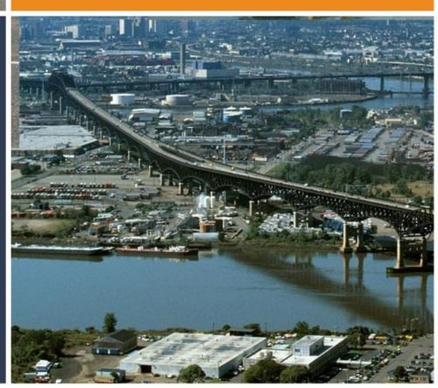
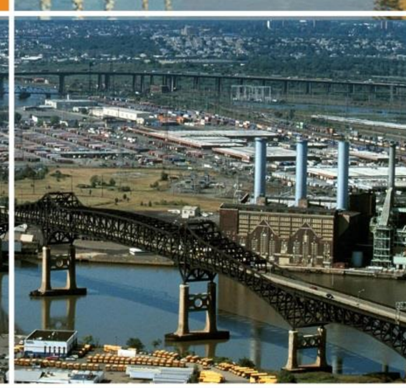
State of New Jersey
DEPARTMENT OF TRANSPORTATION

Division of Transportation Systems Management

Effectiveness of Safety Service Patrol Extended Coverage During Pulaski Skyway Rehabilitation Project





March 2015

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ITS Resource Center

Activity 4-D: Evaluation of Traffic Mitigation Strategies

Effectiveness of Safety Service Patrol Extended Coverage During Pulaski Skyway Rehabilitation Project

Final Report

March 2015

This report has been prepared as part of the CY 2013-2014 work program for the ITS Resource Center at the New Jersey Institute of Technology. The project team and authors of the report include:

Authors:

Lazar Spasovic, Ph.D., *New Jersey Institute of Technology*

Dejan Besenski, Ph.D., *New Jersey Institute of Technology*

Branislav Dimitrijevic, *New Jersey Institute of Technology*

Prepared for

New Jersey Department of Transportation

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EXECUTIVE SUMMARY

The New Jersey Department of Transportation (NJDOT) launched Pulaski Skyway bridge structure rehabilitation project on April 12th, 2014. To facilitate this major project, the northbound travel lanes on Pulaski Skyway have been closed and will remain closed for approximately 24 months while rehabilitation of the bridge deck is underway. A comprehensive traffic mitigation plan that was developed for this project aimed at minimizing adverse effects of the roadway closure on regional mobility and traffic safety. The plan includes a number of transportation systems management and operations (TSMO) strategies, including route diversions, deployment of adaptive signal control on adjacent signalized arterials, deployment of traffic detection and monitoring technology, travel advisory program, and a traffic incident management program.

In anticipation of increased frequency of traffic incidents in the vicinity of the Pulaski Skyway reconstruction area, NJDOT expanded the coverage of the Safety Service Patrol (SSP) to include Pulaski Skyway Southbound, US 1&9 Truck (Southbound and Northbound), US 1&9 (Tonnelle Ave), NJ Route 7 and Essex County Road 508 (Figure 1). Two patrol vehicles were assigned to service two new beats in this area from 4:00 AM to 8:00 PM on weekdays, and from 10:00 AM – 8:00 PM on weekends. In addition, the adjacent SSP beat along I-78 was extended to include portions of US 1&9 and US 1&9 TRUCK, and I-280 beat was extended to Essex County Road 508 to provide coverage closer to NJ Route 7.

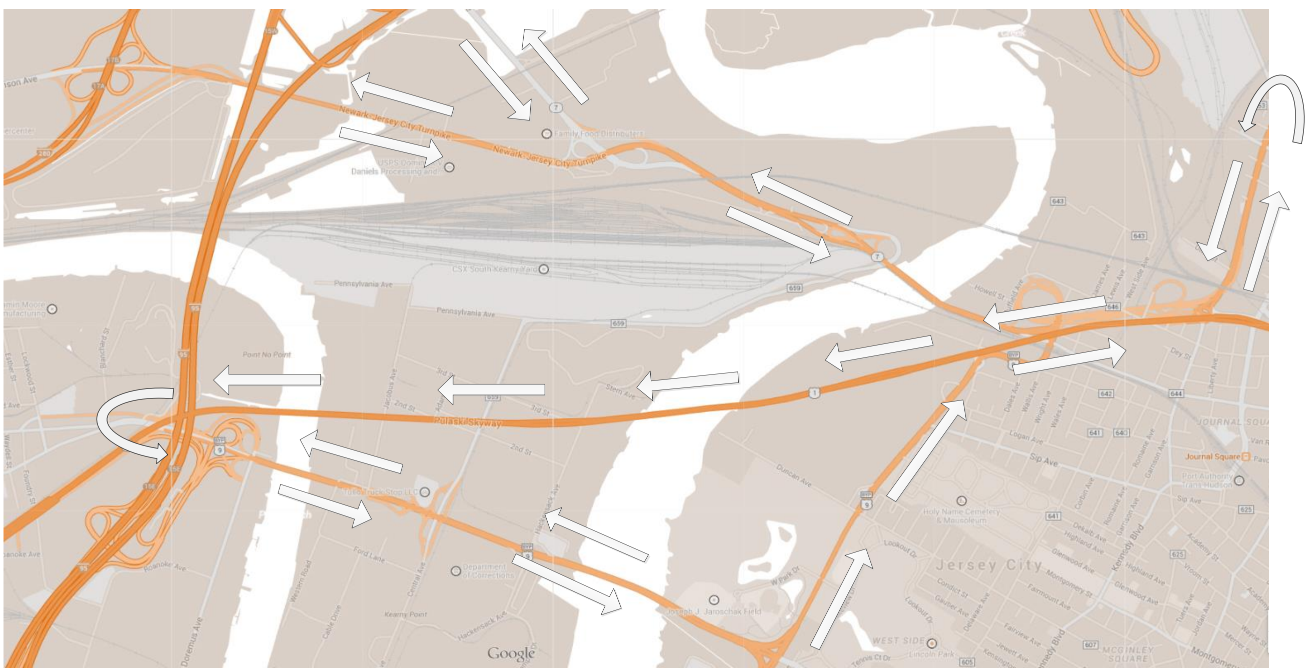

Figure 1: Expanded SSP coverage along Pulaski Skyway Southbound and US 1&9 Truck

The findings of the study are summarized as follows:

- The police incident statistics shows that there were 75 crashes on roadways included in expanded SSP coverage during the six weeks preceding the reconstruction. In contrast, there were 81 crashes on same roadways during the first six weeks following the start of reconstruction, which is an 8% increase.
- The most significant increase in crashes occurred on NJ 7 (120%), followed by US 1&9 Truck Route (65%) while the number of crashes reduced on Pulaski Skyway and US 1&9/ Tonnelle Avenue by 12% and 59% respectively.
- The number of recorded incidents in the OpenReach database during the first six weeks of reconstruction was 251. On same roadways, only 50 incidents were reported during the six weeks preceding the reconstruction demonstrating an increase in the number of reported incidents by 502%.
- 62% of incidents can be attributed to vehicle breakdowns (disabled cars, truck and tractor trailers) and 36 % to accidents.
- The average incident duration on patrolled routes ***was reduced by 55%*** (or close to 22 minutes) during the first six weeks of the reconstruction project to less than 18 minutes per incident.
- It is estimated that the overall duration of traffic incidents during the first six weeks of the project was reduced by almost 160 hours as a result of SSP deployment. This translates to ***savings of over $900,000***[1] to motorists who traveled on Pulaski Skyway Southbound and US 1&9 Truck during this time.

It can be concluded that the deployment of SSP was very effective in reducing duration and negative impacts of traffic incidents. It is important as well to emphasize the role of SSP not in only in incident clearance but detection as well. As measured by savings in user cost, the strategy was also cost-effective.

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[1] Appendix A

1 Introduction

1.1 Background

The New Jersey Department of Transportation (NJDOT) is currently in the process of rehabilitating the Pulaski Skyway (Figure 2). Pulaski Skyway, opened for traffic in 1932, is a 3.5-mile long steel structure, consisting of two main river-crossing spans of 550 feet in length. Carrying approximately 74,000 vehicles per day traversing between Newark and Jersey City, it also serves as an express link for cars and buses to and from the Holland Tunnel.

Figure 2: Pulaski Skyway “full view" by Jack E. Boucher

The northbound travel lanes on Pulaski Skyway have been closed since April 12th, 2014 and will remain closed for approximately 24 months while the New Jersey Department of Transportation (NJDOT) rehabilitates the bridge deck[2]. To minimize traffic congestion, the diversion of northbound vehicles from the Pulaski Skyway to other roadways in the area is being coordinated with other regional transportation infrastructure projects and agencies. Despite NJDOT’s efforts to promote public awareness of lane closures, detour routes, and the use of public transit or telecommuting as alternatives during this long term rehabilitation project, increases in traffic congestion are expected

[2] http://www.state.nj.us/transportation/commuter/roads/pulaski/ (Accessed June 2014)

to result from the changing traffic patterns. The increased congestion is a potentially significant safety concern on such a highly-utilized highway.

The NJDOT SSP is a critical component of the Department's incident management program. The SSP uses roaming vehicles to patrol congested critical sections of the statewide freeway network, in order to quickly detect and respond to incidents and to assist law enforcement with traffic control at crash scenes. The SSP statewide coverage area[3] is divided into 23 zones defined by route and mile post. One of the NJODOT's maintenance yards is located in Jersey City in the vicinity of the Pulaski Skyway rehabilitation area. NJIT's 2013 study[4] showed that the SSP service is effective and reduces incident duration by approximately 9%. The SSP service has proven to be cost effective as well. The study shows that the benefits far outweighed the costs of their use in incident response by a ratio of 6.2 to 1.

1.1 Study Objective

The objectives of this research study are twofold:

1. Analyze traffic incident statistics (number and duration of incidents by type) along the affected roadways six weeks before and after the start of the rehabilitation project.

2. Determine whether the Incident Management program, and specifically deployment of SSP, was effective in reducing the time for incident response and clearance in the study area.

Among the benefits of faster responses and clearances of highway incidents is the speedier restoration of the normal traffic conditions that existed before the incident occurred, which helps reduce the vehicle queuing and congestion associated with the incident. This results in savings from:

- Reduced traffic delay;
- Reduced vehicle emissions;
- Reduced fuel consumption.

To fully evaluate the impact of the Pulaski Skyway rehabilitation project on traffic safety, the surrounding major roadways and traffic pattern shifts needed to be incorporated in the analysis. Thus, in addition to the Pulaski Skyway, US Route 1&9 Truck (Lincoln Highway), Essex County Road 508 and NJ Route 7 is included in the study as the major detour route expected to accommodate traffic diverted from Pulaski Skyway (Figure 3).

3 Appendix F

4 "Estimating the Benefits of NJDOT Safety Service Patrol", NJIT, 2013, Prepared for NJDOT

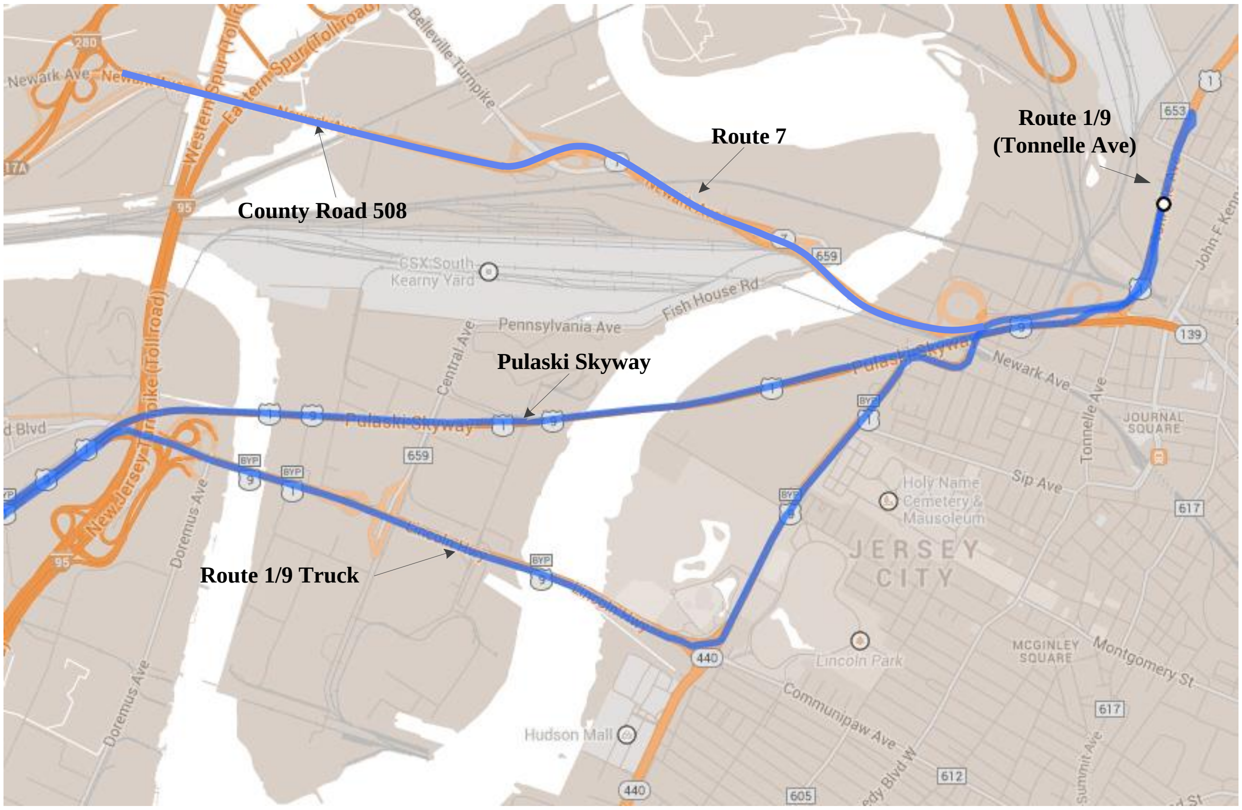

Figure 3: Analysis Focus Area

2 NJDOT Statewide Incident Management Program

NJDOT's Statewide Traffic Incident Management (TIM) program is a systematic tool used for the command, control, and coordination of a highway emergency response and represents a collaborative effort between NJDOT and the New Jersey State Police (NJSP). The program is used for managing the state's transportation infrastructure and for restoring lanes of traffic in a safe and expeditious manner in the event of traffic incidents. The TIM program permits improved cooperation between agencies at the scene of traffic incidents: it does this by using common terminology and standard operating procedures for controlling personnel, facilities, equipment, and communications.

The TIM program employs several NJDOT resources including the Incident Management Response Team (IMRT), Maintenance Operations, the Safety Service Patrol (SSP), Traffic Operations Centers (TOCs), and the Statewide Traffic Management Center (STMC). This inter-agency collaboration with the NJSP results in enhanced detection, response, assistance, and clearance of various types of traffic incidents. The NJDOT Bureau of ITS Engineering also assists in effective incident management through the development and deployment of Intelligent Transportation Systems.

2.1 Incident Management Response Team (IMRT)

An important component of the NJDOT/NJSP Incident Management Program is the Incident Management Response Teams (IMRT). The activities of the NJDOT and NJSP personnel at the incident scenes are managed and coordinated through the IMRT. These specially-trained teams respond to incidents that have a major impact on transportation by providing technical, logistical, and incident management support to the Incident Commander (IC). A primary goal of the IMRT team is to keep the traffic moving safely by:

- Setting up traffic safety devices, demarcating diversion routes, and warning motorists.
- Serving as the mobilization resources liaison for NJDOT.
- Safely and quickly restoring traffic flow lanes.
- Expediting necessary repairs and roadway re-openings.

2.2 Maintenance Operations

NJDOT dispatches its Maintenance Operations personnel to sites of major traffic incident with expected incident duration greater than 60 minutes, in order to address the traffic management aspect of roadway incident response. The Maintenance Operations are part of a collaborative response from NJDOT that fulfils the requirements of the National Incident Management System (NIMS). When dispatched to traffic incident sites under the Incident Management Program, the responsibilities of the Maintenance Operations personnel include:

- Assistance with providing traffic control at the scene of major incidents;
- Providing containment of major spills;
- Determining incident clearance needs and resources (i.e. loaders, mobile sweepers, dump trucks, etc.) and other relevant equipment;
- Handling incident clearance activities (i.e. relocate fluid spills, relocate/remove spilled cargo/debris, and relocate damaged trucks and vehicles from the travel lanes);
- Assisting in the coordination of NJDOT resources (i.e. personnel, equipment) for incident clearance;
- Assisting NJSP with establishing alternate routes and diversion signing.

2.3 Safety Service Patrol (SSP)

Another very important element of NJDOT's Traffic Incident Management program is the SSP. The program focuses on the core mission of mitigating roadway congestion and enhancing safety for the motoring public. The SSP patrols over 225 center-lane miles of New Jersey's roadways. When certain circumstances result in lane closures, the SSP can extend its coverage area by an additional 58 miles. The responsibilities of the SSP include the following:

- Utilize roaming vehicles to patrol congested sections of the statewide freeway network to quickly detect and respond to minor incidents;
- Assist with incident detection – SSP is routinely the first responder at an incident site;
- Assist NJSP and other secondary responders by safely diverting traffic around incident scenes;
- Assist and remove disabled vehicles, and provide for safety until Maintenance Operations Personnel arrive on scene;
- Relocate vehicles, remove debris and provide for safety until Maintenance Operations Personnel arrive on scene;
- Patrol the highway around the scene to prevent the occurrence of secondary incidents Handle containment of minor spills when necessary.

The SSP program covers over 225 center-lane miles of New Jersey's roadways, centered along high-traveled corridors, as follows:

- In the northern part of the state, SSP operates on I-78, I-80, I-280, I-287 and Route 440 (in Bergen, Essex, Hudson, Middlesex, Morris, Passaic, Somerset and Union Counties).
- In the central and southern part of the state, SSP operates on I-295, I-95, I-195, I-676, I-76 and Routes 29, 42 and 55 (in Burlington, Camden, Gloucester and Mercer Counties).

Under certain circumstances that result in lane closure, the SSP will extend its coverage area by additional 58 miles.[5]

2.4 Expanded SSP Coverage for Pulaski Skyway Rehabilitation

The NJDOT established an additional route specifically designed to service the major roadways in the vicinity of the Pulaski Skyway reconstruction area. Two SSP vehicles are designated to patrol Pulaski Skyway Southbound, US 1&9 Truck (Southbound and Northbound), US 1&9 (Tonnelle Ave). One of them traverses the Pulaski Skyway Southbound/Route 1&9 Truck Northbound loop, while the second vehicle follows a Route 1&9 Truck loop. Part of the existing SSP route on I-78 was extended along Route 1&9, turning around at Jacobus Ave (on Route 1&9 Truck) and the existing I-280 route was extended to Essex County Road 508 to provide coverage closer to NJ Route 7. The coverage of NJ Route 7 by SSP was provided as well (Figure 4). The official operating hours for the SSP are Monday through Friday, from 4:00 AM - 8:00 PM, and Saturday – Sunday, from 10:00 AM – 8:00 PM.

[5] Appendix A, "Estimating the Benefits of NJDOT Safety Service Patrol", NJIT, 2013, Prepared for NJDOT

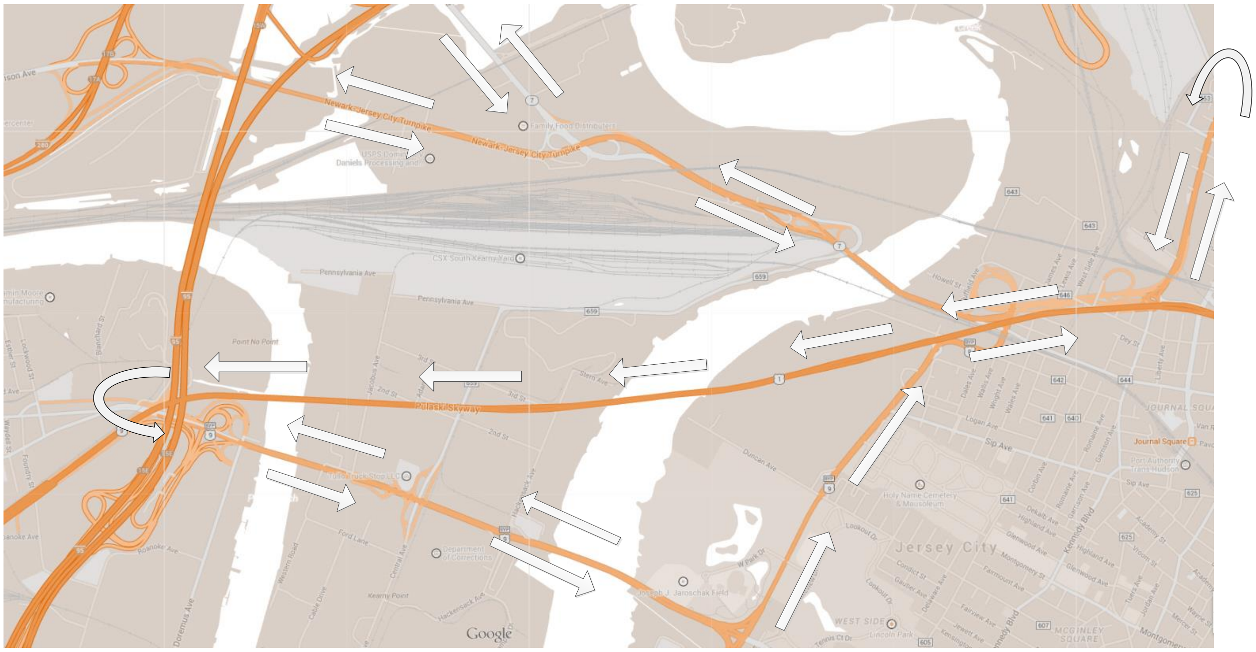

Figure 4: Expanded SSP coverage

3 Data Collection and Analysis

The data used in this report was collected during the period of March 1st – May 24th, 2014, from the following sources: NJDOT's Crash Records and OpenReach database, New Jersey Congestion Management System (NJCMS), and INRIX data archive. The Crash Record database provides information regarding crashes reported by the law enforcement. OpenReach data source provides information related to incidents (accidents, debris, disabled vehicles, etc.) reported to NJDOT's Traffic Operation Center (TOC). The NJCMS data source provides roadway geometric data such as lanes, functional class, and traffic volumes, including 24 hour distribution of hourly volumes and truck percentages. The INRIX Dataset provides link-based speed data.

Two distinctive time periods are used to analyze incident data and vehicle speed data:

- Before Reconstruction: the time period from March 1st – April 12th 2014;
- During Reconstruction: the time period from April 12th – May 24th 2014.

3.1 New Jersey Crash Record Data

The New Jersey Department of Transportation's (NJDOT's) Bureau of Safety Programs provides to public crash record data based on the New Jersey State Police Crash investigation form NJTR-[6]1. This form is completed by the responding police officer at the crash scene. The police crash investigation reports are processed and entered into pertinent databases. The crashes in this study were classified into three categories based on their severity:

- Fatal;
- Injury;
- Property damage.

The crash records used in this study for the analysis are:

- The facility (roadway) name
- SRI;
- Milepost;
- The day and time crash occurred;
- Severity.

[6] Appendix G

3.2 OpenReach Data Management System

NJDOT OpenReach management information and communication system is used by NJDOT's TOC. OpenReach provides a common platform for TOC operators to record information about traffic conditions on major roadways, including incident information. The incidents are reported to TOC operators by either SPP crews or police.

The incident record contains the following information describing the pertinent traffic incident:

- Incident type (accidents, disabled vehicles, debris, etc.);
- Location, described by the facility (roadway) name, milepost, street intersection, and geographic coordinates;
- Time the incident was reported;
- Time the incident was closed;
- Incident duration.

The accidents in OpenReach database may not be logged in police crash records and vice versa.

3.3 New Jersey Congestion Management System (NJCMS)

The roadway geometry and traffic flow data in this report was obtained from NJCMS, NJDOT's New Jersey Congestion Management System. NJCMS is a data management and data analysis computer software used by NJDOT's Bureau of Commuter and Mobility Strategies to estimate congestion measures for New Jersey highways. It is used to identify congested routes, perform congestion analysis for projects, provide recommendation for possible congestion improvements, and monitor congestion throughout New Jersey.

3.4 INRIX Vehicle-Probe Data

The vehicle-probe data provides estimated prevailing travel speed and travel times on major arterials based on the vehicle location data collected in real time. The probe-vehicle data used in this study is from INRIX dataset, and it was obtained through the I-95 Corridor Coalition and its Vehicle Probe Project (VPP). INRIX system collects vehicle location data from millions of anonymous mobile phones, as well as large fleet of commercial vehicles equipped with GPS locator devices. INRIX collects and aggregates this data in real time, providing estimated prevailing vehicle speed minute-by-minute for every highway link included in INRIX network coverage (TMC location[7]). Figure 5 shows the locations of INRIX TMC end-points in the study area. The INRIX probe-vehicle data was

[7] TMC location is used by the leading electronic map databases vendors to uniquely define road segments for which travel time data is collected.

provided for roadway sections between each pair of adjacent end points (i.e. all TMC links along the analyzed roadways). This data was used in the analysis to calculate vehicle speeds.

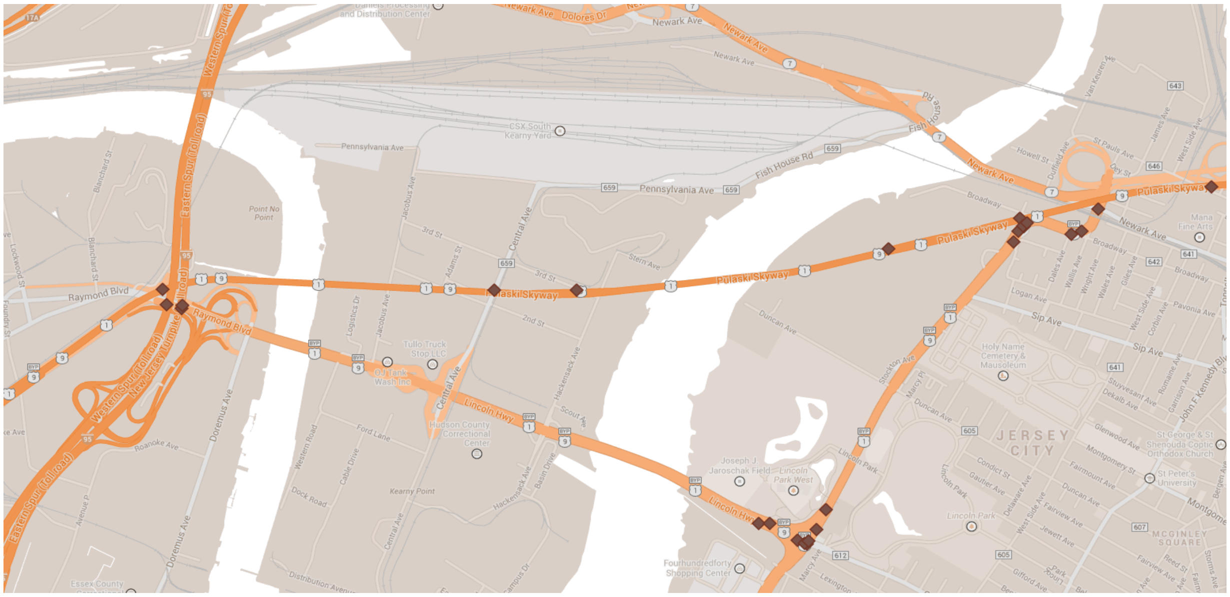

Figure 5: INRIX Data Collection Points

3.5 Data Integration

The highway links in the NJCMS tables were identified by Standard Route Identifier (SRI) or Route Name (e.g., I-80, or NJ-46), and by beginning and end milepost. The link information from the NJCMS was then attached to the incidents from the OpenReach database using the SRI and the beginning and end milepost. Roadway geometry, traffic flow data, and incident information were used to calculate link capacities and traffic delays caused by an incident. This data was then used for the evaluation phase of the project, as described in the next section.

3.6 Estimating Benefits of Quicker Incident Response and Clearance

The evaluation methodology applied in this study was previously used in NJIT reports in 2009[4] and 2012[5] to analyze the effectiveness of incident management support by NJDOT Maintenance Operations. The model is based on calculation procedures outlined in the Highway Capacity Manual and Traffic Incident Management Handbook (USDOT, 2000). The method considers incident characteristics, roadway geometry, and traffic flow characteristics to calculate the impact of each incident on vehicle queuing and delay. These impacts can then be translated to user (motorist) costs, and can be used to ascertain benefits of quicker response to incidents and quicker roadway clearance and return to normal traffic operations, including:

- Reduction in travel delay,

- Reduction in wasted gallons of fuel due to idling, stopping, and slow-moving traffic;
- Reduction in emissions;
- Reduction in number and severity of secondary incidents.

The benefits of the Maintenance Operations support in incident response are best calculated using monetary terms. That means that savings in time, vehicle emissions, fuel, and secondary incidents have to be multiplied by the appropriate unit costs in order to obtain the total dollar savings (benefit). Dollar values of each parameter used in the calculations are shown in Appendix A Table 8.

In order to calculate the savings, we needed to compare the incident clearance times with assistance of NJDOT Maintenance Operations crews to ones without. Therefore, we increased the incident duration for incidents where Maintenance Operations crews responded in 1 minute increments (from 1 minute up to 30 min) to better illustrate the impact of Maintenance Operations crews on incident duration and user cost. Also, by responding, the disruption of traffic flow (congestion, delays) has been effectively reduced.

4 Evaluation Results

This chapter presents the findings from an analysis of incidents recorded in the Crash Record database and OpenReach database. The outcomes were grouped into two distinctive six week time periods, one immediately before and one immediately after the start of reconstruction.

4.1 Crash Records Summary Statistics

Prior to beginning the Pulaski Skyway reconstruction project, 75 crashes were recorded during the time period March 1st – April 12th 2014. After reconstruction began, 81 crashes were recorded during the time period April 12th – May 24th 2014, demonstrating an increase in the number of crashes by 8%[8] during the six weeks after starting reconstruction. Table 1 shows the number of crashes by severity during the two time periods.

Table 1: Number of Crashes by Severity in the Study Area

Severity	Before Reconstruction	During Reconstruction
Property Damage	62	64
Injury	13	17
Total	75	81

Table 2 shows the number of crashes and the corresponding change by roadway before and after the reconstruction was started.

Table 2: Crashes by Roadway

Facility Name	Before Reconstruction	During Reconstruction	Change (%)
Pulaski Skyway	33	29	-12
US 1&9/ Tonnelle Avenue	17	7	-59
NJ Route 7	5	11	120
US 1&9 Truck Route	20	33	65
County Route 508	0	1	100

[8] (81-75)/75

The most significant increase in crashes occurred on NJ 7 (120%), followed by US 1&9 Truck Route (65%) while the number of crashes reduced on Pulaski Skyway and US 1&9/ Tonnelle Avenue by 12 and 59 percent respectively.

Figure 6 shows the geographic locations where crashes occurred. The size of the circle represents the magnitude of crashes which occurred at each particular location.

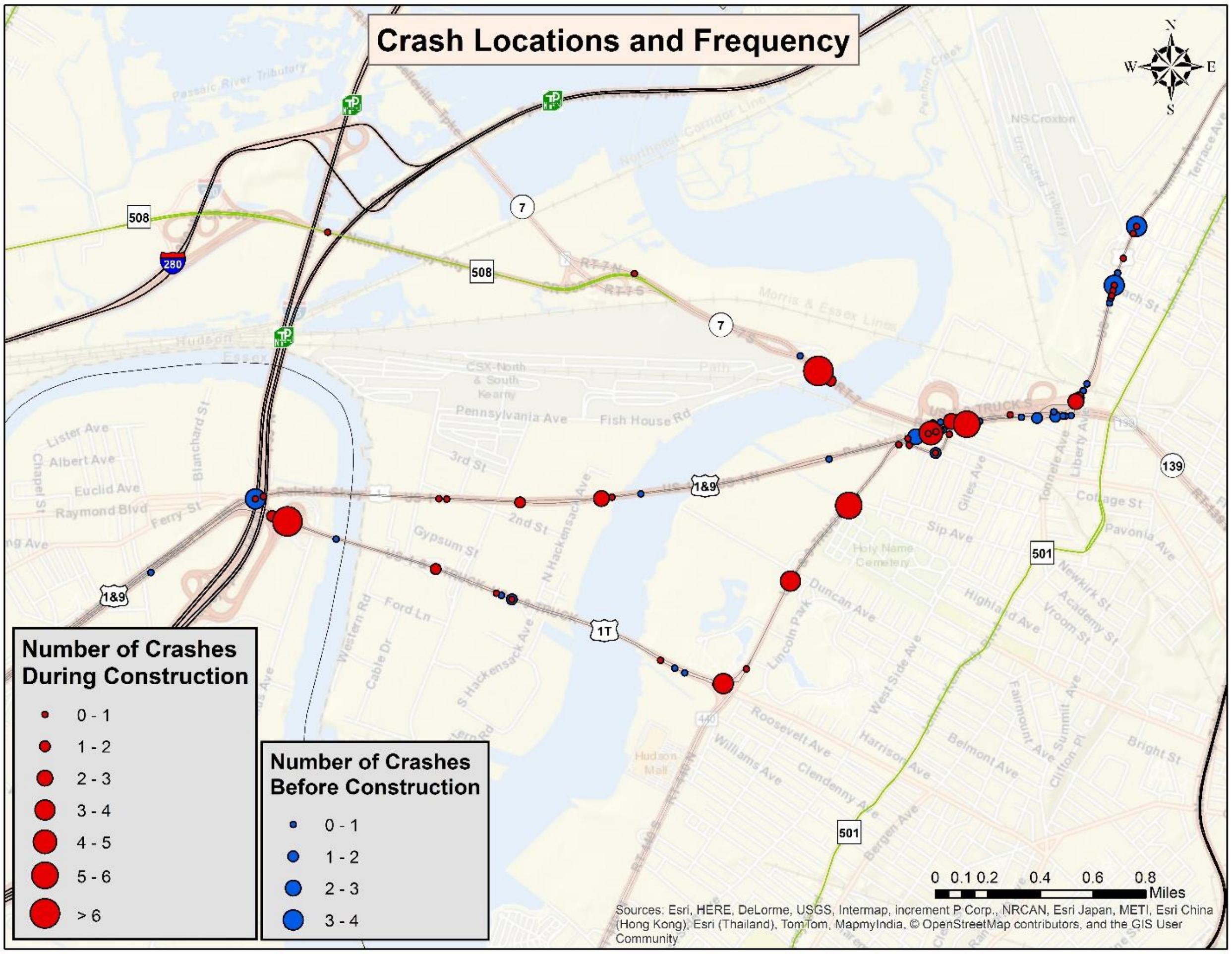

Figure 6: Crash Locations and Frequency

The geographic location of crashes by type before and after reconstruction started is shown in Appendix B.

4.2 Traffic Incident Summary Statistics

Prior to beginning the Pulaski Skyway reconstruction project, 50 incidents were recorded during the time period March 1st – April 12th 2014. After reconstruction began, 251 incidents were recorded during the time period April 12th – May 24th 2014, demonstrating an increase in the number of incidents of 502%[9] during the six weeks after starting reconstruction. Table 3 shows the number of incidents that occurred by type during the two time periods.

Table 3: Number of Incidents in the Study Area by Event Type

Incident Type	Before Reconstruction	During Reconstruction
Accident	26	89
Disabled cars	14	118
Disabled truck	4	11
Disabled tractor trailer	3	25
Vehicle fire	1	0
Fluid Spill	1	0
Overturned vehicle	1	1
Debris spill	0	3
Disabled bus	0	2
Vehicle spun out	0	1
Total	**50**	**251**

It should be noted that before reconstruction commenced, the SSP patrols were not deployed in the area and that is the reason why there is a significant disparity in number of reported incidents. This only solidifies the importance of SSP crews in incident detection.

The results in Table 3 show that during the first six weeks following the start of reconstruction 62% of incidents can be attributed to vehicle breakdowns (disabled cars, truck and tractor trailers) and 36 % to accidents. The results in table 3 emphases the importance of SSP crews in incident detection since most likely SSP crews are first responder at an incident site. Table 4 shows the number of incidents by roadway after reconstruction started.

[9] 251/50

Table 4: Incidents by Roadway

Incident Type	Pulaski Skyway	US 1&9/Tonnelle Avenue	US 1&9 Truck Route	NJ Route 7	County Route 508
Accident	14	8	62	4	2
Disabled Vehicles	28	10	108	7	2
Debris	2	0	1	3	

For the reported incidents, the incident duration was reduced on average by approximately 55% (or 22 minutes) from 40 minutes per incident to approximately 18 minutes per incident. The statistics on average incident duration by event type before and during the rehabilitation project is shown in Table 5.

Table 5: Average Incident Duration

Incident Type	Average Incident Duration (min)		Percent Change[10]
	Before Reconstruction	During Reconstruction	
Accident	0:36:27	0:21:19	-42%
Disabled vehicle	0:18:11	0:15:08	-17%
Disabled truck	0:33:44	0:19:04	-43%
Disabled tractor trailer	1:13:25	0:15:37	-79%
Vehicle fire	0:35:57		
Fluid Spill	0:07:11		
Overturned vehicle	1:01:57	0:24:42	-60%
Debris spill		0:02:19	
Disabled bus		0:13:02	
Vehicle spun out		0:23:50	

Table 6 shows the percent change in incident duration by type on major roadways in the study area. The average accident duration on Pulaski Skyway and section of US 1&9 Tonnelle Avenue has been reduced by 43% and 71% respectively. The average accident duration times on US 1&9 Truck route increased by 11.6 %. The average incident duration related to disabled vehicles and debris was reduced on all examined roadways.

10 (During Reconstruction – Before Reconstruction)/Before Reconstruction

Table 6: Percent Change in Incident Duration

Incident Type	Pulaski Skyway	US 1&9/Tonnelle Ave.	US 1&9 Truck Route
Accident	-43.7%	-71.0%	11.6%
Disabled Vehicles	-5.5%	-71.9%	-57.1%
Debris	N/A	N/A	-20.0%

The geographic location of incidents by type before and after reconstruction started is shown in Appendix C.

4.3 The Benefits of Expanded SSP Deployment

As explained in Chapter 3.5, the analysis focused on determining savings by looking at reduction of costs from faster incident clearance in areas of travel delay, fuel consumption, vehicle emissions, and secondary incidents. In order to estimate the benefits of deploying incident response crews to major traffic incidents, the duration of each incident to which it responded was increased by 1-30 minutes in one minute increments.

Various incident duration reduction scenarios are presented and summarized in Table 6 and Figure 7. The results show that greater reduction in incident duration results in greater savings. For example, a 1 minute reduction in duration of every incident results in an overall decrease of person-delay by 80 hours. This translates to cost savings of $36,345. A reduction of 30 minutes of duration time per translates to cost savings of $1.4 million.

The average reduction in incident duration of 21 minutes and 39 sec accomplished due to SSP deployment translates to user cost savings of $932,326. These savings reflect decrease in person-delay, consumed fuel, vehicle emissions, and secondary incidents (Figure 7).

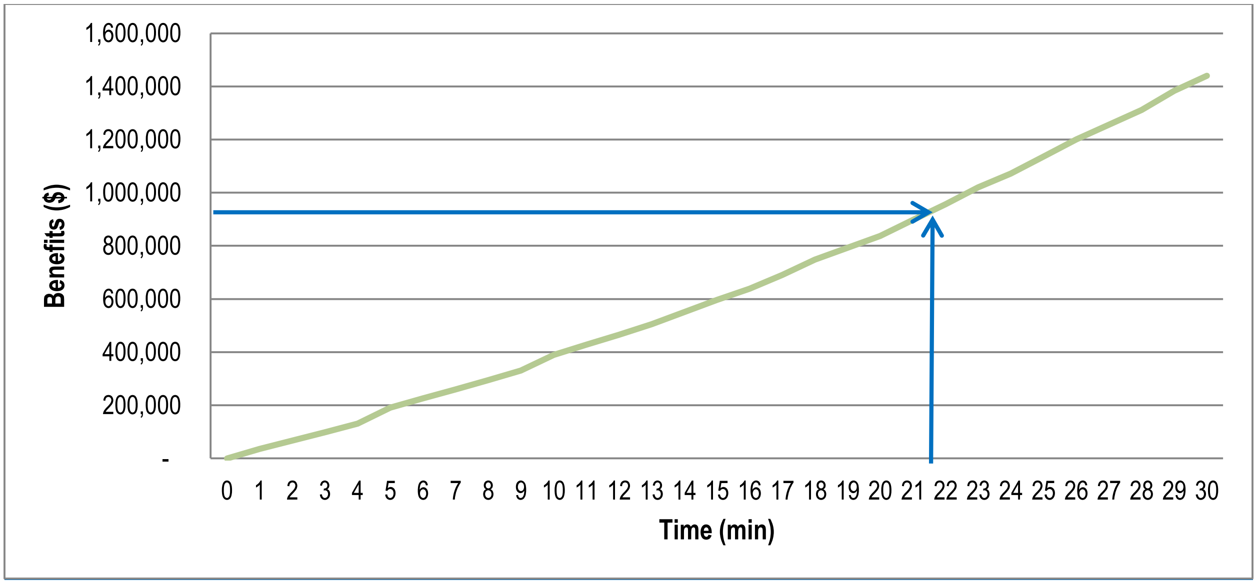

Figure 7: Benefits of incident management operations resulting from assumed reduction in incident duration from 1 to 30 minutes per incident

The most significant savings are realized in the category of reduced travel delays, which translates into more productive time for motorists. Additional benefits result in savings from avoided secondary incidents, reduced fuel consumption, and reduced vehicle emissions due to reduced congestion.

Changing traffic patterns can potentially increase the traffic volume on Route 1 and 9 Truck route. The unavailability of traffic volume counts in the construction area prompted the research team to modify CMS traffic flow data during peak hours. The traffic volume was increased in 1% increments and the resultant change in benefits is recorded. An analysis was conducted in which the duration of each incident was increased by 1-30 minutes, in one minute increments. The study shows how a minimal increase in traffic volume (+1%) results in an additional 4% in cost savings if incident duration is reduced by 1 minute. A change in volume of 10% results in an additional 28% in cost savings, while a 30% increase in traffic volume results in a 131% difference in cost savings (Table 11 Appendix E).

Table 7: Summary Results of the Benefit Analysis

Savings category	Reduction in Incident Duration per Incident due to Incident Management Operations						
	1 minute	5 minutes	10 minutes	15 minutes	20 minutes	25 minutes	30 minutes
Reduction in Incident Duration (Hours)	80	95	115	134	154	174	193
Value of Reduced Travel Delay ($)	$23,121	$128,467	$270,780	$425,602	$609,494	$842,036	$1,082,260
Value of Reduced Vehicle Emissions ($)	$1,712	$9,552	$20,143	$31,655	$45,355	$62,684	$80,565
Value of Reduced Fuel Consumption ($)	$3,726	$21,458	$45,418	$71,295	$102,532	$142,098	$182,612
Value of Avoided Secondary Incidents ($)	$7,705	$32,185	$53,384	$68,403	$79,599	$91,212	$95,179
TOTAL Cost Savings ($)	*$36,345*	*$191,757*	*$389,839*	*$597,089*	*$837,134*	*$1,138,203*	*$1,440,811*

5 Conclusions

This study was conducted to evaluate the effectiveness of deploying additional NJDOT Safety Service Patrol (SSP) crews to cover roadways most affected by the roadways closures and detours during the Pulaski Skyway rehabilitation project. The analysis showed that this strategy resulted in significant reduction of incident duration in the first six weeks following the start of the rehabilitation project. The analysis also showed that SSP crews play an important role and are very effective in identifying incidents, clearing obstructions from roadways, and assisting law enforcement with traffic control at incident locations, which altogether contributed to reducing incident response and clearance times. Subsequently this resulted in significant monetary savings for the traveling public.

The findings of this study are summarized below:

- There were 75 crashes on roadways included in expanded SSP coverage preceding the reconstruction (March 1st – April 12th 2014) on roadways included in the study area.
- In contrast, there were 81 crashes on same roadways during the first six weeks following the start of reconstruction, which is an 8% increase.
- The most significant increase in crashes occurred on NJ 7 (120%), followed by US 1&9 Truck Route (65%) while the number of crashes reduced on Pulaski Skyway and US 1&9/ Tonnelle Avenue by 12% and 59% respectively.
- The number of recorded incidents in the OpenReach database during the first six weeks of reconstruction was 251. On same roadways, only 50 incidents were reported during the six weeks preceding the reconstruction demonstrating an increase in the number of reported incidents by 502%.
- 62% of incidents can be attributed to vehicle breakdowns (disabled cars, truck and tractor trailers) and 36 % to accidents during the first six weeks following the start of reconstruction.
- The average duration of incidents was significantly reduced due to expanded SPP coverage. The average incident duration on patrolled routes was reduced by 55% (or close to 22 minutes) during the first six weeks of the reconstruction project to less than 18 minutes per incident.
- It is estimated that the overall duration of traffic incidents during the first six weeks of the project was reduced by almost 160 hours as a result of SSP deployment. This translates to savings of over $900,000 to the motorists who traveled on Pulaski Skyway Southbound and US 1&9 Truck during this time.

6 References

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7 Appendix A

7.1 Calculating Cost Savings

To calculate a Benefit/Cost (B/C) ratio of the Maintenance Operations support in incident response, it is necessary to express all the above benefits in monetary terms. That means that savings in time, vehicle emissions, fuel, and secondary incidents have to be multiplied by the appropriate unit costs in order to obtain the total dollar savings (benefit). Thus, the total cost savings can be calculated as follows:

7.1.1 Savings in Vehicle Delay

$$\Delta C_d = \Delta T_d \cdot \left[\left(P_{PC} \cdot occ \cdot C_{PERS} \right) + \left(P_{TR} \cdot C_{TR} \right) \right] \qquad \text{Equation 1}$$

Where:

ΔC_d = Total cost savings due to reduced vehicle delay ($);
P_{PC} = Percent of passenger cars in traffic (this value is obtained from NJCMS database for each incident location);
occ = Average occupancy of passenger cars obtained from NJCMS database for each incident location (persons/vehicle);
C_{PERS} = Average value of time per passenger ($/person-hour) – provided in Table 7.
P_{TR} = Percent of trucks in traffic (this value is obtained from NJCMS database for each incident location);
C_{TR} = Average cost of truck per hour of delay ($/truck-hour) – provided in Table 7.

7.1.2 Savings in Vehicle Emissions

It is assumed that vehicle emissions are directly proportional to the total time vehicles spend in the queue. Therefore, reducing the duration of an incident and thus the queue will also reduce the total vehicle emissions. The total vehicle emissions resulting from the traffic delay can be calculated using equations shown below:

$$E_{HC} = T_d \cdot e_{HC} \;\; ; E_{CO} = T_d \cdot e_{CO} \;\; ; E_{NOx} = T_d \cdot e_{NOx} \qquad \text{Equation 2}$$

Where:

EHC, ECO, ENOx = Total emissions of HC, CO, and NOx in tons;
eHC, eCO, eNOx = Vehicle emissions of HC, CO, and NOx in tons/hour; these are considered as constants and are given in Table 7.

The total savings in vehicle emissions can be calculated by replacing the total delay by delay reduction in equations 2:

$$\Delta E_{HC} = \Delta T_d \cdot e_{HC} \,;\, \Delta E_{CO} = \Delta T_d \cdot e_{CO} \,;\, \Delta E_{NOx} = \Delta T_d \cdot e_{NOx} \qquad \text{Equation 3}$$

Where:

ΔE_{HC}, ΔE_{CO}, ΔE_{NOx} = Reduction in emissions of HC, CO, and NOx in tons due to reduced delay.

Total cost savings due to reduced vehicle emissions can be calculated as follows:

$$\Delta C_e = \Delta E_{HC} \cdot c_{HC} + \Delta E_{CO} \cdot c_{CO} + \Delta E_{NOx} \cdot c_{NOx} \qquad \text{Equation 4}$$

Where:

ΔC_e = Total cost savings due to reduced vehicle emissions ($);
c_{HC}, c_{CO}, c_{NOx} = Unit cost savings from reduction of emissions of HC, CO, and NOx respectively ($/ton) – provided in Table 7.

7.1.3 Savings in Wasted Fuel

It is assumed that the vehicle fuel consumption is directly proportional to the total time it spends in the queue. It is also assumed that trucks consume diesel and all other vehicles gasoline. The total fuel consumed by the vehicles in the queue is calculated using the following formula:

$$F_{PC} = T_d \cdot V_{avg} \cdot g_{PC} \quad F_{TR} = T_d \cdot V_{avg} \cdot g_{TR} \qquad \text{Equation 5}$$

Where:

F_{PC}, F_{TR} = Total fuel consumption during the incident (queue) of passenger cars and trucks respectively, in gallons;
g_{PC}, g_{TR} = Average fuel economy of passenger cars (gallons of gasoline per mile) and trucks (gallons of diesel per mile) respectively. The estimated fuel economy of passenger cars and trucks is given in Table 7;
V_{avg} = Average speed of vehicles during incident, assumed to be 20 mph.

The total savings in fuel can be calculated by replacing the total delay by delay reduction in Equations 5:

$$\Delta F_{pc} = \Delta T_d \cdot V_{avg} \cdot g_{pc} \quad ; \quad \Delta F_{tr} = \Delta T_d \cdot V_{avg} \cdot g_{tr} \qquad \text{Equation 6}$$

Total cost savings due to reduced amount of wasted (consumed) fuel can be calculated as follows:

$$\Delta C_f = \Delta F_{PC} \cdot c_{gas} + \Delta F_{TR} \cdot c_{diesel}$$ Equation 7

Where:

ΔC_f = Total cost savings due to reduced amount of wasted (consumed) fuel ($);
c_{gas}, c_{diesel} = Market price at the pump of gasoline and diesel ($/gallon) – provided in Table 7.

Table 8: Dollar value of Parameters Used in Calculations

Parameter	Value	Measure	Source
Cost per Driver/Passenger (estimated statewide average hourly wage in New Jersey)	25.6	$/hour	U.S. Department of Commerce, 2012
Cost of Trucks	32.15	$/hour	USDOT, 2005
HC emissions per hour of delay	0.000025676	tons	Guin et al, 2007
CO emissions per hour of delay	0.00033869	tons	Guin et al, 2007
NOx emissions per hour of delay	0.000036064	tons	Guin et al, 2007
Average speed of the vehicles in congestion	20	mph	NJCMS
Fuel consumption of passenger cars (estimated for an average passenger car at 20 mph speed)	0.070	gallons/mile	California Air Resources Board, EMFAC2002
Fuel consumption of trucks (estimated for an average truck at 20 mph speed)	0.169	gallons/mile	California Air Resources Board, EMFAC2002
Cost savings resulting from HC reduction	6,700	$/ton	Guin et al, 2007
Cost savings resulting from CO reduction	6,360	$/ton	Guin et al, 2007
Cost savings resulting from NOx reduction	12,875	$/ton	Guin et al, 2007
Average price of gasoline in NJ	3.42	$/gallon	AAA Daily Fuel Gauge Report
Average price of diesel in NJ	3.7	$/gallon	AAA Daily Fuel Gauge Report
Average cost of secondary incident	$4,437	$/incident	Blincoe et al., 2002

7.1.4 Secondary Incidents

A simplified method described in the evaluation study of NaviGAtor program in Georgia (7) is used to calculate the number of secondary incidents. In the case study of Georgia NaviGAtor program Guin et al. assumed that 15% of all highway incidents are secondary, and that their occurrence is directly proportional to incident duration. This assumption is based on widely used findings of a study by Raub (1997). With this, the equation used in the preliminary methodology to calculate the reduction in number of secondary incidents is the following:

$$\Delta N_s = 0.15 \cdot N \cdot \frac{\Delta T_I}{T_{I-Base}} \qquad \text{Equation 8}$$

Where:

ΔN_s = Decrease in secondary incidents;
N = Total number of incidents to which SSP responded;
ΔT_I = Reduction in incident duration resulting from the SSP response;
$T_{I\text{-}Base}$ = Total duration of incidents without the SSP response.

Thus, the total cost savings due to reduced number of secondary incidents can be calculated as follows:

$$\Delta C_{si} = \Delta N_s \cdot c_a \qquad \text{Equation 9}$$

Where:

ΔC_{si} = Total cost savings due to reduced number of secondary incidents ($);
c_a = Average cost per accident ($/accident) – given in Table 7.

Therefore, TOTAL BENEFIT (COST SAVINGS) can be now calculated as:

$$B = \Delta C_d + \Delta C_e + \Delta C_f + \Delta C_{si} \qquad \text{Equation 10}$$

where B stands for benefits.

8 Appendix B

8.1 Crash Locations Before and After Reconstruction Commenced

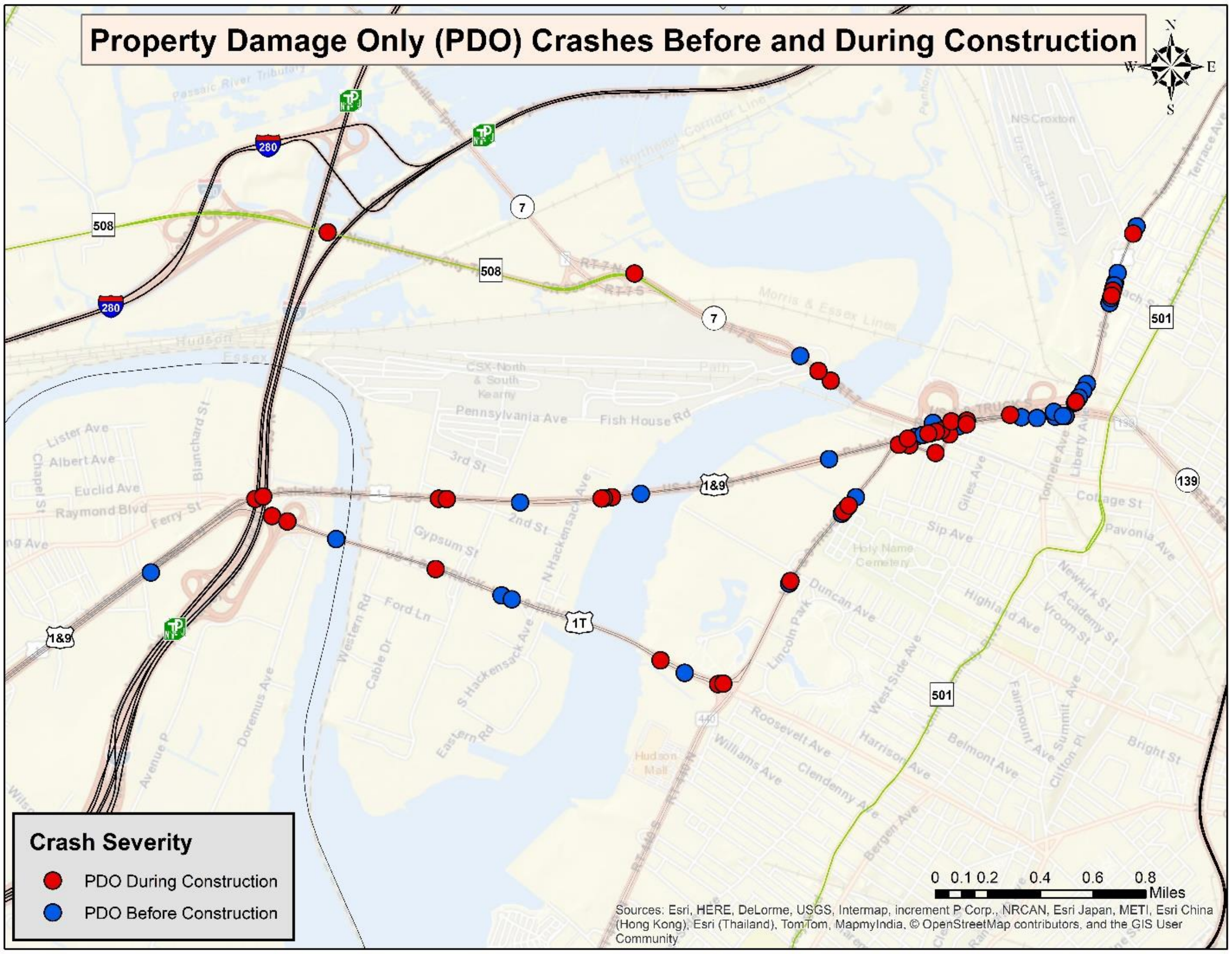

Figure 8: PDO Crash Locations Before and After Reconstruction Commenced

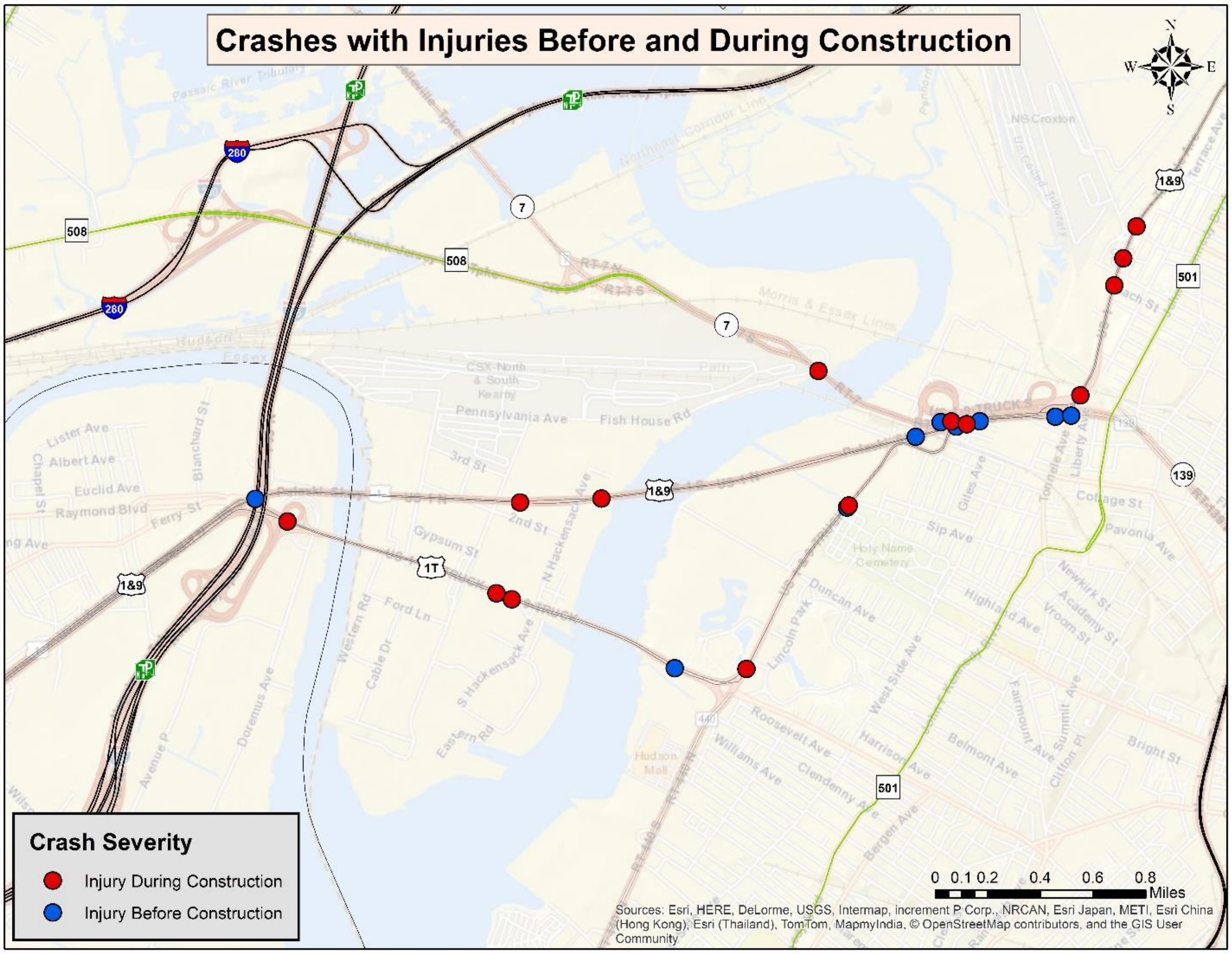

Figure 9: Crash Locations with Injuries Before and After Reconstruction Commenced

9 Appendix C

9.1 Incident Locations Before and After Reconstruction Commenced

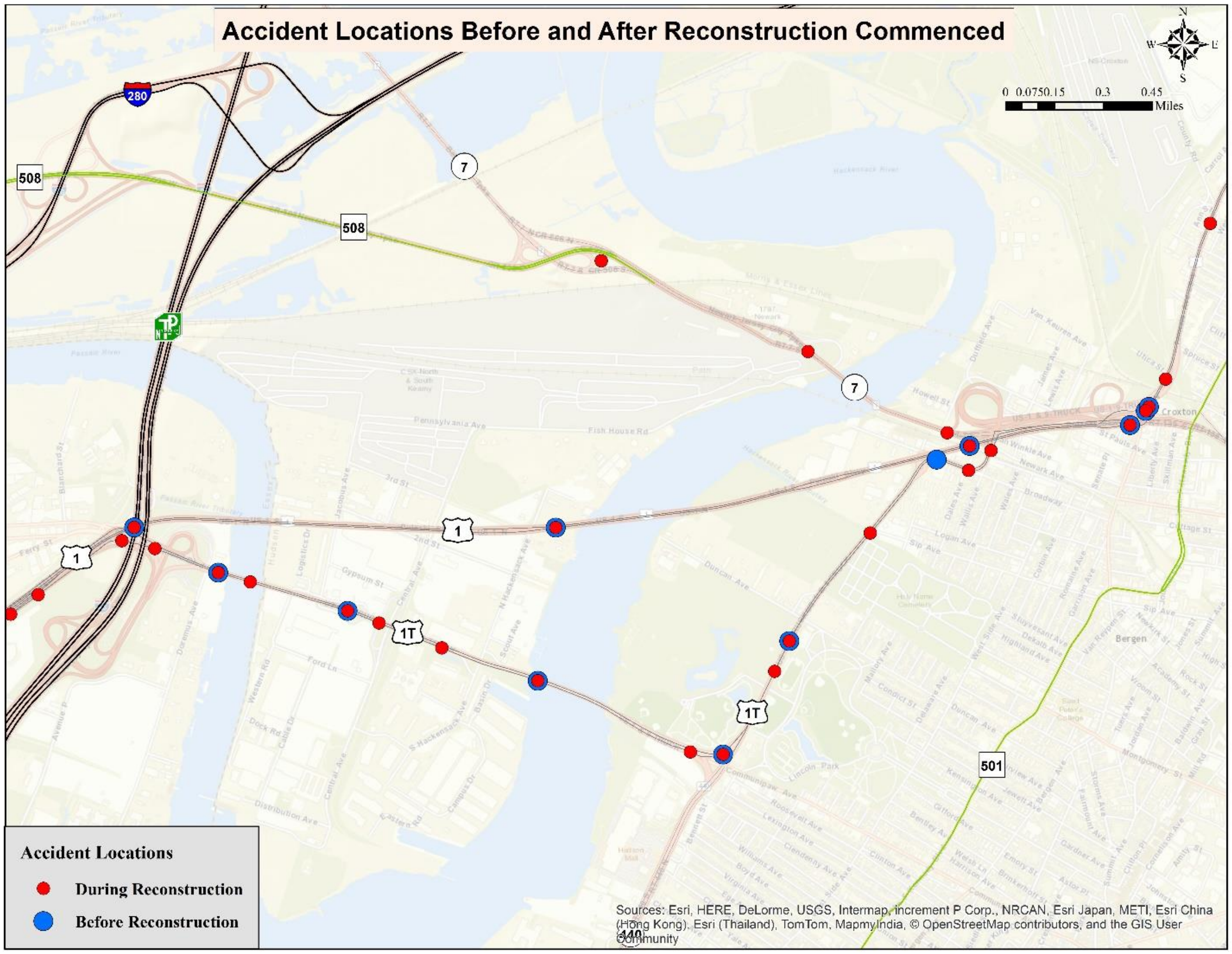

Figure 10: Accident Locations Before and After Reconstruction Commenced

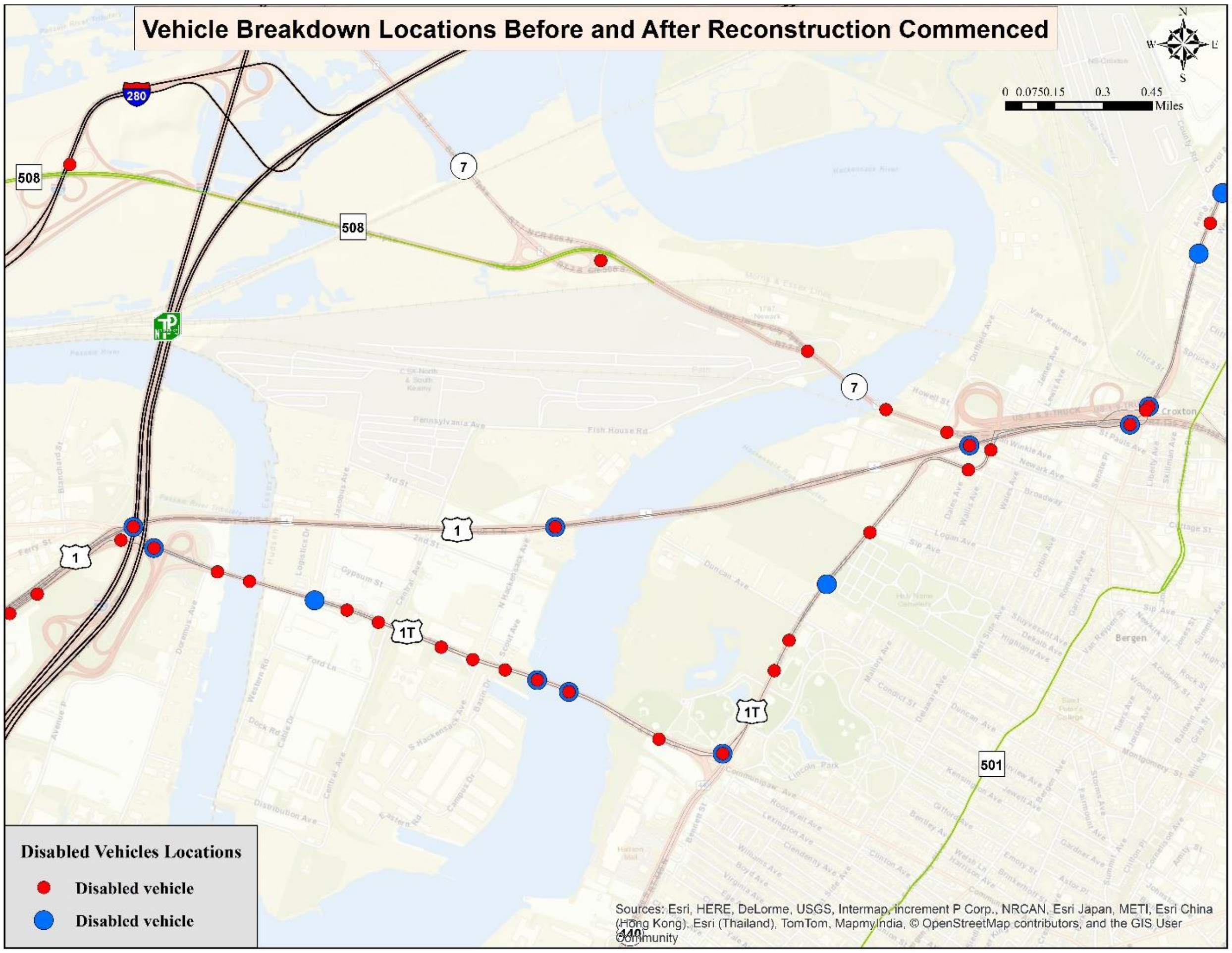

Figure 11: Vehicle Breakdown Locations Before and After Reconstruction Commenced

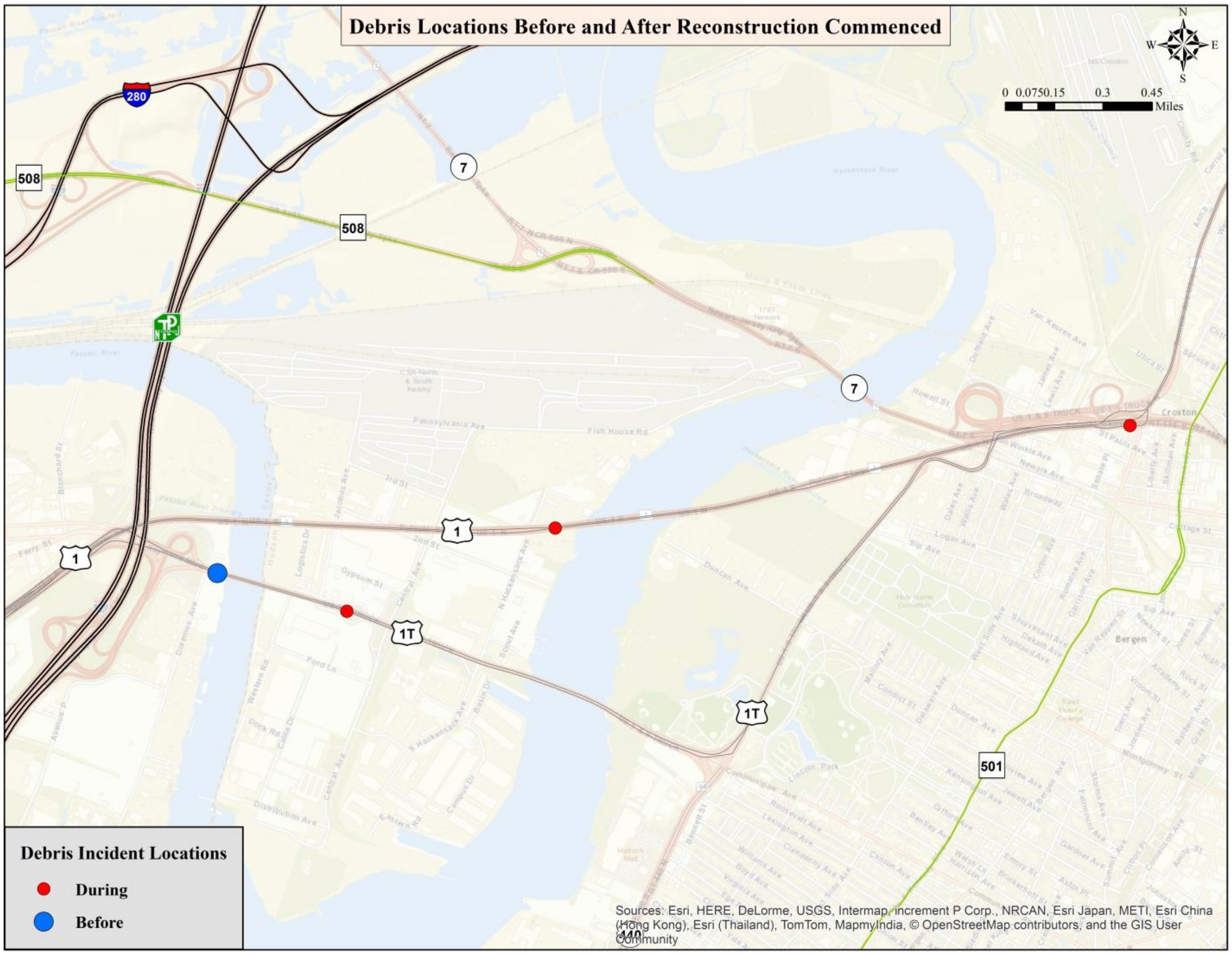

Figure 12: Debris Locations Before and After Reconstruction Commenced

10 .... Appendix D

10.1 Number of Crashes by Type by Roadway

Table 9: Number of PDO Crashes by Roadway)

Incident Type	Before Reconstruction	During Reconstruction	Percent Change (%)
Pulaski Skyway	26	10	-62
US 1&9/ Tonnelle Avenue	15	17	13
NJ Route 7	3	8	167
US 1&9 Truck Route	18	28	56
County Route 508	0	1	100

Table 10: Number of Crashes with Injuries by Roadway

Incident Type	Before Reconstruction	During Reconstruction	Percent Change (%)
Pulaski Skyway	10	5	-29
US 1&9/ Tonnelle Avenue	17	4	100
NJ Route 7	8	3	50
US 1&9 Truck Route	28	5	150
County Route 508	1		100

11 .... Appendix E

11.1 Change in Cost Savings as a Result in Change in Volume

Table 11: Change in Cost Savings as a Result in Change in Volume

Change in Incident Duration	Change in Traffic Volume						
	1%	5%	10%	15%	20%	25%	30%
1 min.	4%	17%	28%	43%	62%	84%	131%
5 min.	7%	13%	28%	51%	72%	114%	144%
10 min.	8%	16%	32%	54%	82%	124%	158%
15 min	8%	20%	38%	67%	94%	127%	162%
20 min.	7%	24%	40%	63%	92%	120%	152%
25 min.	8%	22%	39%	61%	84%	113%	146%
30 min.	7%	23%	35%	58%	81%	110%	139%

12 .... Appendix F

12.1 SSP Roadway Coverage by Yard

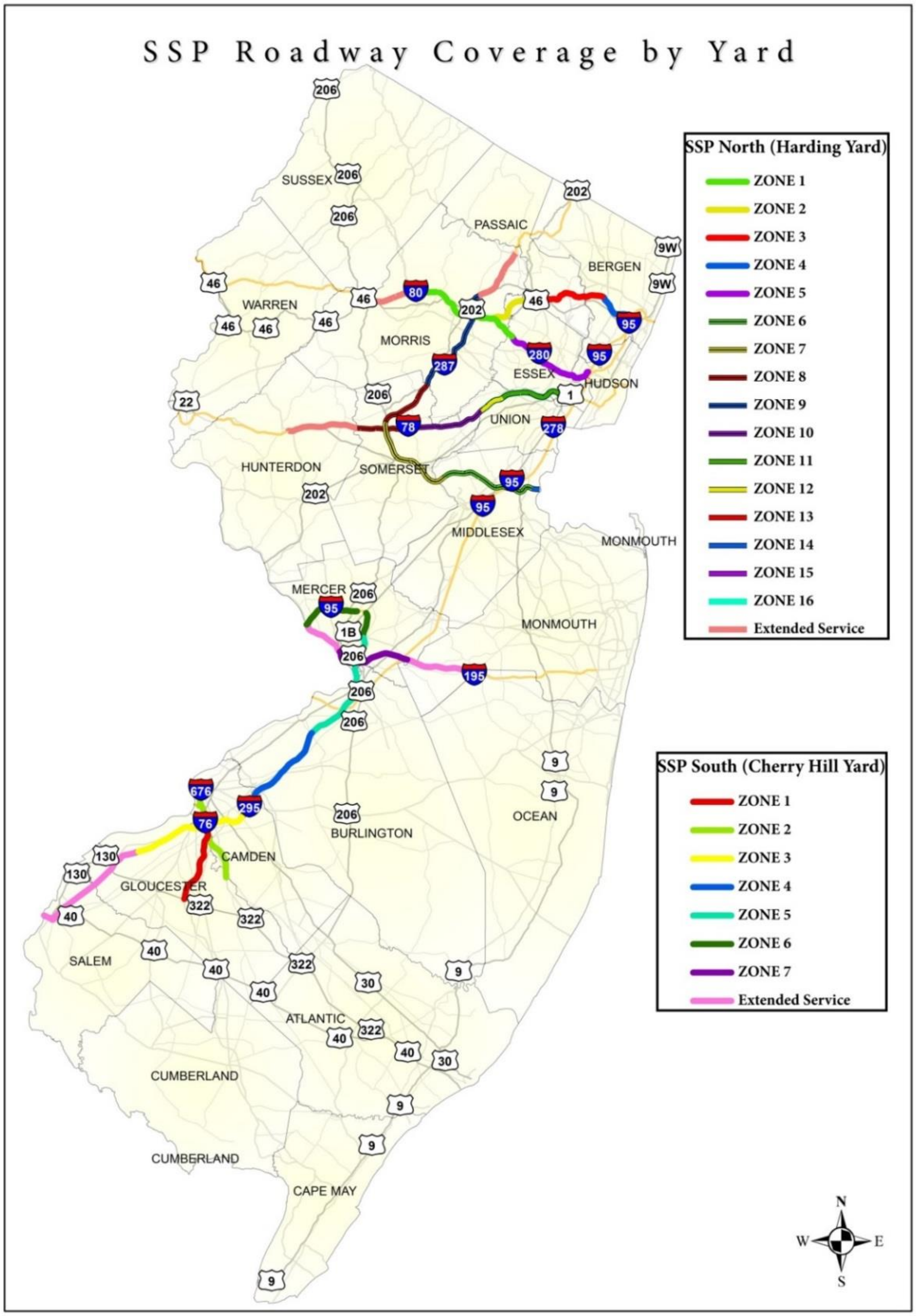

Figure 13: SSP roadway coverage by yard and zone

Table 12: SSP Zones by yard

Harding Yard

ZONE	LIMITS
1	I-80: 35.3 – 46.1 EX I-280: 0.0-exit 4
2	I-80: 42.0 – 54 Local
3	I-80: 52.0 – 63 Local
4	I-80: 61-68 Express and Local
5	I-280 4.0-17
6	NJ 440: 0-4.2 I-287: 0-9.0
7	I-287: 9.0 – 22.0
8	I-287: 22.0- 30.0 I-78: 27.1- 33.0
9	I-287: 30.0-45.0
10	I-78: 33.0-44.5
11	I-78: 48.2- 58.3 Local
12	I-78: 44.5- 58.3 Express
13	Roamer :I-80: Exit 42 to Exit 63
14	Roamer 440:0-5.2 I-287: Exit 0 to Exit 22
15	15= Roamer 280: Exit 1 to Exit 17
16	Roamer : I-78: Exit 44.5 to 58.3 Local & Express
SUPERVISION	Shift Supervisor Area: I-80 and I-280
	Shift Supervisor Area: I-78 and I-287
	Shift Supervisor Area: I-287 and I-80

Cherry Hill Yard

ZONE	LIMITS
1	NJ 55: Exit 50 to Exit 60
2	I-76: 0.0 to 2.3
	I-676: 0.0 to 3.7
	NJ 42: 6.2 to 14.3
3	I-295: Exit 16 to Exit 32
4	I-295: Exit 32 to Exit 47
5	I- 295: Exit 47 to Exit 63
6	I- 295: Exit 61 to Exit 67
	I- 95: 0.0 to Exit 8
7	NJ 29: 0.0 to 3.0
	I-195: 0.0 to Exit 7
Daily Roamer	Covers Zone 2 & 3
Roamer # 2	Covers Zone 6 & 7
	10:30 am to 8:30 pm
Roamer # 3	Covers Zone 4 & 5
	10:30 am to 12:30 pm
Roamer # 4	Covers Zone 1 & 2 10:30 am to 12:30 pm
Roamer # 5	Covers Zone 2 & 3
	10:30 am to 12:30 pm
	Friday Only
Shift Supervisor	Zones 1, 2 & 3
Shift Supervisor	Zones 4, 5, 6 & 7
Shift Supervisor	Zones 3, 4, 5 & 6

13 .... Appendix G

13.1 New Jersey State Police Crash Form – NJTR-1

Align with top edge of Report - 9/16" from top of this overlay

Cut here 21/32 " from left

96 **Road Divided By**
01 Barrier Median 02 Curbed Median 03 Grass Median 04 Painted Median 05 None

97 **Temporary Traffic Control Zone**
01 None 02 Construction Zone 03 Maintenance Zone 04 Utility Zone 05 Incident Zone

98 **Light Condition**
01 Daylight 03 Dusk 05 Dark (no street lights) 07 Dark (street lights on, spot)
02 Dawn 04 Dark (street lights off) 06 Dark (street lights on, continuous)

99 **Road System**
01 Interstate 03 State/Interstate Authority 05 County 07 Municipal 09 Private Property
02 State Highway 04 State Park or Institution 06 Co Auth, Park or Inst 08 Mun Auth, Park or Inst 10 US Govt Property

100 **Road Character**
01 Straight and Level 03 Straight at Hillcrest 05 Curve and Grade
02 Straight and Grade 04 Curve and Level 06 Curve at Hillcrest

101 **Road Surface Type**
01 Concrete 02 Blacktop 03 Gravel 04 Steel Grid 05 Dirt

102 **Road Surface Condition**
01 Dry 02 Wet 03 Snowy 04 Icy 05 Slush 06 Water (Standing/Moving) 07 Sand, Mud, Dirt 08 Oil

103 **Environmental Condition**
01 Clear 03 Snow 05 Overcast 07 Blowing Snow 09 Severe Crosswinds
02 Rain 04 Fog/Smog/Smoke 06 Sleet/Hail/Freezing Rain 08 Blowing Sand/Dirt

104 **Total Number of Motor Vehicles Involved in Crash**

105 ***Crash Type***

with Other MV as First Event
01 Same Direction (Rear End)
02 Same Direction (Side Swipe)
03 Right Angle
04 Opposite Direction (Head On, Angular)
05 Opposite Direction (Side Swipe)
06 Struck Parked Vehicle
07 Left Turn / U Turn
08 Backing
09 Encroachment

with Below as First Event
10 Overturned
11 Fixed Object
12 Animal
13 Pedestrian
14 Pedalcyclist
15 Non-fixed Object
16 Railcar -vehicle

106 Veh 1 / 107 Veh 2 **Oversize/Overweight Permit ? (Comm Veh Only)**
01 Yes 02 No

108 Veh 1 / 109 Veh 2 **Vehicle Type**

Passenger Vehicles (01-19)
01 Car/Station Wagon/Minivan
02 Passenger Van (< 9 Seats)
03 Cargo Van (10K lbs or less)
04 Sport Utility Vehicle
05 Pickup
06 Recreational Vehicle
07 All Terrain Vehicle
08 Motorcycle
09 (reserved)
10 any previous w/Trailer
11 Moped
12 Streetcar/Trolley
13 Pedalcycle
19 Other Pass Vehicle

Trucks / Bus (20-30)
20 Single Unit (2 axle)
21 Single Unit (3+ axle)
22 Light Truck w/Trailer
23 Single Unit Truck w/Trailer
24 Truck Tractor (Bobtail)
25 Tractor Semi-Trailer
26 Tractor Double
27 Tractor Triple
29 Other Truck
30 Bus / Large Van (9 or more Seats)

110 Veh 1 / 111 Veh 2 **Vehicle Use**
01 Personal
02 Business/Commerce
03 Government
04 Responding to Emergency
05 Machinery in Use

112 Veh 1 / 113 Veh 2 **Special Function Vehicles**
01 Work Equipment *
02 Police
03 Military
04 Fire/Rescue
05 Ambulance
06 Taxi/Limo
07 Veh Used as School Bus
08 Veh Used as Other Bus
09 School Bus
10 Transit Bus
11 Other Bus
12 Veh Used as Snowplow
13 Vehicle Towing Another Veh

114 Veh 1 / 115 Veh 2 **Cargo Body Type (Comm Veh Only)**
01 Bus (9-15 seats)
02 Bus (> 15 seats)
03 Van/Enclosed Box
04 Cargo Tank
05 Flatbed
06 Dump
07 Concrete Mixer
08 Auto Transporter
09 Garbage/Refuse
10 Hopper (grain,gravel,chips)
11 Pole (trailer)
12 Intermodal Chassis
13 No Cargo Body

116 Veh 1 / 117 Veh 2 **Direction of Travel of Vehicle**
01 North 02 East
03 South 04 West

Location of Most Severe Physical Injury
01 Head
02 Face
03 Eye
04 Neck
05 Chest
06 Back
07 Shoulder / Upper Arm
08 Elbow / Lower Arm / Hand
09 Abdomen / Pelvis
10 Hip / Upper Leg
11 Knee / Lower Leg / Foot
12 Entire Body

Which Vehicle Occupied
1 Vehicle 1 B Pedalcycle
2 Vehicle 2 P Pedestrian O Other

Position In/On Vehicle
01 Driver 02 thru 09 Passengers
10 Cargo Area 11 Riding/Hanging on Outside

11
1 2 3
4 5 6
7 8 9
10
11

Ejection From Vehicle
01 Not Ejected 03 Ejected
02 Partial Ejection 04 Trapped

Type of Most Severe Physical Injury
01 Amputation
02 Concussion
03 Internal
04 Bleeding
05 Contusion/Bruise/Abrasion
06 Burn
07 Fracture / Dislocation
08 Complaint of Pain

Victim's Physical Condition
01 Killed
02 Incapacitated
03 Moderate Injury
04 Complaint of Pain

Refused Medical Treatment
1 Yes 2 No

Safety Equipment
01 None
02 Lap Belt
03 Harness
04 Lap Belt & Harness
05 Child Restraint
06 Helmet
07 (reserved)
08 Airbag
09 Airbag & Seatbelts
10 Safety Vest (Ped only)

Avail Used

Airbag Deployment
01 Front 07 Other
02 Side 08 Multiple

Age **Sex** **Hosp Code**

83 84 85 86 87 88 89 90 91 92 93 94 95

Cut here 1 5/16 " from bottom

State of New Jersey Police Crash Investigation Report NJTR-1

Use Code 00 for Unknown.

Use Code 99 for Other.

Explain Other in Crash Description

Also, Explain Items Marked with asterisk (*) in Crash Description

If an Item Does Not Apply, Enter a Dash (-)

NOTE:
Boxes 1 - 7 must be completed for all pages of the report.

Boxes 8-22 and 96-105 are only required on page 1 of the report.

All other information is completed as necessary.

Websites for :

Crash References -
http://www.state.nj.us/transportation/refdata/accidents/policeres/shtm

Insurance Codes -
5 digit NAIC - http://www.nj.gov/dobi/data/inscomp.htm
3 digit MVC - http://www.state.nj.us/mvc/numeric.pdf

Hospital Codes
- http://www.state.nj.us/health/ems/jems.pdf

Overlay Page 1 of 2

Cutting at designated positions will permit arrows on each side to be displayed when the appropriate overlay is paged. It will also permit the first overlay to be slightly longer than the second for easy paging.
Printing should be done Portrait, Duplex, Flip on Short Edge

Figure 14. NJTR-1