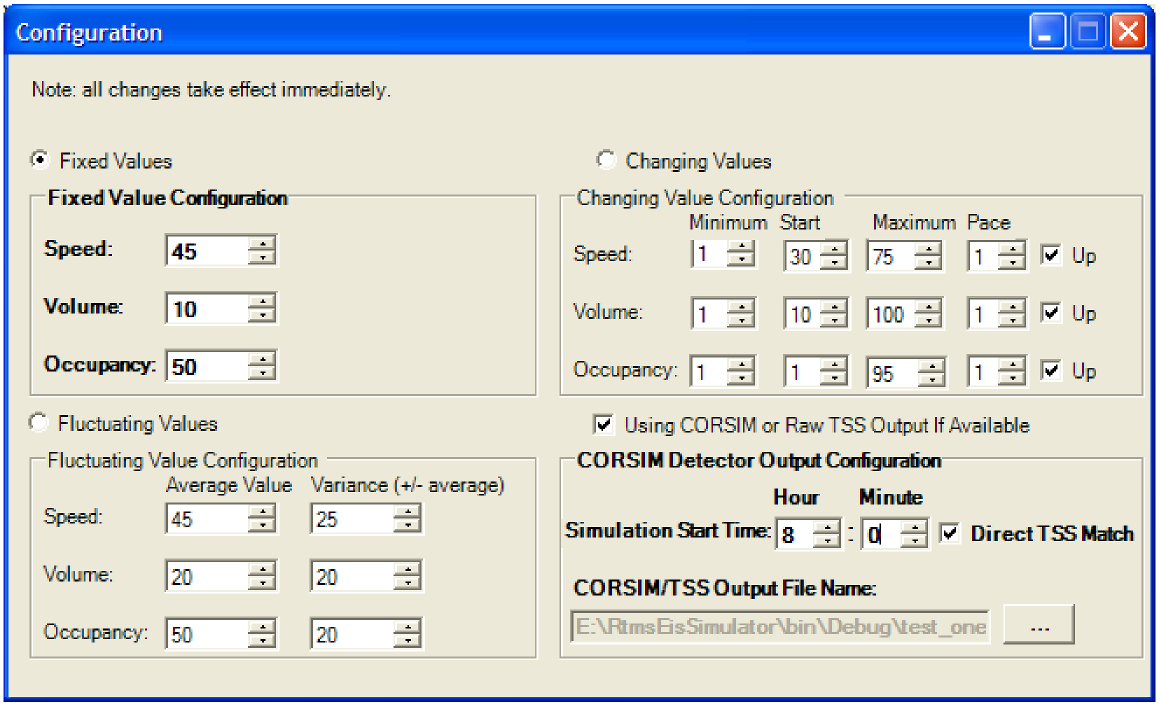
Figure 5-4 RTMS Simulator Interface

5.3.4 Data Configuration

At any time, the end user can choose “Configure Data” under the “File” menu to specify how and what data will be populated to the SunGuide system. As shown in Figure 5-5, there are four possible ways to feed data into the SunGuide system: fixed values, fluctuating values, changing values, or using CORSIM/TSS outputs. The default option is to use fixed values. Once selected, the desired option is indicated in bold. The meanings of the four data feeding methods are as follows:

- Fixed values: The simulator program will feed the SunGuide detectors with fixed speed, volume, and occupancy data values specified by the user. The range for speed values is from 0 to 100 mph. The range for volume is from 0 to 100 vehicles per reporting period (every 20 seconds). The range for occupancy is from 0% to 100%
- Fluctuating values: The simulator program will feed the SunGuide detectors with fluctuating speed, volume, and occupancy data, which is calculated using average and variance values specified by the end user.

- Changing values: The simulator program will feed the SunGuide detectors with user-specified, non-fixed values. The end user needs to specify the minimum, maximum, start, and pace (i.e., the value to change for each time interval) values of the speed, volume, and occupancy for detectors. The end user can also specify if the values will go up or down.
- CORSIM or raw TSS output: The simulator program will feed the SunGuide detectors with the matched detector outputs from CORSIM or the historical TSS output data. When this option is selected and the "Direct TSS Match" checkbox is checked, the simulator knows that the end user wants to directly input historical TSS output to the SunGuide system. If the "Direct TSS Match" checkbox is not checked, the CORSIM simulation output will be used. In any event, the end user should specify a text file (either from CORSIM output or historical TSS output) as the input to the simulator program. In addition to specifying the CORSIM/TSS output file, the end user can also specify when to start the use of CORSIM simulation or TSS outputs to allow for the use of a combination of CORSIM/TSS outputs and one of the other three methods described above. The simulator program can automatically determine the length of the period covered by CORSIM/TSS output, based on the data in the CORSIM/TSS output file. Outside this time period, the simulator program will feed the SunGuide detectors with one of the previous three methods as chosen by the end user. Figure 5-5 shows an example of this scenario. Suppose in this case that the historical TSS output is for a whole day (from 00:00 to 24:00); the RTMS simulator program will then feed the SunGuide system with only TSS data from 8:00 (which is the Simulation Start Time) to 24:00. However, if the historical TSS output is from 10:00 to 24:00, the "Fixed Values" for the time period from 8:00 to 10:00 will be fed into the SunGuide System first, and subsequently, the historical TSS data will be fed into the SunGuide system from 10:00 to 24:00.



Note: all changes take effect immediately.

● Fixed Values

Fixed Value Configuration

Speed: 45
Volume: 10
Occupancy: 50

○ Changing Values

Changing Value Configuration

	Minimum	Start	Maximum	Pace	
Speed:	1	30	75	1	☑ Up
Volume:	1	10	100	1	☑ Up
Occupancy:	1	1	95	1	☑ Up

○ Fluctuating Values

Fluctuating Value Configuration

	Average Value	Variance (+/- average)
Speed:	45	25
Volume:	20	20
Occupancy:	50	20

☑ Using CORSIM or Raw TSS Output If Available

CORSIM Detector Output Configuration

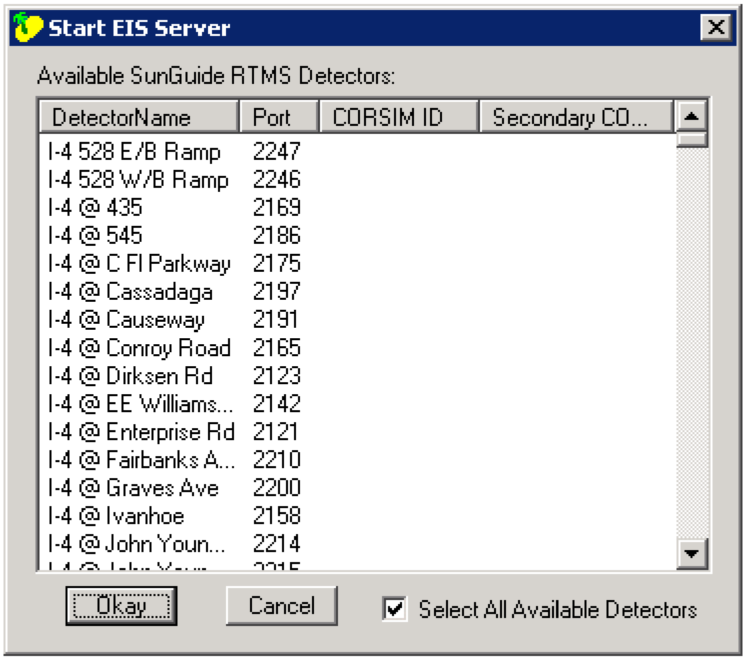
	Hour		Minute	
Simulation Start Time:	8	:	0	☑ **Direct TSS Match**

CORSIM/TSS Output File Name: E:\RtmsEisSimulator\bin\Debug\test_one

Figure 5-5 RTMS Simulator Interface for “Data Configuration”

5.3.5 Starting RTMS Simulator Server

When clicking on “Start Server” under the “File” menu, the pop-up window shown in Figure 5-6 is displayed. This display includes a list of the available SunGuide RTMS detectors, which have been specified in the SunGuide system using the Administrators interface in the previous step. In addition to displaying the SunGuide Detector Name, the pop-up window also displays the detector port number. If CORSIM output is configured, CORSIM ID and secondary CORSIM ID (for ramps) will also be displayed. The reason for having two detector IDs for detectors covering on/off-ramp lanes in CORSIM is that CORSIM requires separately coding the detectors for freeway mainline and ramps with different IDs.

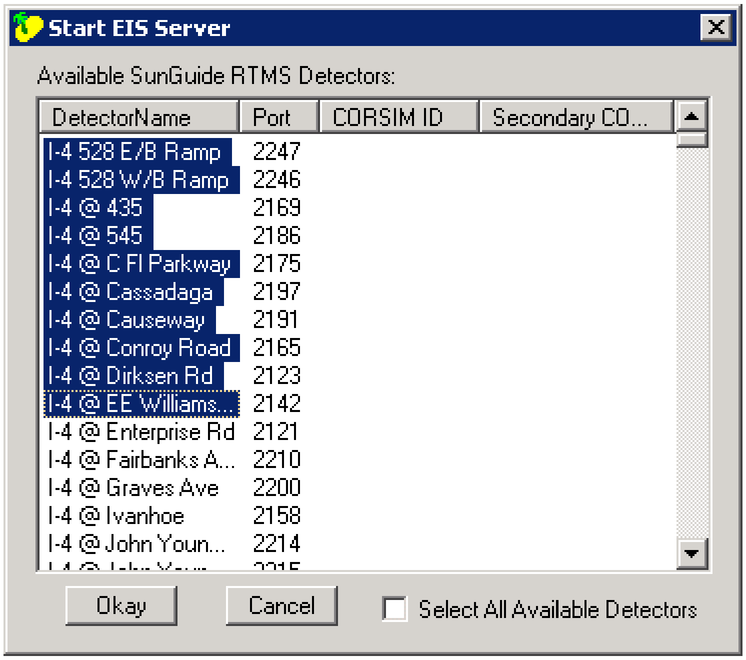


DetectorName	Port	CORSIM ID	Secondary CO...
I-4 528 E/B Ramp	2247		
I-4 528 W/B Ramp	2246		
I-4 @ 435	2169		
I-4 @ 545	2186		
I-4 @ C Fl Parkway	2175		
I-4 @ Cassadaga	2197		
I-4 @ Causeway	2191		
I-4 @ Conroy Road	2165		
I-4 @ Dirksen Rd	2123		
I-4 @ EE Williams...	2142		
I-4 @ Enterprise Rd	2121		
I-4 @ Fairbanks A...	2210		
I-4 @ Graves Ave	2200		
I-4 @ Ivanhoe	2158		
I-4 @ John Youn...	2214		

☑ Select All Available Detectors

Figure 5-6 RTMS Simulator Interface for "Start Server"

By default, all available detectors are chosen to run and wait on the designated ports for a connection request. If an end user wants to select only a few of the detectors, the user can hold the SHIFT or CTRL key and use the mouse pointer to select the detectors, as shown in Figure 5-7.

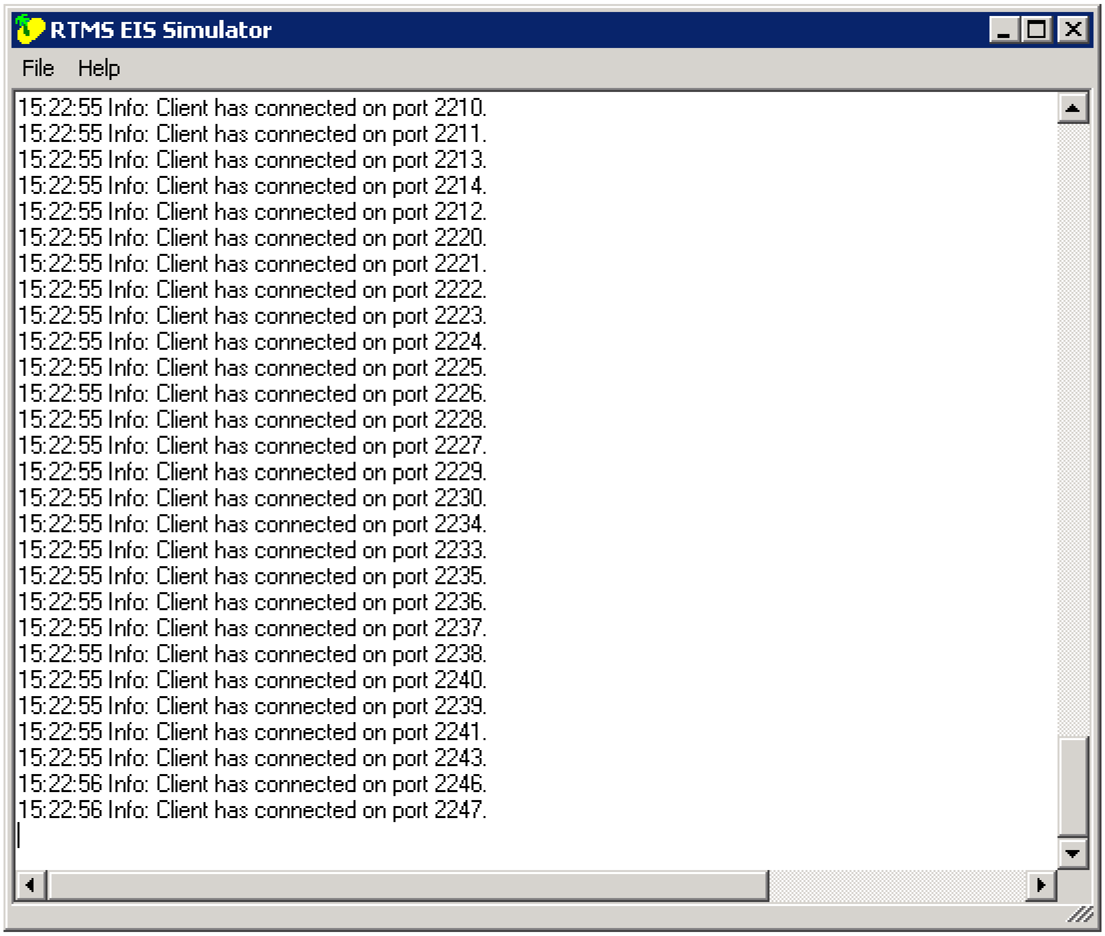


DetectorName	Port	CORSIM ID	Secondary CO...
I-4 528 E/B Ramp	2247		
I-4 528 W/B Ramp	2246		
I-4 @ 435	2169		
I-4 @ 545	2186		
I-4 @ C Fl Parkway	2175		
I-4 @ Cassadaga	2197		
I-4 @ Causeway	2191		
I-4 @ Conroy Road	2165		
I-4 @ Dirksen Rd	2123		
I-4 @ EE Williams...	2142		
I-4 @ Enterprise Rd	2121		
I-4 @ Fairbanks A...	2210		
I-4 @ Graves Ave	2200		
I-4 @ Ivanhoe	2158		
I-4 @ John Youn...	2214		

☐ Select All Available Detectors

Figure 5-7 RTMS Simulator Interface for Detector Selection

After selecting the list of detectors to simulate, the end user can click on the "Okay" button to start the simulators and listen on the designated ports for SunGuide connection requests. Once the connections to the SunGuide System are created, the connection information is shown on the user interface, as illustrated in Figure 5-8, and the RTMS simulator program will begin feeding data into the SunGuide System.



```
15:22:55 Info: Client has connected on port 2210.
15:22:55 Info: Client has connected on port 2211.
15:22:55 Info: Client has connected on port 2213.
15:22:55 Info: Client has connected on port 2214.
15:22:55 Info: Client has connected on port 2212.
15:22:55 Info: Client has connected on port 2220.
15:22:55 Info: Client has connected on port 2221.
15:22:55 Info: Client has connected on port 2222.
15:22:55 Info: Client has connected on port 2223.
15:22:55 Info: Client has connected on port 2224.
15:22:55 Info: Client has connected on port 2225.
15:22:55 Info: Client has connected on port 2226.
15:22:55 Info: Client has connected on port 2228.
15:22:55 Info: Client has connected on port 2227.
15:22:55 Info: Client has connected on port 2229.
15:22:55 Info: Client has connected on port 2230.
15:22:55 Info: Client has connected on port 2234.
15:22:55 Info: Client has connected on port 2233.
15:22:55 Info: Client has connected on port 2235.
15:22:55 Info: Client has connected on port 2236.
15:22:55 Info: Client has connected on port 2237.
15:22:55 Info: Client has connected on port 2238.
15:22:55 Info: Client has connected on port 2240.
15:22:55 Info: Client has connected on port 2239.
15:22:55 Info: Client has connected on port 2241.
15:22:55 Info: Client has connected on port 2243.
15:22:56 Info: Client has connected on port 2246.
15:22:56 Info: Client has connected on port 2247.
```

Figure 5-8 RTMS Simulator Interface for Detectors Connection

5.3.6 Detector Operations in SunGuide System

After the connection between the SunGuide System and the RTMS simulator program has been created, the operator can perform detector operations, such as checking the detector status and the link status in the SunGuide system as if all the data are from the real detectors. Figure 5-9 shows an example of the map interface of the SunGuide system with the detectors on an I-4 segment located close to the Fairbanks interchange for an incident day. The links in red in the map show that a queue has formed due to an incident in the southbound direction on I-4.

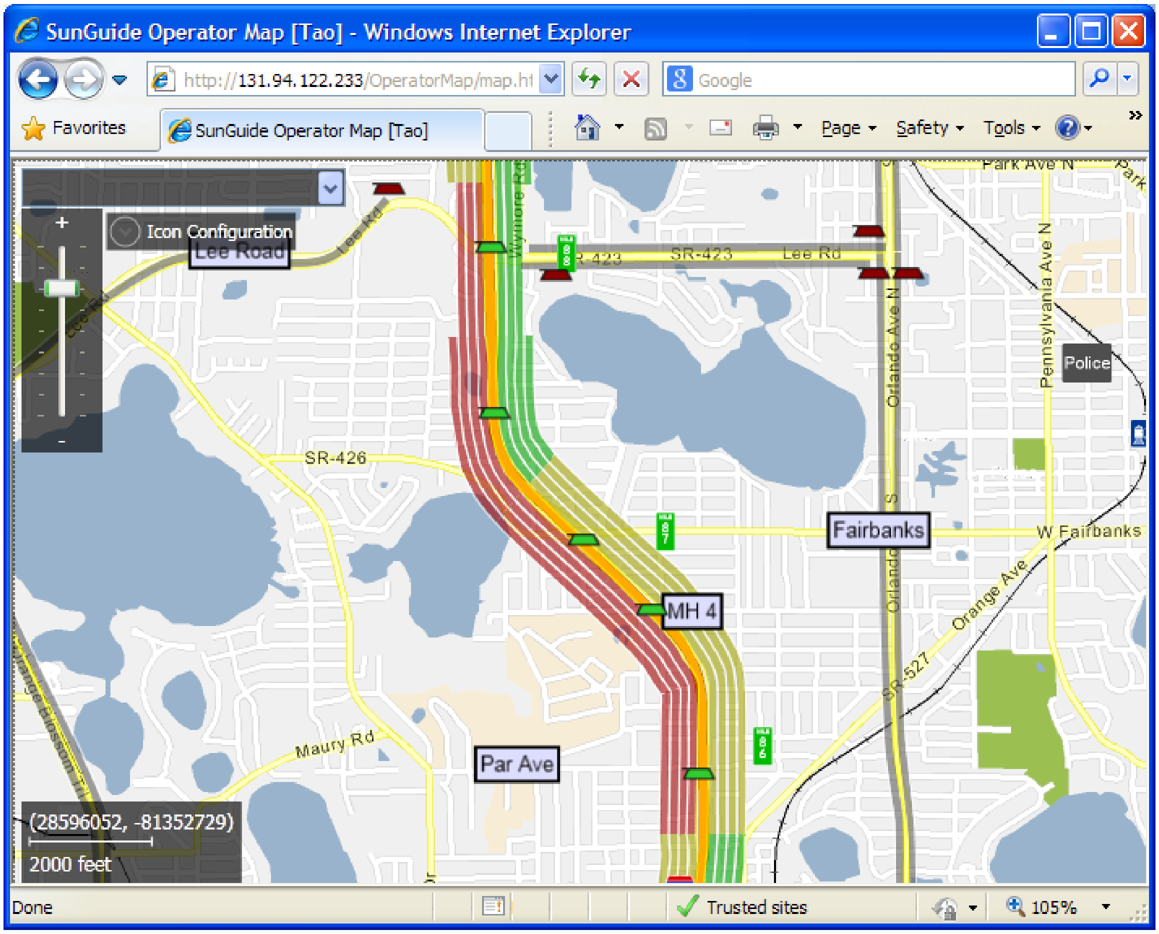
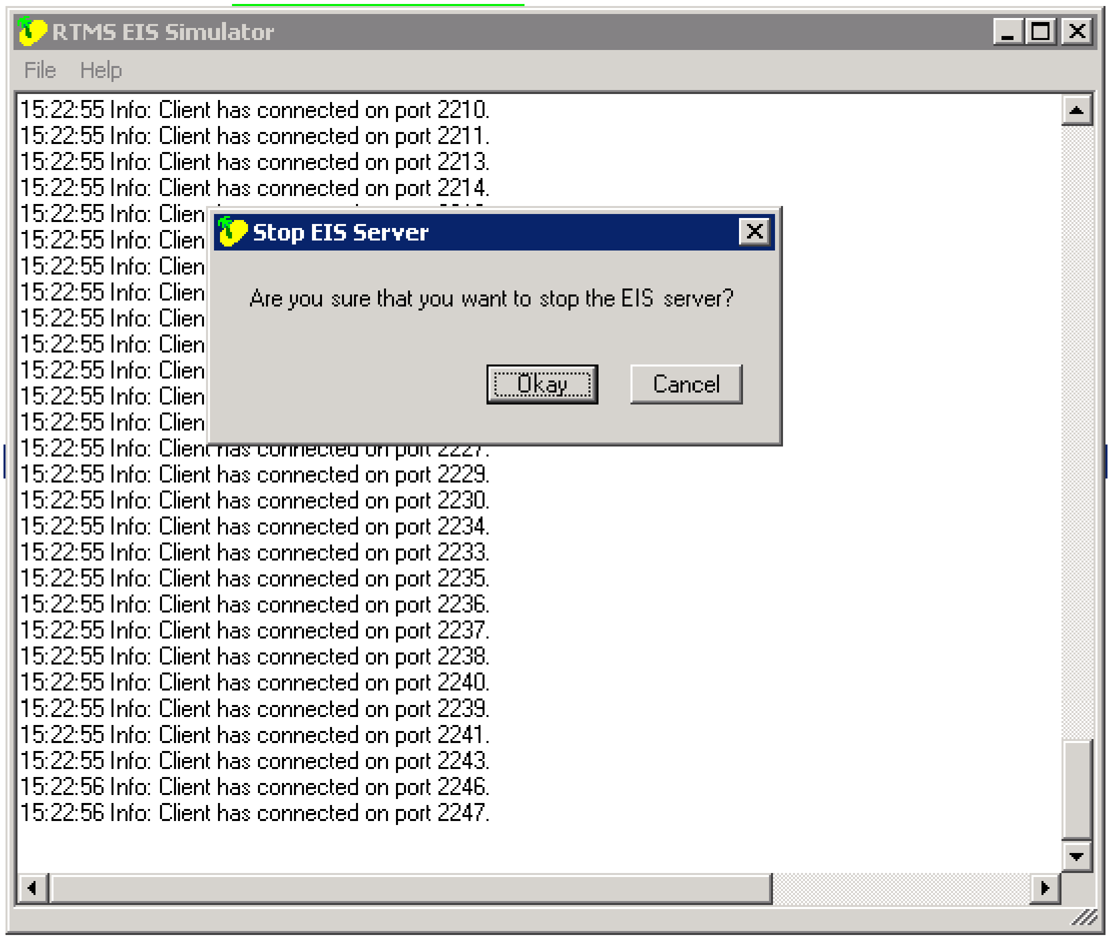


Figure 5-9 Detector Status in the SunGuide System

5.3.7 Stopping RTMS Simulator Server

If the user wants to stop the simulators at any time, they can choose “Stop Server” under the “File” menu, and a dialog box will be displayed that will ask for confirmation of this action, as shown in Figure 5-10. If the user chooses “Okay,” all of the simulators (one for each detector) will stop listening on the designated ports, and the simulator program will stop sending data for established connections to the SunGuide system.



```
15:22:55 Info: Client has connected on port 2210.
15:22:55 Info: Client has connected on port 2211.
15:22:55 Info: Client has connected on port 2213.
15:22:55 Info: Client has connected on port 2214.
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15:22:55 Info: Clien
15:22:55 Info: Client has connected on port 2227.
15:22:55 Info: Client has connected on port 2229.
15:22:55 Info: Client has connected on port 2230.
15:22:55 Info: Client has connected on port 2234.
15:22:55 Info: Client has connected on port 2233.
15:22:55 Info: Client has connected on port 2235.
15:22:55 Info: Client has connected on port 2236.
15:22:55 Info: Client has connected on port 2237.
15:22:55 Info: Client has connected on port 2238.
15:22:55 Info: Client has connected on port 2240.
15:22:55 Info: Client has connected on port 2239.
15:22:55 Info: Client has connected on port 2241.
15:22:55 Info: Client has connected on port 2243.
15:22:56 Info: Client has connected on port 2246.
15:22:56 Info: Client has connected on port 2247.
```

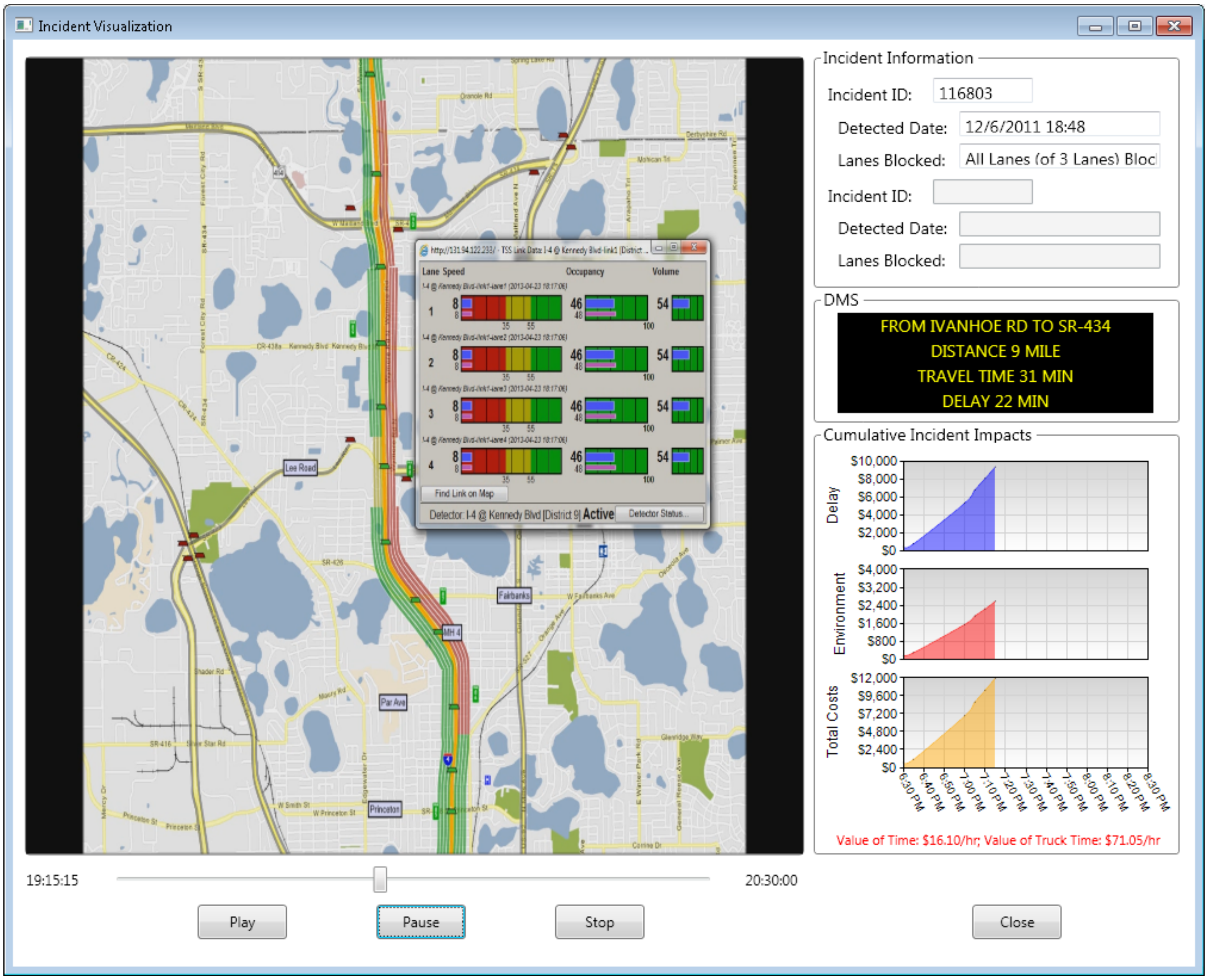
Are you sure that you want to stop the EIS server?

Figure 5-10 RTMS Simulator Interface for "Stop Server"

If the end user chooses the "Debug Logging" menu, a text file is generated at the back-end to log the program console outputs. This option is mainly for debugging issues and problems that may not be encountered by general users. When an end user selects the "Clear Display" menu, the interactive message for "virtual" detector waiting/connection will be eliminated. This option can be used to clean messages shown on the screen when clutter occurs. When an end user selects the "Exit" menu, the program will terminate.

5.4 Visualization of Incident Impacts

The "play back" of historical TSS data using the RTMS simulator can be applied to visualize incident impacts. For example, the "play back" of historical TSS data in the SunGuide operator map during incidents can be recorded as a video and integrated into a previously developed incident impacts visualization tool to simultaneously visualize the incident information and incident impacts. Figure 5-11 shows snapshots of this tool. As shown in this figure, the left= hand side of the user interface is used to play videos of the incidents and/or the SunGuide displays during the incident.. In this case study, it is a video recorded from the SunGide operator map, which shows the variations of queue length and speed with respect to time. Instead of playing a recorded SunGuide operator map video, a CCTV camera feeds video can also be used. The users have the options of playing, pausing, dragging, or stopping the video. The top part of right-hand side simultaneously displays the current incident information, including current active incidents, their detected dates, and number of lanes blocked. The middle part of the right-hand side emulates a display of a DMS, showing origin, destination, travel distance, current travel time and delay information. The bottom part of the right-hand side shows the additional cumulative incident delay, fuel consumption and emission costs that correspond to the timestamp shown in video. The cumulative total costs resulted from the incident are also displayed in the figure.



Incident ID: 116803

Detected Date: 12/6/2011 18:48

Lanes Blocked: All Lanes (of 3 Lanes) Bloc

Incident ID:

Detected Date:

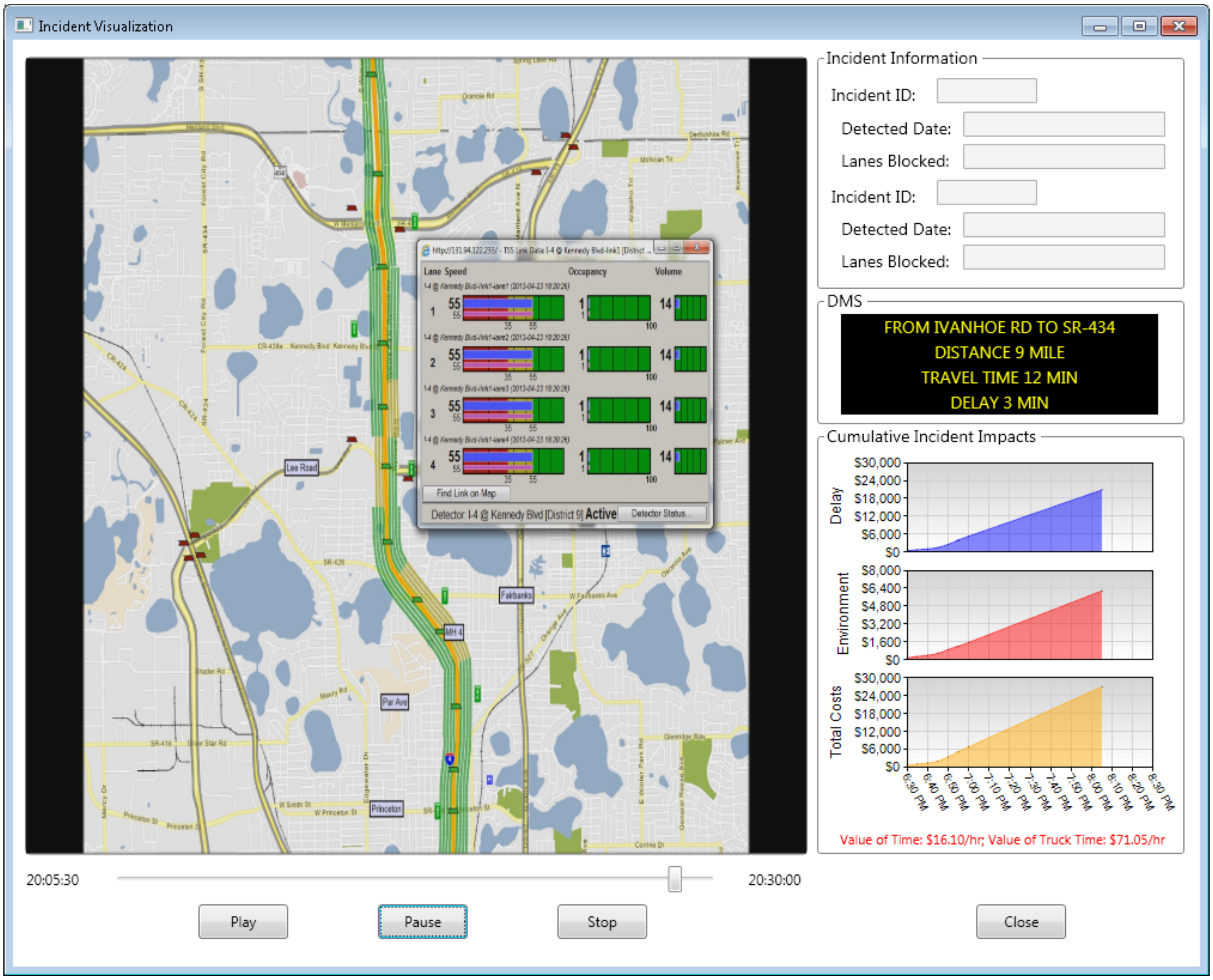
Lanes Blocked:

FROM IVANHOE RD TO SR-434
DISTANCE 9 MILE
TRAVEL TIME 31 MIN
DELAY 22 MIN

Value of Time: $16.10/hr; Value of Truck Time: $71.05/hr

(a)

Figure 5-111 Incident Impacts Visualization



Incident ID:
Detected Date:
Lanes Blocked:
Incident ID:
Detected Date:
Lanes Blocked:

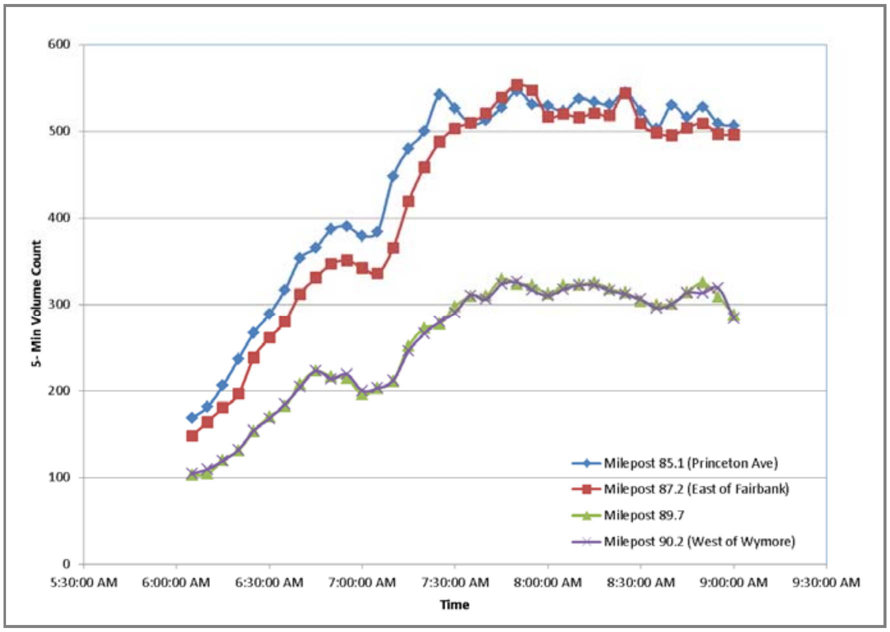
FROM IVANHOE RD TO SR-434
DISTANCE 9 MILE
TRAVEL TIME 12 MIN
DELAY 3 MIN

Value of Time: $16.10/hr; Value of Truck Time: $71.05/hr

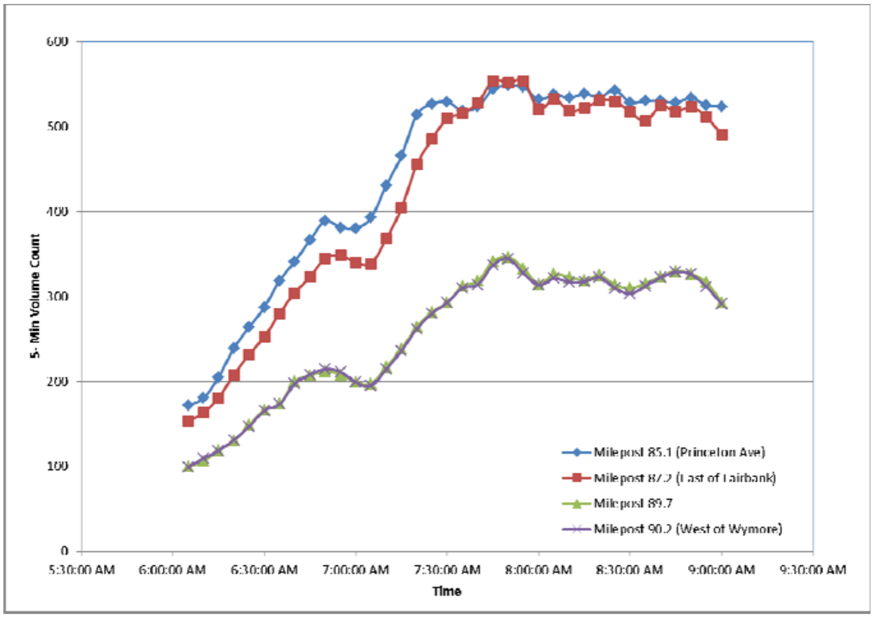
(b)

Figure 5-11 Incident Impacts Visualization (Continued)

Appendix A: Average Volume under Normal Conditions

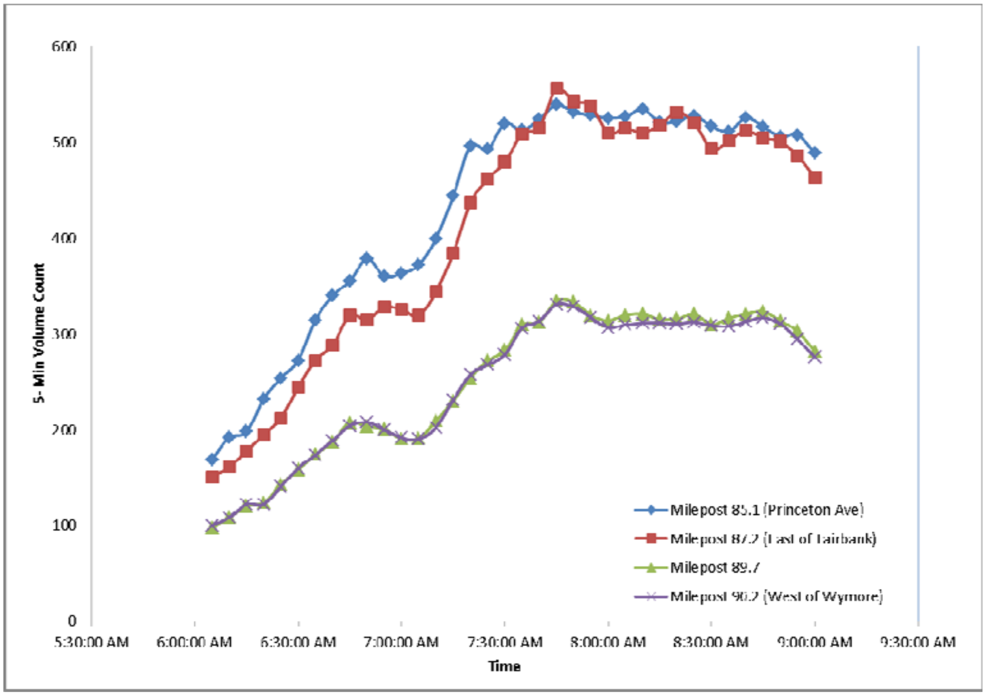


(a) Monday



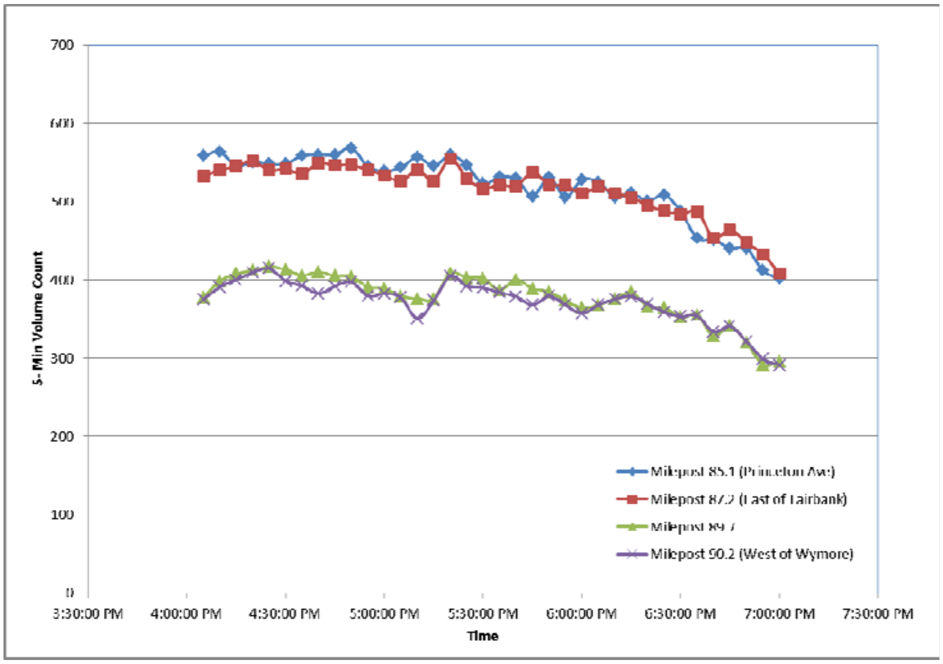
(b) Tuesday/Wednesday/Thursday

Figure A-1 Average Volume for I-4 EB Study Segment during AM Peak Period

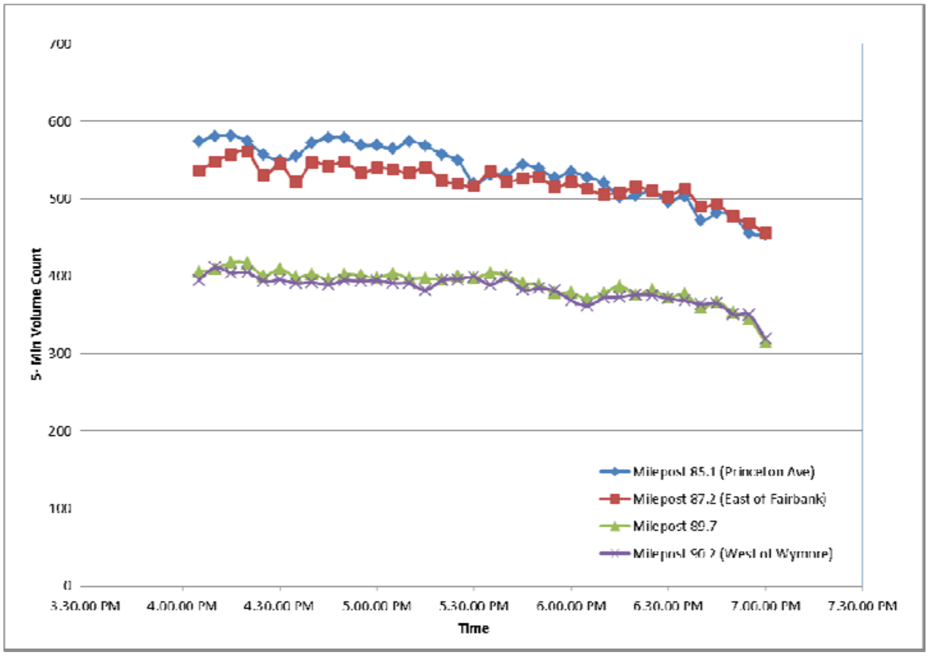


(c) Friday

Figure A-1 Average Volume for I-4 EB Study Segment during AM Peak Period (Continued)

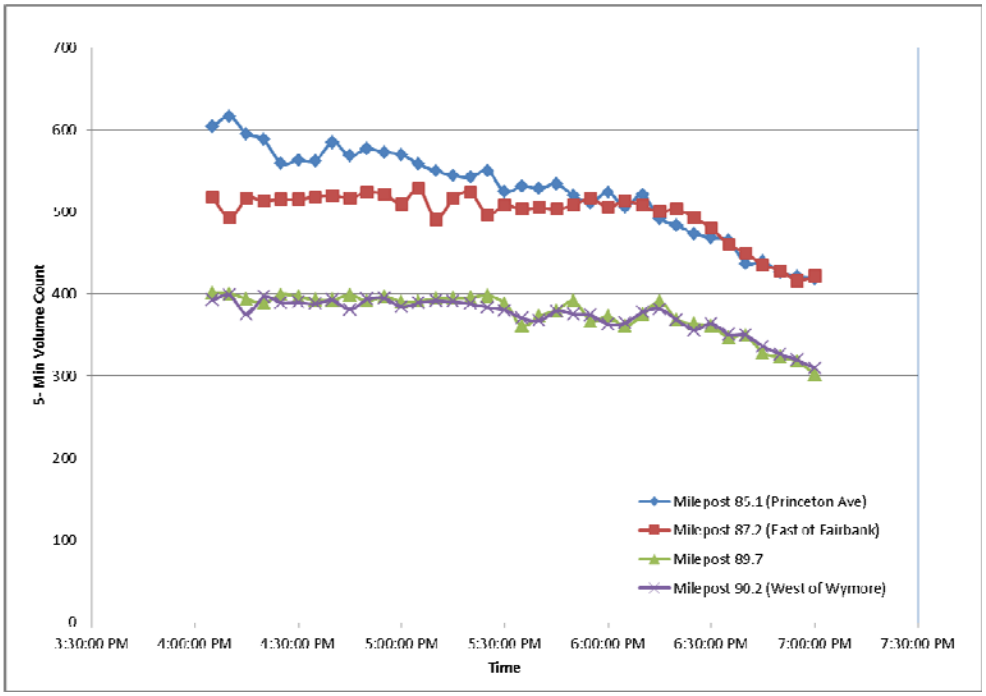


(a) Monday



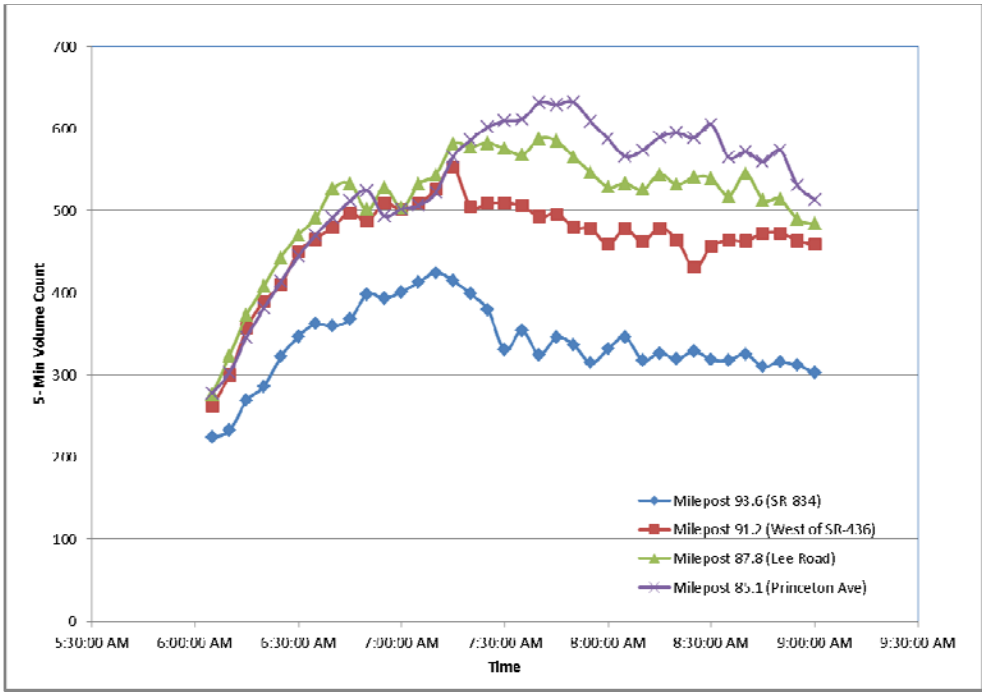
(b) Tuesday/Wednesday/Thursday

Figure A-2 Average Volume for I-4 EB Study Segment during PM Peak Period

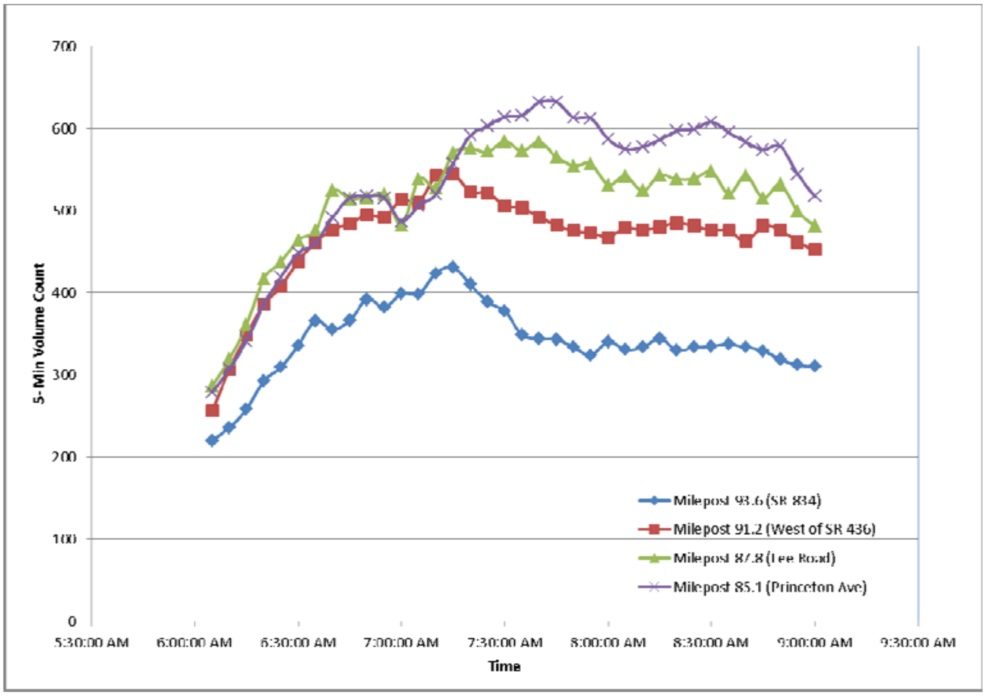


(c) Friday

Figure A-2 Average Volume for I-4 EB Study Segment during PM Peak Period (Continued)

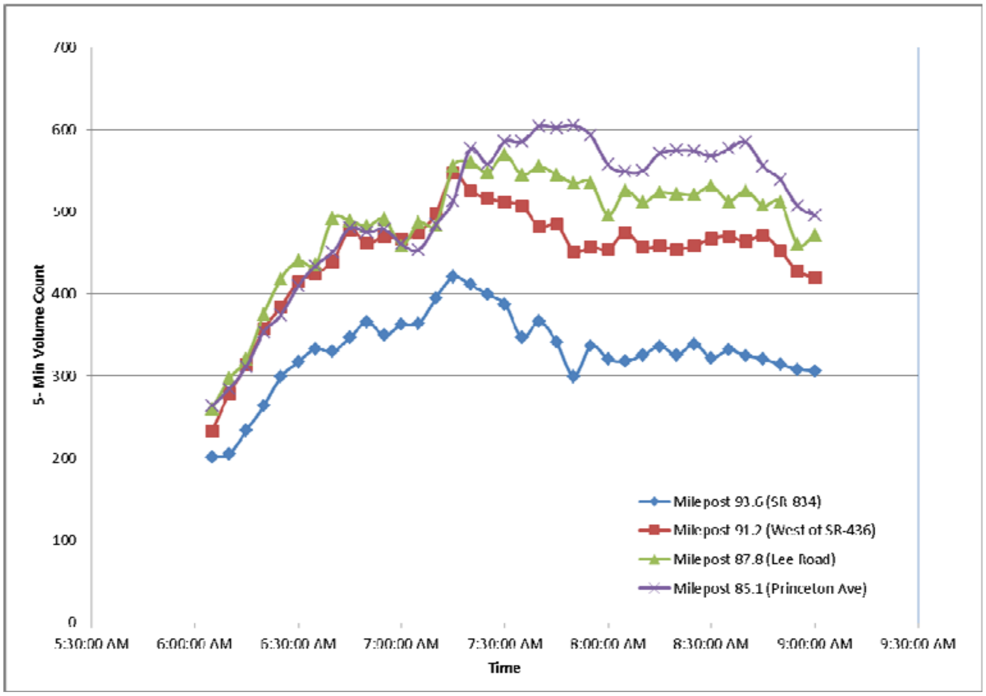


(a) Monday



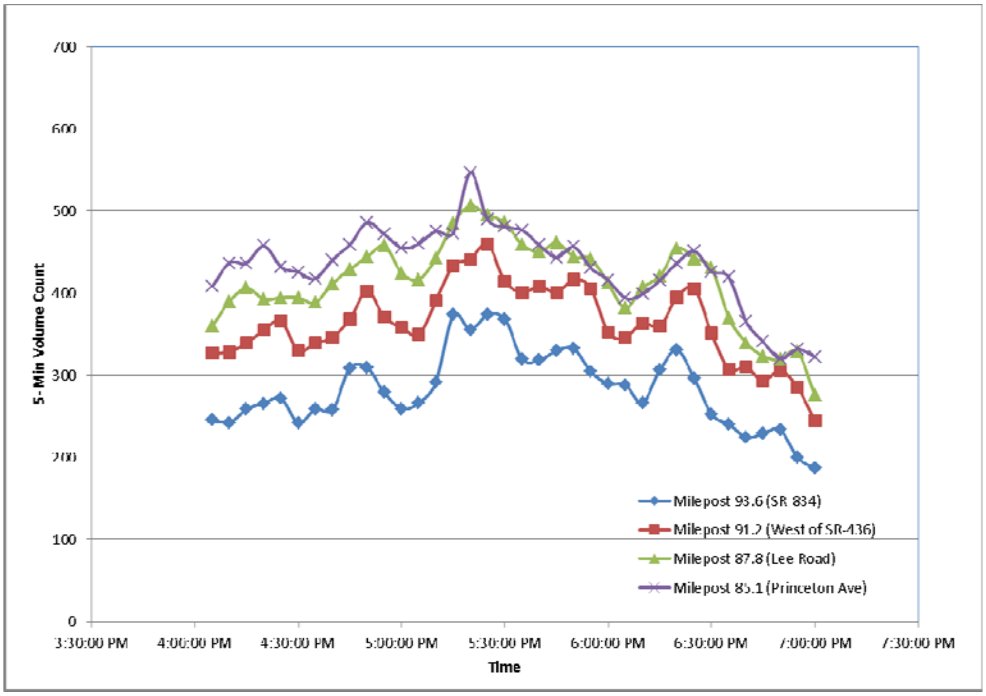
(b) Tuesday/Wednesday/Thursday

Figure A-3 Average Volume for I-4 WB Study Segment during AM Peak Period

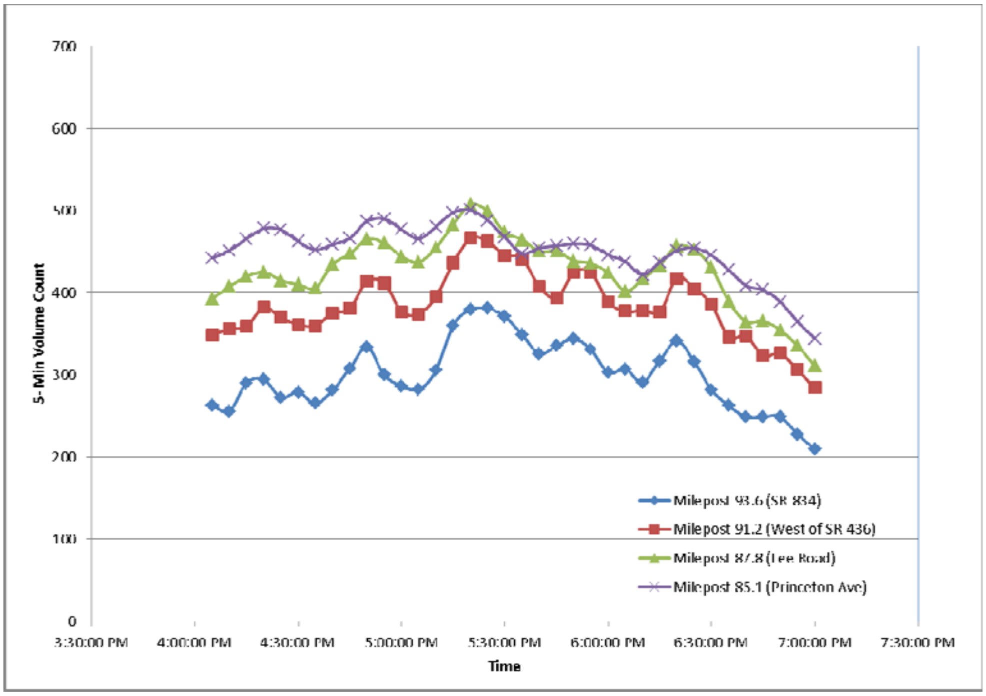


(c) Friday

Figure A-3 Average Volume for I-4 WB Study Segment during AM Peak Period (Continued)

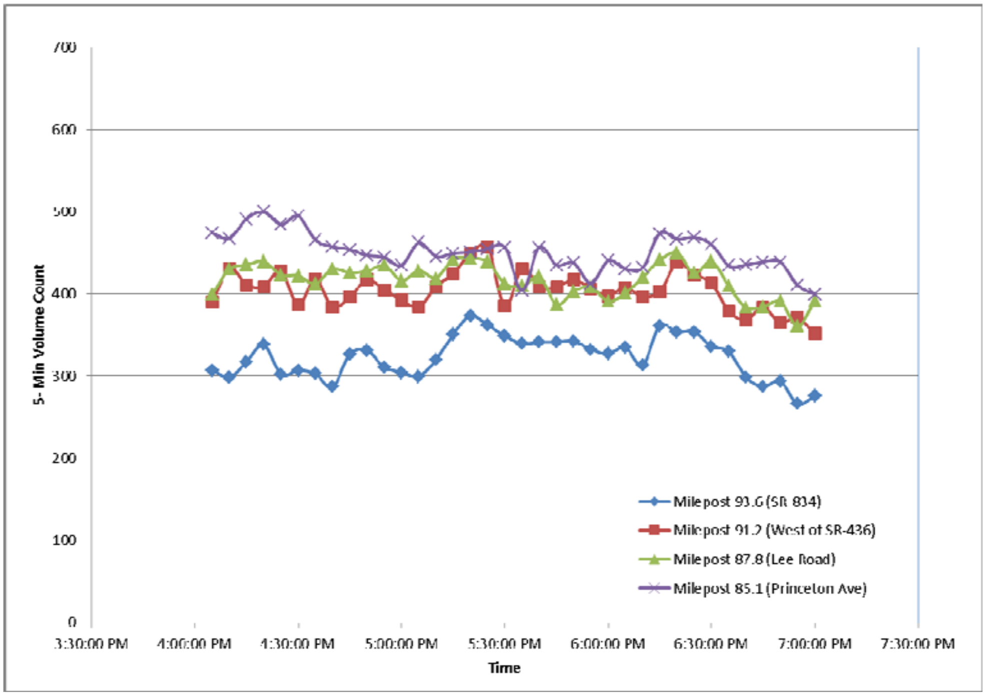


(a) Monday



(b) Tuesday/Wednesday/Thursday

Figure A-4 Average Volume for I-4 WB Study Segment during PM Peak Period



(c) Friday

Figure A-4 Average Volume for I-4 WB Study Segment during PM Peak Period (Continued)