Task Order 82

Estimating the Benefits of NJDOT Safety Service Patrol

FINAL REPORT

NOVEMBER 29, 2013
REVISED DECEMBER 19, 2013

Prepared for

Prepared by

New Jersey's Science & Technology University

PROJECT TITLE
Task Order 82: Intelligent Transportation Systems Resource Center

REPORT TITLE
Estimating the Benefits of NJDOT Safety Service Patrol

Authors
Lazar Spasovic, Ph.D. (Principal Investigator)
Professor

Dejan Besenski, Ph.D.
Senior Research Planner

Branislav Dimitrijevic
Principal Research Planner

Kitae Kim, Ph.D.
Senior Research Engineer

New Jersey Institute of Technology
Department of Civil & Environmental Engineering
University Heights
Newark, NJ 07102

NJIT
New Jersey's Science &
Technology University

Table of Contents

EXECUTIVE SUMMARY 1

INTRODUCTION 5

1.1 Research Objectives 7

1.2 Organization of the Report 7

NJDOT STATEWIDE INCIDENT MANAGEMENT PROGRAM 8

2.1 Safety Service Patrol (SSP) 8

2.2 SSP Coverage Area 9

REVIEW OF THE STATE OF PRACTICE 11

3.1 Traffic Flow and Queuing Model 11

3.2 Detection and Response Time 12

3.3 Capacity Reduction Due to an Incident 13

3.4 Type of Incidents 15

3.5 Delay Calculation 15

3.6 Costs of Freeway Service Patrol 19

3.7 Benefit-Cost Ratio 19

3.8 FSP Evaluation and Predictor Model 20

DATA COLLECTION 23

4.1 OpenReach Data Management System 23

4.2 New Jersey Congestion Management System (NJCMS) 24

4.3 Data Integration 24

EVALUATION METHODOLOGY 25

5.1 Service Description 26

5.2 Design Characteristics 26

5.3 Traffic Characteristics 27

5.4 Incident Characteristics 27

5.5 Additional Parameters 27

ANALYSIS OF THE INCIDENT DATA 29

EVALUATION OF THE SAFETY SERVICE PATROLS 34

7.1 The Results of the Benefit/Cost Analysis 34

7.2 Sensitivity Analysis 38

CONCLUSIONS 40

REFERENCES 42

APPENDIX A. ESP vs. SSP ROADWAY COVERAGE 44

APPENDIX B. SSP ZONES BY YARD 45

APPENDIX C. INCIDENT FREQUENCY AND CHARACTERISTICS 46

APPENDIX D. AVERAGE INCIDENT DURATION BY EVENT TYPE AND BY ROADWAY 47

APPENDIX E. SSP SERVICE DESCRIPTION 50

APPENDIX F: DISTRIBUTION OF INCIDENT TYPES BY LOCATION AND AVERAGE INCIDENT DURATION 51

F.1. Harding Yard – Zone 1 51

F.2. Harding Yard – Zone 2 52

F.3. Harding Yard – Zone 3 53

F.4. Harding Yard – Zone 4 54

F.5. Harding Yard – Zone 5 55

F.6. Harding Yard – Zone 6 56

F.7. Harding Yard – Zone 7 57

F.8. Harding Yard – Zone 8 58

F.9. Harding Yard – Zone 9 59

F.10. Harding Yard – Zone 10 60

F.11. Harding Yard – Zone 11 61

F.12. Harding Yard – Zone 12 62

F.13. Cherry Hill Yard – Zone 1 63

F.14. Cherry Hill Yard – Zone 2 64

F.15. Cherry Hill Yard – Zone 3 65

F.16. Cherry Hill Yard – Zone 4 66
F.17. Cherry Hill Yard – Zone 5 67
F.18. Cherry Hill Yard – Zone 6 68
F.19. Cherry Hill Yard – Zone 7 69

APPENDIX G. SENSITIVITY ANALYSIS RESULTS 70
Harding Yard – Zone 1 70
Harding Yard – Zone 2 71
Harding Yard – Zone 3 72
Harding Yard – Zone 4 73
Harding Yard – Zone 5 74
Harding Yard – Zone 6 75
Harding Yard – Zone 7 76
Harding Yard – Zone 8 77
Harding Yard – Zone 9 78
Harding Yard – Zone 10 79
Harding Yard – Zone 11 80
Harding Yard – Zone 12 81
Cherry Hill Yard – Zone 1 82
Cherry Hill Yard – Zone 2 83
Cherry Hill Yard – Zone 3 84
Cherry Hill Yard – Zone 4 85
Cherry Hill Yard – Zone 5 86
Cherry Hill Yard – Zone 6 87
Cherry Hill Yard – Zone 7 88

List of Tables

Table 1. Remaining Freeway Capacity (%) Recommended by HCM 14
Table 2. Benefit/Cost Ratios of the Service Patrols 20
Table 3. Model Inputs and Data Sources 25
Table 4. Number of Incidents by Road and Service Area (Year 2012) 29
Table 5. Incidents per Mile Rate (IPMR), 2012. 31
Table 6. Incident Rate, 2012 32
Table 7. Average Incident Duration and Percent Reduction in Incident Duration (2012) 32
Table 8. The B/C Ratios for Harding and Cherry Hill Yards 35
Table 9. Savings and B/C Ratio for Harding Yard Zones 36
Table 10. Savings and B/C Ratio for Cherry Hill Yard Zones 37
Table 11. Change in Benefit-Cost Ratio for Harding Yard 38
Table 12. Change in Benefit-Cost Ratio for Cherry Hill Yard 38
Table 13. The B/C Ratios for Harding and Cherry Hill Yards (wage with fringe benefits) 39
Table 14. Comparison Between ESP and SSP Roadway Coverage 44
Table 15. Events by Category and Their Frequency 46
Table 16. Average Incident Duration by Event Type and By Roadway (ESP Service) 47
Table 17. Average Incident Duration by Event Type and By Roadway (SSP Service) 48
Table 18. Harding Yard Hours of Operation and Staffing 50
Table 19. Cherry Hill Yard Hours of Operation and Staffing 50
Table 20. Average Incident Duration 51
Table 21. Average Incident Duration in Zone 2 Harding Yard 52
Table 22. Average Incident Duration in Zone 3 Harding Yard 53
Table 23. Average Incident Duration in Zone 4 Harding Yard 54
Table 24. Average Incident Duration in Zone 5 Harding Yard 55
Table 25. Average Incident Duration in Zone 6 Harding Yard 56
Table 26. Average Incident Duration in Zone 7 Harding Yard 57
Table 27. Average Incident Duration in Zone 8 Harding Yard 58
Table 28. Average Incident Duration in Zone 9 Harding Yard 59
Table 29. Average Incident Duration in Zone 10 Harding Yard 60
Table 30. Average Incident Duration in Zone 11 Harding Yard 61
Table 31. Average Incident Duration in Zone 12 Harding Yard 62
Table 32. Average Incident Duration in Zone 1 Cherry Hill Yard 63
Table 33. Average Incident Duration in Zone 2 Cherry Hill Yard 64
Table 34. Average Incident Duration in Zone 3 Cherry Hill Yard 65
Table 35. Average Incident Duration in Zone 4 Cherry Hill Yard 66
Table 36. Average Incident Duration in Zone 5 Cherry Hill Yard 67
Table 37. Average Incident Duration in Zone 6 Cherry Hill Yard 68
Table 38. Average Incident Duration in Zone 7 Cherry Hill Yard 69

List of Figures

Figure 1. Roadway Coverage Area by ESP and SSP 2
Figure 2. Roadway Coverage Area by ESP and SSP 6
Figure 3. SSP roadway coverage by yard and zone 10
Figure 4. Cumulative Vehicle Volume vs. Time Graph for a Highway Incident 12
Figure 5. Distribution of Incident Types by Location in Zone 1 Harding Yard 51
Figure 6. Distribution of Incident Types by Location in Zone 2 Harding Yard 52
Figure 7. Distribution of Incident Types by Location in Zone 3 Harding Yard 53
Figure 8. Distribution of Incident Types by Location in Zone 4 Harding Yard 54
Figure 9. Distribution of Incident Types by Location in Zone 5 Harding Yard 55
Figure 10. Distribution of Incident Types by Location in Zone 6 Harding Yard 56
Figure 11. Distribution of Incident Types by Location in Zone 7 Harding Yard 57
Figure 12. Distribution of Incident Types by Location in Zone 8 Harding Yard 58
Figure 13. Distribution of Incident Types by Location in Zone 9 Harding Yard 59
Figure 14. Distribution of Incident Types by Location in Zone 10 Harding Yard 60
Figure 15. Distribution of Incident Types by Location in Zone 11 Harding Yard 61
Figure 16. Distribution of Incident Types by Location in Zone 12 Harding Yard 62
Figure 17. Distribution of Incident Types by Location in Zone 1 Cherry Hill Yard 63
Figure 18. Distribution of Incident Types by Location in Zone 2 Cherry Hill Yard 64
Figure 19. Distribution of Incident Types by Location in Zone 3 Cherry Hill Yard 65
Figure 20. Distribution of Incident Types by Location in Zone 4 Cherry Hill Yard 66
Figure 21. Distribution of Incident Types by Location in Zone 5 Cherry Hill Yard 67
Figure 22. Distribution of Incident Types by Location in Zone 6 Cherry Hill Yard 68
Figure 23. Distribution of Incident Types by Location in Zone 7 Cherry Hill Yard 69
Figure 24. Annual Savings and B/C Ratio for Harding Yard Zone 1 70
Figure 25. Savings and B/C Ratio for Harding Yard Zone 2 71
Figure 26. Savings and B/C Ratio for Harding Yard Zone 3 72
Figure 27. Savings and B/C Ratio for Harding Yard Zone 4 73
Figure 28. Savings and B/C Ratio for Harding Yard Zone 5 74
Figure 29. Savings and B/C Ratio for Harding Yard Zone 6 75
Figure 30. Savings and B/C Ratio for Harding Yard Zone 7 76
Figure 31. Savings and B/C Ratio for Harding Yard Zone 8 77
Figure 32. Savings and B/C Ratio for Harding Yard Zone 9 78
Figure 33. Savings and B/C Ratio for Harding Yard Zone 10 79
Figure 34. Savings and B/C Ratio for Harding Yard Zone 11 80
Figure 35. Savings and B/C Ratio for Harding Yard Zone 12 81
Figure 36. Savings and B/C Ratio for Cherry Hill Yard Zone 1 82
Figure 37. Savings and B/C Ratio for Cherry Hill Yard Zone 2 83
Figure 38. Savings and B/C Ratio for Cherry Hill Yard Zone 3 84

Figure 39. Savings and B/C Ratio for Cherry Hill Yard Zone 4 85
Figure 40. Savings and B/C Ratio for Cherry Hill Yard Zone 5 86
Figure 41. Savings and B/C Ratio for Cherry Hill Yard Zone 6 87
Figure 42. Savings and B/C Ratio for Cherry Hill Yard Zone 7 88

EXECUTIVE SUMMARY

Background

The New Jersey DOT Safety Service Patrol (SSP) is one of the critical elements of Department's incident management program. The purpose of SSP is to utilize roaming vehicles to patrol congested critical sections of the statewide freeway network in order to quickly detect and respond to incidents, and to assist the law enforcement with traffic control at crash scenes. The SSP, previously known as Emergency Service Patrol (ESP), has been recently reorganized, resulting in a 28% reduction of patrolled freeway miles compared to the former ESP operation. The SSP now operates in a service area including 225 center-lane miles of New Jersey's core commuter and high traffic-volume freeways. The ESP and SSP coverage is shown in Figure 1.

Study Objectives

The objectives of this research study are twofold:

- Determine whether the SSP program is effective in reducing incident duration.
- Quantify the benefits and cost-effectiveness of the SSP program.

The effectiveness of SSP is measured vis-à-vis costs and benefits associated with its response to incidents and incident clearance activities. The benefits of early response and faster clearance of highway incidents result from the ability to restore more quickly the normal traffic conditions that existed before the incident had occurred, thus reducing the vehicle queuing and congestion associated with the incident. The resulting savings include:

- Reduced traffic delay,
- Reduced vehicle emissions, and
- Reduced fuel consumption.

In conducting this analysis, the following questions will be answered:

1. Does the SSP coverage area contain a majority of incidents that occurred on the roadway previously covered by the ESP?
2. How risky or safe are the roads patrolled by SSP?
3. How risky or safe are the individual roads patrolled by SSP?

The corollary of these is the following question: Has the re-organized SSP service increased a chance of a faster detection of incidents, thus reducing the incident response and duration times?

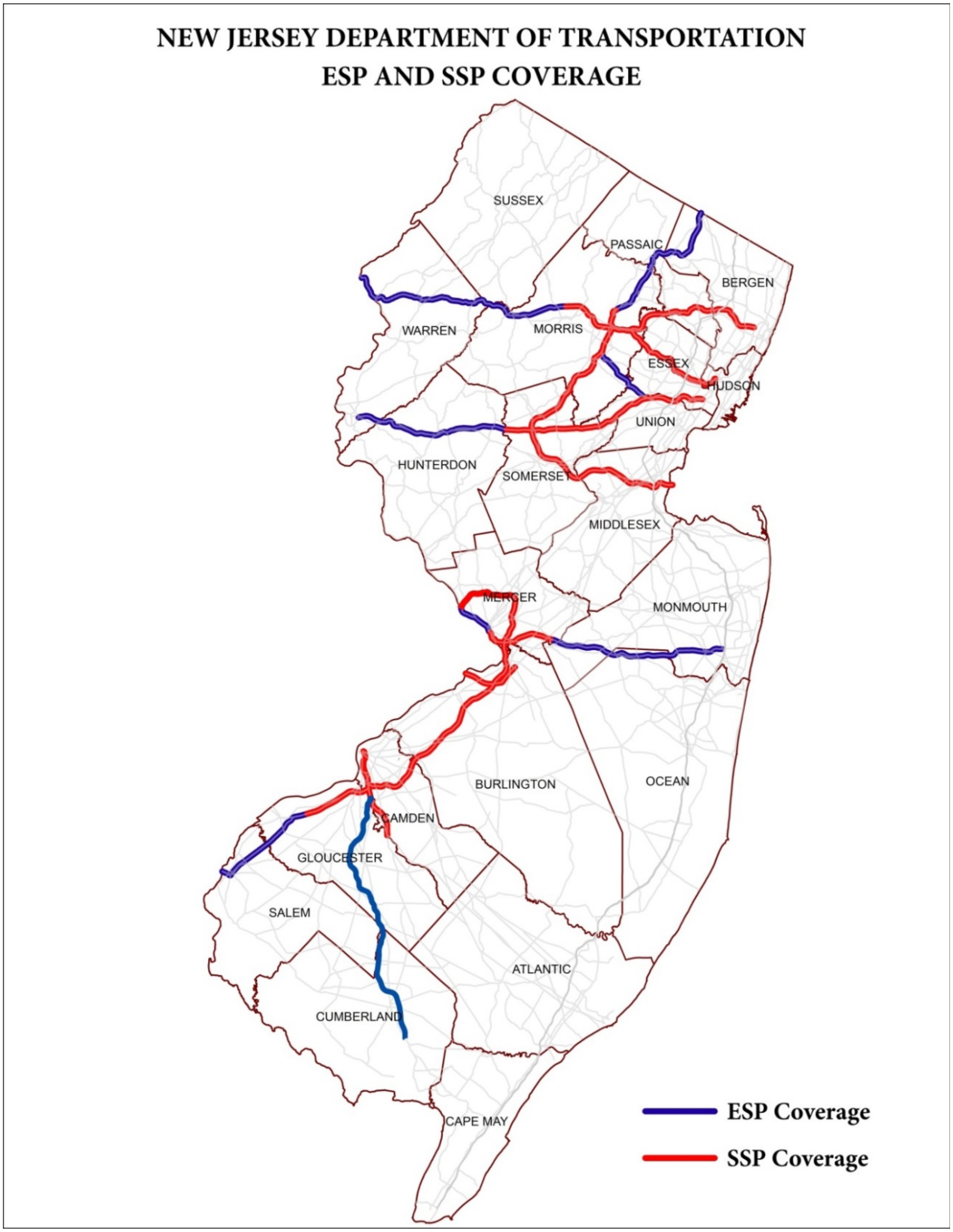

Figure 1. Roadway Coverage Area by ESP and SSP

Data Collection and Analysis

The benefits and cost-effectiveness of the SSP were estimated using the Freeway Service Patrol Evaluation (FSPE) model. The FSPE was developed by the University of California at Berkeley, and it estimates the benefits of the freeway patrol programs in terms of savings in travel time and fuel resulting from quicker incident detection, response, and clearance.

The FSPE model was calibrated to fit New Jersey roadway, traffic and SSP service conditions. The data inputs for the FSPE model were obtained from the relevant databases pertaining to NJDOT SSP and ESP operations, including: (a) traffic incident data archived in the NJDOT OpenReach database; (b) roadway geometry and traffic flow data, including synthesized hourly vehicle volumes for roadways patrolled by the SSP obtained from the New Jersey Congestion Management System (NJCMS); and (c) detailed SSP zone[1] information, including vehicle and crew assignments and frequencies. The evaluation was conducted for six-month period between January and June of 2012.

The incident statistics was also analyzed for the routes patrolled by SSP and previously by ESP. Particularly, the indicators such as number of incidents, number of incident responses, and (average) incident duration were compared between the SSP and ESP service areas to determine any change in effectiveness of these programs after the transition from ESP to SSP.

Results

The findings of this study are as follows:

- The data for the first 6 months of 2012 shows that the roadway sections patrolled by the SSP accounted for 95.5 % of all incidents that occurred within the network previously patrolled by the ESP. This is despite a decrease in SSP roadway coverage by 28% as compared to ESP. Therefore, it can be concluded that the SSP has been patrolling the sections of the New Jersey highway network where the need for its service is the highest.
- The realigned (SSP) roadway network has higher incident rate and incident per mile rate. These higher rates could be interpreted to mean that the realigned network needs more attention as it is “risker” – more likely to contain incident location. By focusing the SSP service to this network, NJDOT is doing the right thing as it allocates its resources to the area that is most in need.

[1] Section(s) of the New Jersey highway network patrolled by SSP

- Consequently, as a result of restructured service, the incident duration was reduced on average by approximately 9%.

- The average incident duration was reduced the most on patrolled sections of highway NJ 55. The reduction was 36%. This was followed by a reduction at I-195 of 30%. The average incident duration was reduced by 22% on I-78.

- The only portion of the network that recorded higher average incident duration with SSP service was highway NJ 29. It increased by 12 %. **Perhaps additional patrol can be added to this road to bring the incident duration down.**

- The SSP is cost effective. **The benefit and cost (B/C) ratio for the entire SSP program is approximately 6.2.** The Benefit/Cost Ratio ranged from 1.4 to 26.1 among the 19 different SSP zones. This translates to a return of $1.4-$26.1 in fuel and time savings for each dollar invested in the SSP program.

Conclusion

The results of the study show that NJDOT SSP Operation provides an important service in identifying incidents, clearing obstructions such as debris and disabled vehicles from roadways, and assisting the law enforcement with traffic control at crash scenes. This leads towards reduction of incident duration and subsequently significant monetary savings for the traveling public and the society. The results also show that reorganized service is more effective (reduced incident duration) and that the service is cost-effective.

Chapter 1.

INTRODUCTION

The New Jersey DOT Safety Service Patrol (SSP) is one of the critical elements of Department's incident management program. The purpose of SSP is to utilize roaming vehicles to patrol congested critical sections of the statewide freeway network in order to quickly detect and respond to incidents. This includes clearing obstructions from roadways (such as debris and dead animals), assistance to disabled vehicles and their removal from the roadway, and providing traffic control and other assistance to the law enforcement at the crash scenes. Similar programs are used nationwide to help mitigate the effects of non-recurring congestion on highways and have become an important and integral part of statewide incident management programs.

The SSP, previously known as Emergency Service Patrol (ESP), has been recently reorganized, resulting in a 28% reduction of patrolled freeway miles compared to the former ESP operation. The SSP now operates in a service area including 225 center-lane miles of New Jersey's core commuter and high traffic-volume freeways. The SSP and the ESP area coverage is shown in Figure 2.

Another element of NJDOT incident management program are Maintenance Operations forces. The Maintenance Operations crews respond to major traffic incidents and assist the New Jersey State Police and Incident Management Response Team (IMRT) with creating safe zones for incident responders and, when needed, clearing the incident sites using heavy equipment. When dispatched, the Maintenance Operations forces are part of a collaborative response from NJDOT that fulfills the requirements of the National Incident Management System (NIMS). NJIT's 2013 study estimated that about 9 percent reduction in incident duration in New Jersey can be attributed to the Maintenance Operations responding to major traffic incidents. The evaluation showed that the benefits far outweigh the costs of their involvement in incident response by a ratio of 6.2 to1.

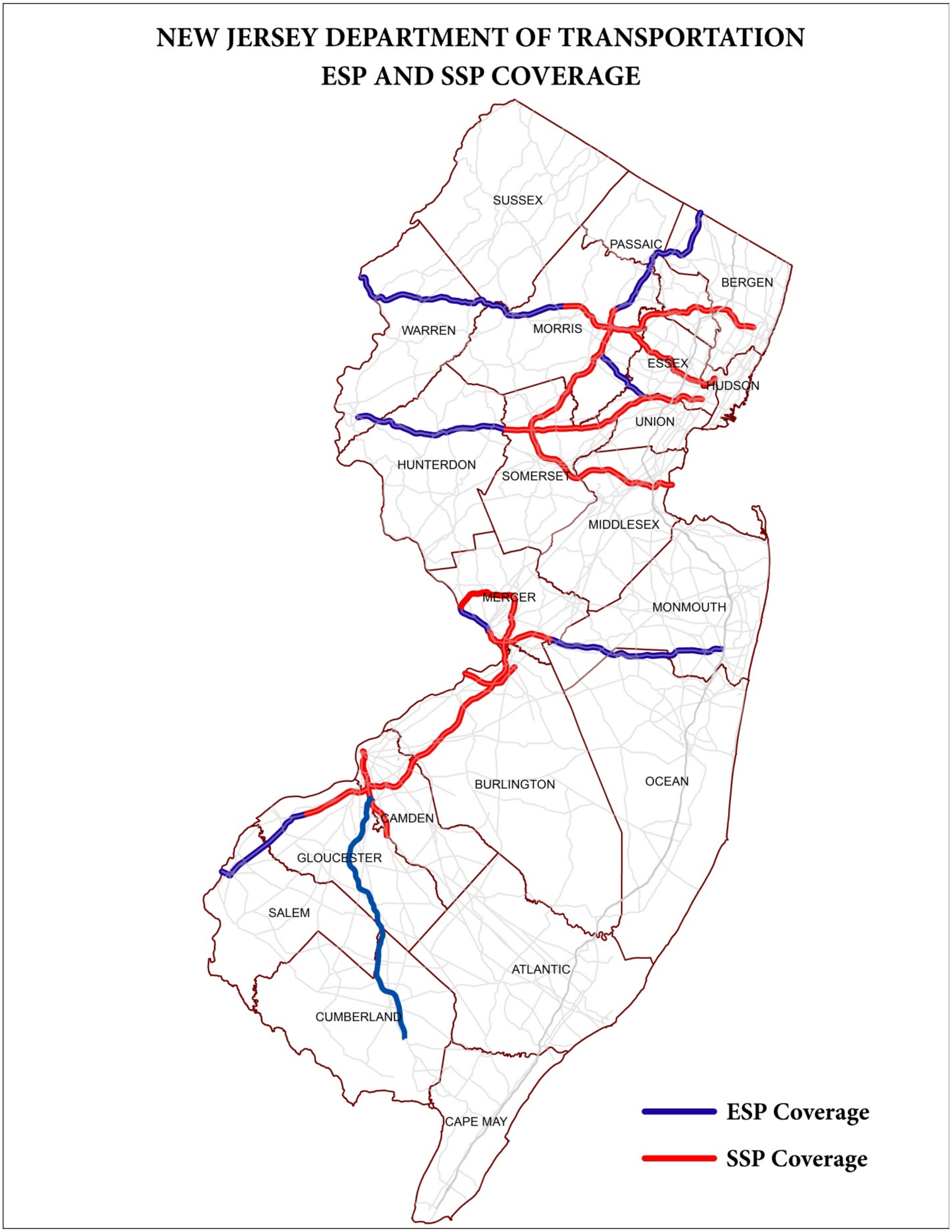

Figure 2. Roadway Coverage Area by ESP and SSP

1.1 Research Objectives

The objectives of this study are twofold:

1. Determine whether the SSP program is effective in reducing incident duration.
2. Quantify the benefits and cost-effectiveness of the SSP program.

The effectiveness of NJDOT's SSP is measured vis-à-vis costs and benefits associated with their response to incidents and incident clearance activities. The benefits of early response and faster clearance of highway incident aftermaths include savings resulting from a highway facility returning quicker to the normal conditions that existed before the incident had occurred. The resulting savings include:

- Reduced traffic delay,
- Reduced emissions, and
- Reduced fuel consumption.

1.2 Organization of the Report

The report is organized in eight chapters. Chapter 2 presents a discussion of NJDOT's Incident Management Program and the role the SSP has in it. Chapter 3 summarizes the state of practice in evaluating benefits of incident management programs. Chapter 4 focuses on data collection and analysis. The sources of incident data used by NJDOT are described in detail. Chapter 5 describes the approaches for evaluating the SSP Operations. Chapter 6 presents an analysis of effectiveness of NJDOT ESP during the January 1st – June 30th, 2011 period. It also presents an analysis of effectiveness of NJDOT SSP during the January 1st – June 30th, 2012 period. It then compares one to the other and draws conclusions. Chapter 7 presents the cost-benefit analysis that shows that a deployment of SSP generates substantial cost savings. The model quantifies the impacts of traffic incidents on mobility and congestion, air quality, and fuel consumption. It outlines the cost-efficiency of the SSP program. Chapter 8 summarizes the conclusions of the study.

Chapter 2.

NJDOT STATEWIDE INCIDENT MANAGEMENT PROGRAM

NJDOT's Statewide Traffic Incident Management (TIM) program is a collaborative effort between NJDOT and the NJSP for managing the state's transportation infrastructure and restoring the lanes of traffic in a safe and expeditious manner in the event of traffic incidents. It is a systematic tool used for the command, control, and coordination of a highway emergency response. This program allows agencies to work together using common terminology and operating procedures for controlling personnel, facilities, equipment, and communications at the scene of a traffic incident.

The TIM program employs several NJDOT resources, including: the SSP, Traffic Operations Centers (TOCs), the Statewide Traffic Management Center (STMC), the Central Dispatch Unit (CDU), as well as Maintenance Operations. These units work together and collaborate with the New Jersey State Police (NJSP) to detect, respond to, assist in, and clear various types of traffic incidents. The activities of the NJDOT personnel and NJSP at the scene of the incident are managed and coordinated through the Incident Management Response Teams (IMRT). NJDOT Bureau of ITS Engineering also provides support in the development and deployment of Intelligent Transportation Systems that can be used to provide an effective incident management.

2.1 Safety Service Patrol (SSP)

One of the most important elements of NJDOT's TIM program is the SSP. As of July 1, 2011, NJDOT ESP program was reorganized and renamed into SSP. The program has been realigned and renamed to bring new focus to the core mission of mitigating roadway congestion and enhancing safety for the motoring public. By realigning the patrolled routes, NJDOT expects to achieve cost savings. Also, for the first time it provided motorists with weekend service. The SSP is operational between 4:00 a.m. and 8:30 p.m. Monday through Friday, and between 10:00 a.m. and 8:30 p.m. Saturday and Sunday. The responsibilities of the SSP include the following:

- Utilize roaming vehicles to patrol congested sections of the statewide freeway network in order 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 diverting traffic around incident scenes in a safe manner.

- Assist disabled vehicles, remove the 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 incident to prevent secondary incidents from occurring.
- Handle containment of minor spills if necessary.

2.2 SSP Coverage Area

The ESP program covered approximately 396 center-lane miles of New Jersey interstate highways and other freeways. The ESP program operated only on weekdays, Monday through Friday. The SSP on the other hand patrols over 225 center-lane miles of New Jersey's roadways. The SSP covers the 72.9% of the ESP. The SSP and the ESP coverage areas are shown in Figure 2. However, the SSP consists of 70 drivers operating 16 hours per day during a workday, and 10 hours per day on weekends. The changes in coverage area by route and mile post are shown in Appendix A. Under certain circumstances that result in lane closure, the SSP will extend its coverage area by additional 58 miles. This "extended coverage" is also shown in Appendix A.

The statewide SSP coverage area[2] is as follows:

- In the northern part of the state, SSP operate 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).

The SSP is operated from two NJDOT yards: Harding Yard (SSP North Region), and Cherry Hill Yard (SSP South Region). The roadways patrolled by the SSP North are divided into 16 zones, and the roadways patrolled by the SSP South are divided into 7 zones. One or more SSP trucks with a service schedule are assigned to each zone. The SSP coverage by yard and by zone is shown in Figure 3. Detailed route assignments with terminal mileposts for each zone are provided in Appendix B.

[2] For actual mile post marker on the roads, please consult Appendix A.

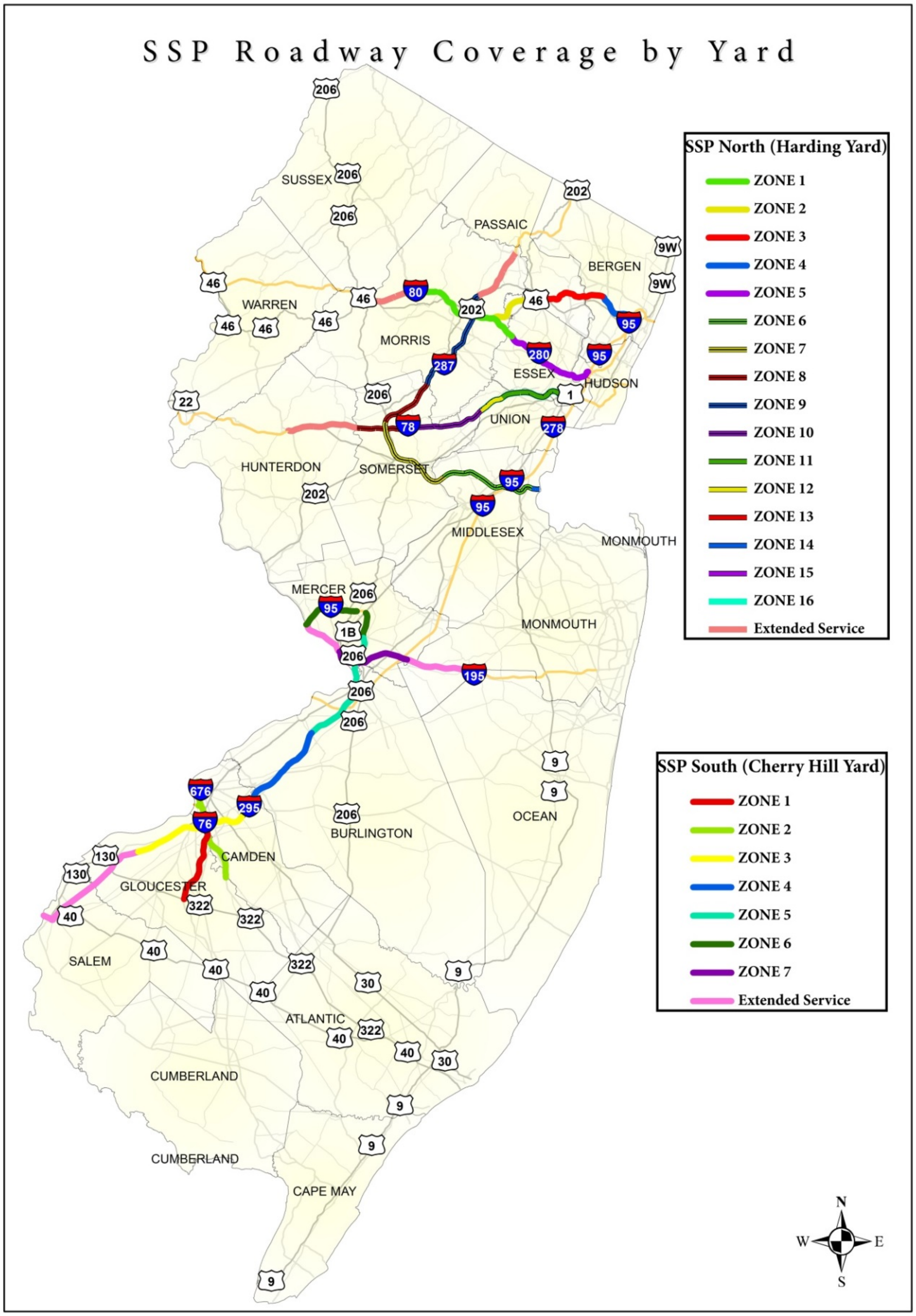

Figure 3. SSP roadway coverage by yard and zone

Chapter 3.

REVIEW OF THE STATE OF PRACTICE

An extensive literature search was done in order to identify studies, research papers, reports, and other publications that are deemed relevant to the scope of the study – namely, evaluating effects of freeway service patrol (FSP) programs. The literature review focused on methodologies for quantifying impacts of reducing incident duration, as well as quantifying benefits of faster cleanup of incidents and restoration of the normal traffic flow conditions. The findings from this review served as a basis for developing an evaluation methodology that was then applied in assessing the benefits of the NJDOT's SSP program.

3.1 Traffic Flow and Queuing Model

The vehicle flow, queue formation, and queue dissipation can be described using a cumulative vehicle volume vs. time graph, as shown in Figure 4. On a highway segment in normal conditions, where demand is smaller than capacity, vehicle flow can be described by vehicle arrival rate λ, in vehicles per hour (represented by the green line in Figure 4). The capacity of the highway segment can be described by the maximum vehicle service rate μ, which is higher than the arrival rate (red line in Figure 4). Arrival and service rates can be considered to be constant and continuous.

When an incident occurs, it reduces the capacity from μ to μ_I (represented by the blue line in Figure 4). If μ_i is smaller than λ, vehicle queuing will occur (vehicle flow following the incident occurrence is described by the blue line in Figure 4). The incident capacity μ_i remains until the incident is cleared. If Maintenance Operations is dispatched to the incident site, the incident will be cleared in time t_R; without the Maintenance Operations units at the site, it would take longer to clear the incident - t_R'. Once the incident is cleared, queue dissipates at the rate μ (red line in Figure 4). Consequently, a response by Maintenance Operations reduces the time necessary for the facility to return to normal flow from t_Q' to t_Q, and allows the savings in total vehicle delay represented by the red shaded area in Figure 4.

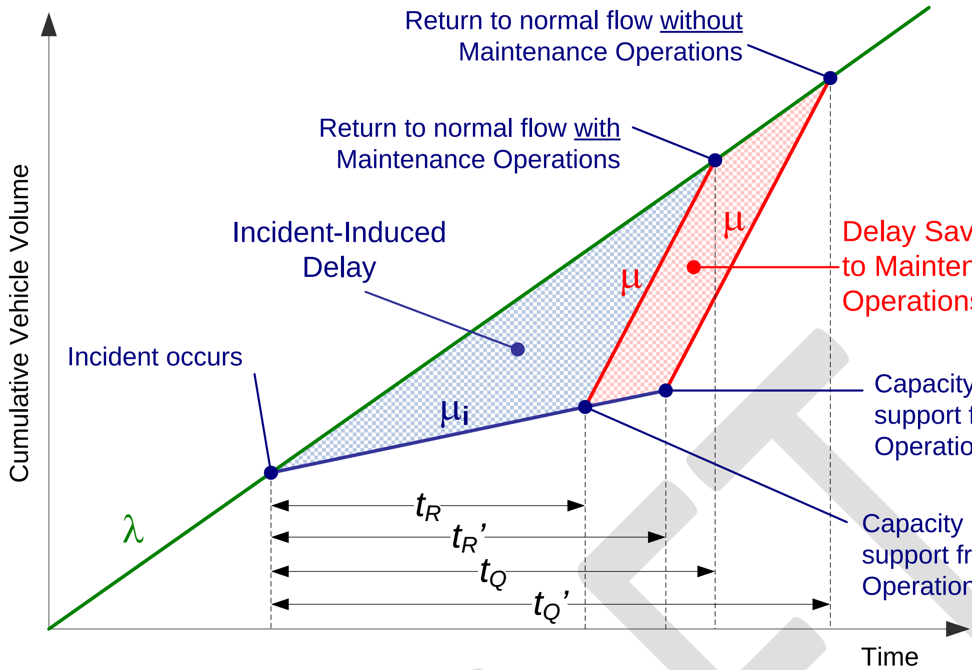

Figure 4. Cumulative Vehicle Volume vs. Time Graph for a Highway Incident

3.2 Detection and Response Time

In general, the main objective of FSP is to reduce the response time and provide assistance to restore the freeway to its full capacity after an incident occurs. In order to achieve this, FSP offers basic auto repairs and gasoline, calling for private tow trucks, providing short-range vehicle relocation, and helping manage traffic around incident location. Drivers are overwhelmingly supportive of this service because it is free, fast, and it increases their sense of safety on the highway. Cuiciti and Jason (1995) evaluated the FSP in Colorado highways and found that the FSP reduced incident response and clearance times by an average of 10.5 minutes for in-lane incidents, and an average of 8.6 minutes for incidents occurring outside the roadway. These numbers were estimated based on actual observations. Hawkins (1993) evaluated Motorist Assistance Program (MAP) in Houston, TX. He reported that the MAP reduced incident duration by 16.5 minutes.

Most FSP programs continuously patrol a section of freeway on the “lookout” for incidents. Thus, they are typically in close proximity to locations of incidents to which they are dispatched. In fact, the patrols often times detect the incidents themselves, are first to report the incidents, and are first responders on site. For instance, the San Francisco/Oakland Incident Management Assistance Patrols (IMAP) detected 92 percent of all incidents in the program’s service area (PB Farradyne, 2000). For lane blocking incidents in the Puget Sound region in Washington State, the average response time without a service patrol program was 7.5 minutes. With a service patrol program, response time was reduced over 50 percent to roughly 3.5 minutes (Carter, 2000). Across the nation, service patrols have been found to reduce incident response times by 19 through 77 percent (Nee and Hallenbeck, 2001). Any reduction in incident detection, response, and clearance times reduces the total duration, which in turn reduces queuing delay. Khattak (1995) found that one minute reduction in response time is associated with approximately 0.6 to 1 minute reduction in clearance time. Average incident clearance times were reduced by 8 minutes. (FHWA, 2001; Fenno and Ogden, 1998).

Calculating the average incident response and duration times is difficult when incident occurrence and report times go unrecorded. This is the case with the roadways that are not patrolled by the FSP service. In such cases the incident response and duration times must be estimated so that effectiveness of FSP on those roadways can be determined. Skabardonis and Mauch (2005) recommended that the average response time of 30 minutes be assumed for the roadways not patrolled by FSP. They outlined a calculation of response time with FSP based on the number of vehicles patrolling, beat characteristics, patrol vehicle speed, and time of day (peak, off-peak and mid-day). Having appropriate values of incident duration with and without the FSP is critical in order to get an accurate estimate of FSP benefits.

3.3 Capacity Reduction Due to an Incident

A number of previous studies (Cuiciti and Janson, 1995; Hawkins, 1993; Fenno and Ogden, 1998) have focused on estimating the reduction in roadway capacity due to an incident. The factors impacting the capacity reduction were:

- Location of the incident (lane, shoulder, or median);
- Number of lanes on the freeway; and
- Number of lanes blocked by the incident.

Some other findings include:

- The actual reduction in capacity of the freeway is much more than just blockage of lane.
- The loss in capacity is likely to be greater than simply the proportion of original capacity that is physically blocked.
- If multiple incidents occur at the same time, the capacity reduction used for the analysis should be the incident which has the maximum impact on the capacity.

Cuciti and Janson (1995) made assumptions on roadway capacity reduction for evaluation of FSPs in Colorado, in terms of number of lanes lost, at the following incident locations: right or left shoulder, 0.7; left or right lane, 1.7; middle lane, 2.3; off road, 0.3. Hawkins (1993) discussed the extent of roadway capacity reduction during incident occurrence through field studies in Houston. Hawkins estimated, for a three lane freeway segment, a 29 percent reduction in roadway capacity for a stalled vehicle located on the shoulder and roadway capacity reduction of 52 percent for a stall or a crash blocking one lane. Similarly for a 4-lane freeway segment, Hawkins reported a 43 percent reduction in roadway capacity for a stalled vehicle blocking one lane, a capacity reduction of 82 percent for blocking 3 lanes and 12.5 percent decrease for a stall blocking a shoulder.

Goolsby (1971) made the first efforts in calculating the effective capacity during the incidents for a certain lane and shoulder blockage. It was found that the effective capacity loss due to incidents is more than the effective loss due to removing a single lane on a four lane roadway. By comparing the traffic volumes under normal and incident conditions, he was able to predict the capacity reductions during incident conditions. Smith (2003) performed a similar study, but he used much more detailed data collected from loop detectors and compared the volumes under normal and incident conditions. Highway Capacity Manual (HCM) also gives a capacity reduction table for various types of incident blockages as shown in Table 1. It is worth noting that he location of the incident is required to use this table. A Freeway Service Patrol Evaluation (FSPE) model recently developed by Skabardonis and Mauch (2005) adopted the percent of capacity remaining due to an incident as provided by the HCM.

Table 1. Remaining Freeway Capacity (%) Recommended by HCM

Incident Type	Location	No. of Freeway Lanes/Direction			
		2	3	4	5+
Accident	Right Shoulder	81.0	83.0	85.0	87.0
	Median	81.0	83.0	85.0	87.0
	1-Lane	35.0	49.0	58.0	65.0
Break Down	Right Shoulder	95.0	98.0	98.0	98.0
	Median	95.0	98.0	98.0	98.0
	1-Lane	35.0	49.0	58.0	65.0
Debris	Right Shoulder	95.0	98.0	98.0	98.0
	Median	95.0	98.0	98.0	98.0
	1-Lane	35.0	49.0	58.0	65.0

3.4 Type of Incidents

Incidents include crashes and a vast array of small events: stalls, flat tires, spills, debris on the road, and even highway maintenance work that diverts drivers' attention and disrupts the normal flow of traffic. Skabardonis and Mauch (2005) defined nine types of incident differentiated based on location where incident occurred to estimate the benefits of FSP program. These types included:

- Accident (on right shoulder, in lane, left shoulder),
- Breakdown (right shoulder, in lane, left shoulder), and
- Debris (right shoulder, in lane, left shoulder).

The average time spent by a service patrol vehicle in each incident category is quite different. A clear classification by type of incident is very helpful to correctly estimate the average incident duration and roadway capacity reduction.

3.5 Delay Calculation

Delay saving is a major benefits of deploying freeway service patrol program. The difference in delay between with and without freeway service patrol is the net benefit of the program. Two studies were conducted to estimate the delay due to incidents on I-880 in San Francisco by Skarbardonis (2005) and Garib (1997). Loop detectors were used to measure the speed of vehicles and probe vehicles were used to detect incidents. Skarbardonis developed a general equation which calculated delay as a function of traffic volume, time of congestion, length of impacted freeway segment, average travel speed, and travel speed during an incident. Garib conducted a regression analysis of I-880 incident data to develop two models to predict incident-induced delay. The Skarbadonis's model used four variables that included number of lanes involved, number of vehicles involved, incident duration, and traffic demand upstream of the incident. The model used in Garib's study excluded traffic demand upstream.

Another method of calculating incident induced delay is queuing theory. Morales (1987) developed a cumulative volume approach to calculate the delays on freeways. Two cumulative volume curves for arrival and departure were plotted against the time, and the area between the two curves represented the extra delay due to an incident. Sullivan (1997) also used queuing theory to estimate incident-related delay. The developed delay model in the study included 4 sub-models:

- incident rate sub-model,

- incident severity sub-model,
- incident duration sub-model, and
- delay sub-model

The capacity reductions were obtained from previous studies and classified incidents into seven category types. Then, each incident type was matched to incident duration to formulate weighted average delay.

Deterministic queuing models were employed to study travel delay estimation due to the TIM program in Georgia (Guin et al., 2007). The estimated travel delay provided input for analytical models developed to estimate corresponding savings in emissions, fuel consumption and secondary incidents. This queuing modeling approach to FSP program evaluation requires data pertaining to traffic volumes prior to, during, and after each traffic incident for travel delay estimation. The FSPE model was used evaluate the benefits of the Road Ranger program in Florida (Hagen et al, 2005) and Northern Virginia Safety Service Patrol (NOVA SSP) program in Virginia (Dougald and Demetsky, 2008). The model was used to estimate the benefits of these programs in terms of savings in travel delay, fuel consumption and pollution. Many service patrol agencies have used the deterministic queuing model to evaluate the benefit-cost ratio of their program. Colorado, Michigan and New York have previously evaluated their programs with queuing type models.

Al-Deek et al. (1995) developed a method which was primarily an improvement to Morales' method. Vehicle speeds were incorporated in conjunction with traffic volumes to develop a delay formula. Historical speed data were used to distinguish between incident and non-incident congestion. However, this method requires a one-minute time interval which may result in formation of "noisy" data, while larger time intervals may not allow for accurate estimation of queue boundaries. In this method, individual slices are summed up to calculate the total delay for a given segment.

Pierce and Sun (2005) used a video re-identification method to estimate the delay due to incidents. A cubic polynomial model was developed to describe the travel time versus elapsed time during the incident duration. Delays were calculated by taking the difference between actual and the normal travel times. This method is very time consuming and labor intensive.

In addition to the delay estimation discussed above, computer simulation is another effective approach in modeling traffic delays due to incidents. By changing the incident durations with and without freeway service patrol, the delay savings can be calculated. Hawkins (1993) used FREQ10PC, a deterministic and macroscopic model, to find incident related delays. As real-time data are not typically available, simulation model was applied to estimate traffic congestion.

Chang and Shrestha (2000) used regression models for estimating travel delay and CORSIM simulation model for calculating fuel consumption to evaluate the Coordinated Highways Action Response Team (CHART) program in Maryland. CHART is the statewide highway incident management program of the Maryland State Highway Administration (MSHA). The CHART evaluation methodology uses simulation models developed for a sample of 120 traffic incidents to calculate the corresponding effects on vehicle delay, fuel consumption, and emissions. It has been used for annual evaluation of the CHART performance since 1996. The data for the simulation models, including roadway geometry, traffic stream, incident duration and lane closure information, were provided from the MSHA database. For each incident, the impacted roadway section was simulated using the CORSIM software. Simulations were performed for baseline conditions (no incident), and incident conditions with and without the assistance of the CHART personnel to determine the effects of the incident in two incident response scenarios. It was assumed that duration of an incident would be 35% longer without the assistance of the service patrol, thus generating longer delays, more wasted fuel and excessive vehicle emissions. The difference between the effects of incidents with and without CHART involvement in cleanup and incident management is used as a measure of benefit of the program. The results from simulations of all sample incident sites are then complied to determine a functional relationship between incident and roadway related factors (e.g. incident duration, total and number of blocked lanes during the incident, vehicle volume), and measured effects, including excessive delay, fuel consumption, and emissions. A regression analysis is used to develop the underlying functional relationships, which are then applied to all reported incidents during a year in order to calculate the benefits for each incident and the overall annual benefits of the program. Examples of calibrated functional relationships developed in this methodology are shown in equations (1) and (2):

$$\Delta \text{Delay} = e^{-10.19} \times (V)^{2.8} \times (NLB / TNL)^{1.4} \times (ID)^{1.78} \tag{1}$$

$$\Delta \text{Fuel} = e^{-10.77} \times (V)^{2.27} \times (NLB / TNL)^{0.9} \times (ID)^{1.69} \tag{2}$$

where,

ΔDelay = Excessive delay due to incidents

ΔFuel = Additional fuel consumption due to incidents

TNL = Total number of lanes

NLB = Number of lanes blocked

V = Traffic volume

ID = Incident duration

Similar to the CHART evaluation study, a model was developed for assessing the New York State's Highway Emergency Local Patrol (H.E.L.P.) program (Haghani et al., 2006). H.E.L.P. is a freeway service patrol program that mitigates the negative impacts of traffic incidents through early detection and response, and adequate incident management and cleanup. The FSP programs are facilitated by specialized vehicles with crews that patrol designated highway sections called beats. Once they detect or are dispatched to an incident site they can provide an immediate assistance and traffic management or, if needed, request support from the police and other emergency response personnel. The evaluation methodology for the H.E.L.P. evolved from the CHART model with added level of detail in simulation analysis. It improved handling of key simulation parameters and settings including incident duration, traffic volume, car-following sensitivity factors, and rubbernecking effects, and implemented regression models to predict the benefit-to-cost ratio as a function of volume-capacity ratio, rubbernecking effect, and potential reduction in total incident duration. The extension study of the H.E.L.P program (Chou et al., 2000) included an extensive simulation based statistical analysis on a sample of 10,000 incidents.

Hundreds of simulation runs of representative incidents with varying incident duration (0 to 40 minutes) and lane blockage characteristics were completed using the PARAMICS simulation platform to analyze Minnesota's Freeway Incident Response Safety Team (FIRST) program (MNDOT, 2004). Total delay and volume computed from the simulation runs were plotted against each other to establish how one varies with the other. This plot was used to estimate delays resulting from actual incidents in an archive of incident data and resulting savings in delay due to the FIRST program. Reduction in environmental pollution and secondary incidents resulting from this program were estimated based on rates of pollution and secondary incidents as a function of travel delay and total incidents, respectively.

Haghani et al. (2006) proposed a similar simulation-based methodology using the CORSIM simulation platform to estimate savings in travel delay, fuel consumption, pollution emissions and secondary incidents. They conducted a sensitivity analysis of performance measures and key parameter settings, such as incident duration, traffic volume, car-following sensitivity factors, and rubbernecking effects, and developed regression models to predict the benefit-to-cost ratio as a function of volume-capacity ratio, rubbernecking effect, and potential reduction in total incident duration. A key finding of their work is that a traffic flow rate of at least 1,500 vehicles per lane per hour provides a significant indicator for the benefits of the FSP program to outweigh its costs.

FREWAY3, CORSIM and XXEXQ are other simulation models that have been used for measuring non-recurrent delays. Skabardonis and Mauch (2005) developed a freeway service patrol evaluation (FSPE) model that handles multiple time periods with different number of FSP tow trucks per time period. The FSPE model was extensively tested and applied to all existing FSP beats in California. This method uses a deterministic queuing model and few assumptions about response time reductions to evaluate delay savings. The model is also equipped with the latest emission sub-model to calculate savings on emissions. The model specification or parameters can be changed to suit local conditions.

3.6 Costs of Freeway Service Patrol

Most state Departments of Transportation in the United States fund and operate their FSP programs, either on their own (in house) or on a contract basis with the third party providers. In some cases, local and state police or metropolitan transportation authorities fund the service patrols. The funding for these programs is provided from various sources, including fuel tax, Department of Motor Vehicles fees, and State or local sales tax. When the funding comes from the FHWA, it is usually through the Congestion Mitigation and Air Quality (CMAQ) program, construction funds, or highway safety funds. In some cases, the funding is sponsored exclusively by private agencies. An example of this is the Samaritan patrol program that operates in 11 northeastern United States metropolitan areas. The patrols are operated by Samaritan, Inc. and funded by large corporations such as CVS pharmacies, First Union Bank, and Bank of Boston. Some privately operated programs are funded by the toll-road authorities, which use collected tolls to pay for the program. State Farm contributes[3] to the funding for NJDOT SSP.

The main cost components of an FSP are capital, administrative and operating costs. The total annual cost depends upon the number of center-line miles covered, hours of operation, and number of service vehicles. California FSP maintains a fleet of over 300 vehicles patrolling in excess of 1,400 miles of freeways in the state. In 2012 close to 40 million dollars are allocated for the program. The service is provided Monday through Friday during peak commute hours. Florida Department of Transportation FSP called Road Ranger Service Patrol consists of 88 vehicles in fleet and provides free service to about 918 miles. Currently, all the seven Districts and Florida Turnpike provide the Road Ranger services except District 3.The hours of operation for District 1, 4, 5, 6 and 7 are 24 hours a day and 7 days a week while for District 2 and Florida Turnpike the service is provided in tow shifts during morning and evening peak hour. The cost of the truck per hour is about in the range of $27.00 to $41.00 per hour.

3.7 Benefit-Cost Ratio

Four studies quantified benefits of the FSP. They found that the FSP generated greater benefit than it cost to run. They are shown below.

Latoski et al., (1998) reported that the benefit/cost ratios ranged from 2 to 36. Fenno and Ogden (1998) reported that the benefit-cost ratios of the existing service patrol programs were in the 3 to 36 range. They are shown in Table 2.

[3] http://www.state.nj.us/transportation/about/press/2012/040412ssp.shtm

Table 2. Benefit/Cost Ratios of the Service Patrols

Service Area	Patrol Name	Year conducted	B/C ratio
Charlotte, NC	Incident Management Assistance Patrol	1993	3 to 7
Chicago, IL	Emergency Traffic Patrol	1990	17
Dallas, TX	Courtesy Patrol	1995	3.3 to 36.2
Denver, CO	Mile high Courtesy Patrol	1996	20 to 23
Detroit, MI	Freeway Courtesy Patrol	1995	14
Fresno, CA	Freeway Service Patrol	1995	12.5
Houston, TX	Motorist Assistance Program	1994	6.6 to 23.3
Los Angeles, CA	Metro Freeway Service Patrol	1993	11
Minneapolis, MN	Highway Helper	1995	5
New York, NY	Highway Emergency Local Patrol	1995	23.5
Norfolk, VA	Safety Service Patrol	1995	2 to 2.5
Oakland, CA	Freeway Service Patrol	1991	3.5
Orange Co., CA	Freeway Service Patrol	1995	
Riverside Co., CA	Freeway Service Patrol	1995	3
Sacramento, CA	Freeway Service Patrol	1995	5.5

An evaluation of CHART in Maryland, which includes incident response along with traffic monitoring, traveler information, and traffic management, reported an annual savings of 40.1 million vehicle hours of delay, 398,000 gallons of fuel, and $30.5 million (Sullivan, 1997). The benefit/cost ratio was 7.5. The benefit was based on savings from reduced traffic delay, fuel consumption, and secondary incident reductions.

Georgia's Intelligent Transportation System, "NAVIGATOR", includes incident management patrols, electronic toll collection, signal control, and other ITS innovations. An evaluation of NAVIGATOR found a 30% reduction in identification, response, and dispatch time, a 23-minute reduction in incident duration that saved $44.6 million. This translated into a 3.2:1 benefit/cost ratio for the freeway and incident management components. Other benefits not fully quantified include air quality impact reductions, fuel consumption savings, crash reduction, more efficient use of emergency services, and more satisfied travelers (Guin et al., 2007).

3.8 FSP Evaluation and Predictor Model

Hagen et al. (2005), Dougald et al. (2008) used the Freeway Service Patrol Evaluation (FSPE) tool developed by the University of California, Berkeley, Skabardonis et al. (2005) to evaluate the FSP programs in Florida and Virginia. The research studies were also conducted to evaluate Tennessee Department of Transportation's (TDOT's) Freeway Service Patrols (Moss et al., 2012) and the Freeway Service Patrol Program in Chicago (Pranav et al., 2010).

The FSPE model estimates incident- induced vehicular delays and delay reductions due to the existence of an SSP service. The FSPE model uses a deterministic queuing model for calculating the delay and estimates the delay savings benefits based on roadway geometric and traffic characteristics, and the frequency and type of SSP assisted incidents. The FSPE methodology employs three different incident types distinguished by location. These incident types are:

1. Accident
2. Breakdown
3. Debris

The location is: right shoulder, in the lane, left shoulder.

The model estimated delay-saving benefits depend on the beat's roadway geometry and traffic characteristics, as well as the frequency and type of FSP-assisted incidents. A secondary model was developed to predict the cost effectiveness of proposed FSP zone which currently provide no FSP service. The model estimates FSP response time, the reduction in response time, incident delays and delay savings. The model can be configures for multiple time periods of service that can be associated with different number of FSP truck deployed. It calculates the benefits for one average day, using the input information, and multiplies it by the number of days of service to give the total benefit. The information required to run the model can be distinguished in two categories:

1. Zone input data (zone service parameters, traffic and incident data)
2. The model parameters (freeway capacity, fuel/emission rates, clearance time reduction data, occupancy rate and traffic flow profiles).

The model can be further improved if detailed segment specific hourly traffic volumes and capacity are available.

The zone input data is divided into four basic sections:

1. Zone/Service Description (hours of operation, number of trucks, cost per truck)
2. Zone Design Characteristics (Zone length (in miles), number of segments per zone and their length, number of lanes)

3. Beat Traffic Characteristics (Average Annual Daily Traffic (AADT) per segment and distribution by direction)

4. Incident Characteristics (number of incidents by type and average duration)

The model parameters contain parameters that are used by the model to estimate hourly traffic flows and the associated vehicular delays and delay reductions, along with those parameters used in the calculation of the measures of effectiveness (MOEs) and the resulting benefit cost estimates. The parameters are:

- Freeway capacity for mixed use lanes (vehicles per lane per hour)
- Freeway capacity for HOV lanes (vehicles per lane per hour)
- Remaining freeway capacity due to incident (from the Highway Capacity Manual 2000)
- Fuel emission rates
- FSP response time (time it took for a FSP truck to arrive on the scene once an incident occurred)
- Response time reduction (the average reduction in FSP truck response times attributed to FSP service)
- Delay cost ($/hour per vehicle)
- Fuel cost ($ per gallon) represents the average cost of fuel during the entire evaluation period
- Vehicle Occupancy rates (used by the FSPE model to determine the proportion the traffic stream that is assigned to HOV lanes (if any)).
- Traffic flow profiles are used to estimate the incident-induced vehicular delays and delay reductions due to FSP service

The freeway capacity in the model was taken from the Highway Capacity Manual (HCM). However, for the analysis, the literature suggests the lower value for the capacity to ascertain the mix of passenger cars, vans, trucks and motorcycles. The reduction in freeway capacity as a result of an incident is based on the values from HCM. The remaining freeway capacity based on the incident type, accident location (right shoulder, median or lane) and number of lanes per direction is shown in Table 1.

Chapter 4.

DATA COLLECTION

This section describes the collection of data that were needed to quantify the benefits of the SSP. The data were collected for two distinctive time periods: January to June 2011, and January to June 2012. The data came from NJDOT's OpenReach database, and New Jersey Congestion Management System (NJCMS). The first data source provides information related to incidents to which the SSP responded. The second data source provided roadway geometric data such as lanes, functional class and traffic volumes, including 24 hour distribution of hourly volumes and truck percentages.

4.1 OpenReach Data Management System

NJDOT OpenReach management information and communication system is used by NJDOT's TMC and provides a common platform for the TMC operators to record information about traffic conditions on major roadways including information about the incidents. The system is used to communicate this information back to the traveling public through 511 traveler information telephone system and 511nj.org website, as well as via dynamic message signs. The database is physically located at and maintained by TRANSCOM[4]. The database consists of two tables:

1. Event table (tblEvent) – in which each incident in a single record. The incident record includes: ID, type, the location described by the facility (roadway) name, milepost, street intersection and geographic coordinates, time the incident was reported, time the incident was closed, and incident duration.

2. Action table (tblAction) – each incident is described by a chronological set of records each documenting a specific action in the database related to an incident, beginning with the entry of the incident into the database, and ending with entering the information that the incident is closed. Each record contains a narrative describing the action: e.g. the time when a Maintenance Operations was dispatched to the incident scene, lane closure or changes in lane closure, communication with other agencies, etc.

[4] TRANSCOM is a coalition of 16 transportation and public safety agencies in the New York - New Jersey - Connecticut metropolitan region. The role of TRANSCOM is to improve the mobility and safety of the traveling public by supporting its member agencies through interagency communication and the enhanced utilization of their existing traffic and transportation management and systems, with a strong ITS component.

4.2 New Jersey Congestion Management System (NJCMS)

The roadway geometry and traffic flow data were obtained from NJDOT's New Jersey Congestion Management System (NJCMS). The NJCMS is a data management and data analysis system used by the Bureau of Systems Planning 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 in New Jersey. The following two data tables form NJCMS were used:

1. SDLINK.dbf – it gives the link operations data generated by NJCMS application. This table contains estimated hourly volumes, hourly V/C ratios, hourly speeds, and hourly truck volumesfor each link in the network by direction

2. SDNET.dbf – it contains the basic roadway geometry and traffic operations data for each link in the network by direction.

4.3 Data Integration

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

Chapter 5.

EVALUATION METHODOLOGY

This section describes the data requirements for FSPE model and its application in evaluating SSP service in New Jersey. The FSPE model was calibrated to fit New Jersey roadway, traffic and SSP service conditions. The calibrated FSPE model is used to perform the benefit-cost analysis of the SSP program. The FSPE Model data required to analyze the SSP operation is divided into four categories:

1. Service Description
2. Design Characteristics
3. Traffic Characteristics
4. Incident Characteristics

The main input parameters for each of their categories and the data sources used in this study are listed in Table 3.

Table 3. Model Inputs and Data Sources

	Parameter	Input Type	Data Sources
Service Description	District and Zone Name	by User	NJ DOT Statewide Traffic Operations Center
	Hours of Operation		
	Number of Trucks		
	Cost of Service		
Design Characteristics	Direction	by User	NJCMS
	Geometric Design		
	Number of Lanes		
	Length		
	HOV lane (if any)		
	Presence of Right Shoulders/Median		
Traffic Characteristics	Average Annual Daily Traffic	by User	NJCMS
	Percentage of Trucks		
	Directionality Factors (AM, Midday, and PM peak periods)		
Incident Characteristics	Average Incident Duration and Percentage of Incidents at Right	by User	OpenReach

	Parameter	Input Type	Data Sources
	Shoulder, Median and In-lane by Each Type (Accidents, Breakdowns, and Debris), response time without SSP		
Additional Parameters	Capacity Values	Model Default	Model
	Remaining Freeway Capacity Factor	Model Default	Highway Capacity Manual
	Fuel/emission Base Rates	Model Default	Mobile 6 EPA
	Delay and Fuel Cost	by User	Urban Mobility Report 2012, AAA Daily Fuel Gauge Report
	Occupancy Rates	by User	Household Travel Survey (NHTS)

5.1 Service Description

The service description includes information such as district name, zone name, date of analysis. The service description for each zone (number of trucks, hours of operation) is included in the analysis and is obtained from NJ DOT for each yard. They are shown in Appendix E.

The cost of service or the SSP truck driver hourly wage is estimated based on a sample of annual salaries obtained from N.J. public employees payroll records[5]. The estimated hourly wage of a SSP truck driver is based on the annual salary of $51,487.

5.2 Design Characteristics

The FSPE model requires the zone roadway coverage to be divided into segments for each travel direction. A segment is defined as a one-way freeway section between on and off-ramps, or at locations where there is a change in freeway capacity (lane drops, weaving sections, steep grades, etc.), or significant changes in traffic volumes (e.g. ADTs) typically at ramp interchanges (Skabardonis et al., 2005). The data on each directional segment include:

- Length (miles),

[5] Asbury Park Press, http://www.app.com/section/DATA

- Number of mixed-flow lanes, HOV lane (if any), and
- Presence of shoulders.

A series of queries were developed that partition zone roadway coverage into segments for each travel direction based on the segment definition criteria.

The FSPE model requires traffic parameters to be the default values used by the model to estimate hourly traffic volumes, delay, and fuel consumption savings. The default values were adjusted to reflect each zone characteristic using NJCMS.

5.3 Traffic Characteristics

For each highway segment, the AADT and traffic directionality factors or the percent of traffic in the peak direction are required for the analysis. The model requires the percentage of trucks on each segment and traffic profiles for zones in order to calculate the hourly traffic volumes for each beat segment. A series of queries were developed to populate the traffic characteristics data from the NJCMS for each segment.

5.4 Incident Characteristics

For each incident type, the model requires a number of annual incidents that were SSP-assisted and the corresponding average incident duration (in minutes). The model requires incidents to be classified into types. Incidents are further categorized based on the location. The location affects capacity reduction on a freeway.

Appendix F shows the number of incidents recorded for SSP by zone.

5.5 Additional Parameters

According to the Texas Transportation Institute (TTI) Urban Mobility Report 2012 (Schrank et al., 2011), travel time value for each person hour of travel is $16 while the truck travel time and operating costs was $88. Assuming that the average vehicle occupancy is 1.5 persons per vehicle[6] and percentage of trucks in total traffic as 5%, the value of travel time delay is calculated as:

$$\text{Value of Travel Time Delay} = \$16 \times 1.5 \times 0.95 + \$88 \times 0.05 = \$27.2$$

[6] NHTS National Household Travel Survey

The average fuel cost per gallon in New Jersey was assumed to be $ 3.58 in 2012[7].

[7] AAA Daily Fuel Gauge Report

Chapter 6.

ANALYSIS OF THE INCIDENT DATA

This chapter presents the findings from an analysis of incidents recorded in the OpenReach database for the study period between January 1 and June 30, 2011, and between January 1 and June 30, 2012.

The first question that the analysis answered was: "Does SSP coverage area contain a majority of incidents that occurred on the roadway previously covered by the ESP?"

In 2011, 2,424 incidents were recorded on the roadway network patrolled by the ESP. In 2012, there were 1,832 recorded incidents on the same roadway network. Out of the 1,832 incidents, 1,750 occurred on the roadway network patrolled by SSP. This means that even after the network coverage decreased by 28%[8], 95.5 %[9] of incidents occurred within the realigned SSP network. **Therefore, the SSP is patrolling the sections of the New Jersey highway network where the need for its service is the highest.**

The distribution of incidents by category for ESP and SSP coverage areas that were recorded in the first six months of 2012 is shown in Appendix C.

Table 4 shows the number of incidents in the first six months of 2012 by roadway, considering the routes patrolled by the SSP and previously patrolled by the ESP. It can be observed that on almost all patrolled roads a very high percentage of incidents occurred within the realigned (SSP) coverage. The NJ 29 had a lowest percentage of incidents that occurred within the SSP coverage area (61%). The percent values where the SSP patrolled area was reduced (as compared to ESP patrolled area) are marked in bold typeface. The extended service on I-295 resulted in 100% incident coverage by SSP.

Table 4. Number of Incidents by Road and Service Area (Year 2012)

Route	Number of Incidents		Percent of Incidents Within SSP Coverage Area
I-78	295	285	**97%**
I-80	272	247	**91%**
I-280	146	146	100%
I-287	175	165	**94%**

[8] (396-225+57.8)/396

[9] 1,750/1,832

Route	Number of Incidents		Percent of Incidents Within SSP Coverage Area
NJ 440	20	20	100%
I-295	456	456	**100%**
I-95	36	36	100%
I-195	60	54	**90%**
I-76	93	93	100%
I-676	59	59	100%
NJ 29	44	27	**61%**
NJ 42	119	119	100%
NJ 55	57	43	**75%**
Total	***1,832***	***1,750***	***94%***

The second question to be answered was: "How risky or safe are the roads patrolled by SSP?"

To answer this question and to compare the SSP roads with those covered by the former ESP, two indicators[10] were calculated. They are:

- "Incident per mile" rate, and
- Incident Rate

An "incident per mile" rate (IPMR) is calculated as:

$$IPMR = \frac{C}{N \cdot L}$$

Where:
IPMR = Incidents per mile for the road segment expressed as incidents per each 1 mile of roadway per year.
C = Total number of incidents in the study period.
N = Number of years of data.
L = Length of the roadway segment in miles

Table 6 presents the IPMR for ESP and SSP.

[10]" Highway Safety Improvement Program (HSIP) Manual", FHWA, 2010

Table 5. Incidents per Mile Rate (IPMR), 2012.

	Incidents per Year	Length (miles)	IPMR
ESP	1,832	396	**4.6**
SSP	1,750	283	**6.2**

Table 6 shows that even though the higher number of incidents occurred on the network patrolled by ESP, the incident per mile rate is higher in the SSP network. One interpretation of this data is that the SSP roadway network is more “risky” or susceptible for future incidents (if judged by the past observations). **Therefore, it warrants more attention in terms of placing the SSP resources to patrol it.**

The third question to be answered was: “How risky or safe are the individual roads patrolled by SSP?” And the corollary of this question was: “Has a reduction in the SSP coverage and resulting refocus of the SSP service on the risky highways, increased the chance of detecting an incident faster and thus reduced the response and duration times? The SSP Service patrolling the reduced roadway coverage area has a higher chance being closer to incidents when they happen and thus discovering them faster and responding to them faster. ”

To answer this question, the incident rate was defined and calculated as:

$$IR = \frac{C \cdot 100{,}000{,}000}{V \cdot 365 \cdot N \cdot L}$$

Where:
IR = incident rate for the road segment expressed as incidents per 100 million vehicle-miles of travel,
C = Total number of incidents in the study period
V = Traffic volumes using AADT volumes
N = Number of years of data
L = Length of the roadway segment in miles

The incident rates for roadways patrolled by ESP and SSP are shown in Table 7.

Table 6. Incident Rate, 2012

	Incident Rate						
	I-78	**I-80**	**I-287**	**I-295**	**I-195**	**NJ 29**	**NJ 55**
ESP	13.58	10.59	7.01	34.69	9.9	31.25	9.21
SSP	19.95	15.4	9.54	32.42	32.9	41.85	19.57

Table 7 shows that the SSP roadways have a higher incident rate. **This means that those particular roadways warrant more coverage in terms of SSP resources. Or conversely, that they are the "right" choice roads for increased safety treatment.**

The average incident duration is shown in Table 8. As a result of restructured SSP service incident duration was reduced on average by approximately 9% (or 3 minutes and 3 seconds). This means that the SSP resulted in marked savings in terms of time and that the SSP realignment was effective in terms increasing efficiency of incident management. It is expected that the increased efficiency will result in a tangible financial benefit. This will be shown in Chapter 7.

Table 7. Average Incident Duration and Percent Reduction in Incident Duration (2012)

Route	Average Incident Duration (min)		Percent Reduction in Incident Duration
	ESP Service Area	SSP Service Area	
I-78	0:42:28	0:33:16	22%
I-80	0:43:47	0:37:39	14%
I-280	0:33:14	0:28:33	14%
I-287	0:39:27	0:38:30	2%
NJ 440	0:48:03	0:48:03	
I-295	0:40:44	0:40:44	
I-95	0:35:03	0:35:03	
I-195	1:07:07	0:46:59	30%
I-76	0:36:03	0:36:03	
I-676	0:32:13	0:32:13	
NJ 29	0:33:32	0:37:36	-12%
NJ 42	0:26:49	0:26:49	
NJ 55	0:55:36	0:35:20	36%
Average	**0:40:39**	**0:37:09**	**9%**

A more detailed look at Table 7 shows that the average incident duration was reduced the most on NJ 55. The reduction was by 36%, followed by I-195 with a 30 % reduction, and I-78 with a 22% reduction. The increase of 12 % or 4 min and 4 seconds was recorded on NJ 29. **Perhaps additional patrol can be added to this road to bring the incident duration down.**

The average incident duration by event type and by roadway for ESP and SSP is shown in Appendix D.

Chapter 7.

EVALUATION OF THE SAFETY SERVICE PATROLS

The NJDOT goal of realigning the service was to further enhance safety for the motoring public and provide even more efficient assistance in clearing incidents. Chapter 6 results indicated that goal had been achieved.

This chapter will quantify the benefit of increased efficiency. The estimated benefits of the SSP program include savings in fuel and vehicular delay to the motorists due to a reduction in the incident duration. The reduction of congestion results in higher average speeds and enables smother traffic flow which reduces the fuel consumption and emissions. The SSP service also provides a sense of security on the freeway, and the faster clearance of incidents may contribute to the avoidance of secondary accidents. The SSP Service also provides faster detection of incidents due to reduced roadway coverage area.

A measure of the SSP program cost-effectiveness was estimated by calculating the benefit-cost ratio (B/C Ratio). The Benefit-Cost ratio estimated by the FSPE model is mainly affected by the following factors: AADT, mean response time to incidents with and without the SSP service, frequency of incidents on the segment, capacity of segment, number of service trucks, segment length etc. All of these parameters are kept constant in evaluating the benefit of the SSP on particular roadway segment.

The only parameter that couldn't be obtained was the mean response incident time without the SSP service. This is an important variable as the difference between the response times with and without SSP service directly affects the amount of delay savings and hence SSP benefits. The literature [4] suggests that value for rotational tow-truck response time is 30 minutes. The Florida DOT study observed that mean response time is 25 minutes while the University of California [27] observed that the incident response times without service patrol was 26 minutes. The FSPE models documentation suggests a 30 min response time without SSP service as a default value in the analysis if this information is not available.

7.1 The Results of the Cost-Benefit Analysis

The B/C ratio for the entire SSP program is approximately 6.2.

The B/C ratios for Harding and Cherry Hill yards are shown in Table 8. The B/C Ratio varies from 1.4 (Zone 5 in Cherry Hill Yard and Zone 7 in Harding Yard) to 26.1 for Zone 11 in Harding Yard. This translates in minimum return of $ 1.4 in fuel and time savings for each dollar invested in the SSP Program. The maximum return is $26.1 for every dollar invested. For all the yards, the benefits outweigh the cost, thus the SSP operation as a whole is economically justified.

Table 8. The B/C Ratios for Harding and Cherry Hill Yards

ZONE\YARD	B/C RATIO	
	HARDING	CHERRY HILL
1	8.5	2.7
2	10.2	8.8
3	14.1	4.4
4	3.0	4.1
5	11.4	1.4
6	11.0	2.0
7	1.5	6.1
8	2.0	
9	4.9	
10	1.9	
11	26.1	
12	2.9	

The higher B/C ratio should not be used to compare the efficiency of individual zone operations. For that, an incremental benefit/cost ratio should be calculated.

Table 9 shows the savings is vehicular delay (veh-hrs) and fuel consumption (gal) expressed in monetary values for zones services by Harding Yard that was used for calculating benefits of the SSP. Table 10 shows the savings is vehicular delay (veh-hrs), fuel consumption (gal) expressed in monetary values for zones services by Cherry Hill Yard.

Table 9. Savings and B/C Ratio for Harding Yard Zones

Savings-Performance Measures	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12
Delay (veh-hrs)	14,492	17,477	24,105	5,066	19,546	18,749	2,529	3,340	8,383	3,169	44,636	4,992
Fuel Consumption (gal)	21,861	26,363	36,360	7,642	29,483	28,281	3,815	5,038	12,645	4,781	67,330	7,530
Emissions												
ROG (kg)	1,825	2,200	3,035	638	2,461	2,360	318	421	1,055	399	5,620	628
CO (kg)	96	116	160	34	130	125	17	22	56	21	297	33
NOx (kg)	406	490	676	142	548	526	71	94	235	89	1,252	140
Cost Effectiveness												
Delay Benefits ($)	394,190	475,381	655,648	137,797	531,643	509,972	68,796	90,848	228,009	86,210	1,214,097	135,782
Fuel Benefits ($)	78,261	94,380	130,169	27,358	105,550	101,248	13,659	18,037	45,268	17,116	241,041	26,957
Total Benefits ($)	472,451	569,761	785,817	165,154	637,193	611,219	82,455	108,885	273,277	103,325	1,455,139	162,739
Driver Cost of the SSP Service ($)	55,772	55,772	55,772	55,772	55,772	55,772	55,772	55,772	55,772	55,772	55,772	55,772
B/C Ratio	**8.5**	**10.2**	**14.1**	**3.0**	**11.4**	**11.0**	**1.5**	**2.0**	**4.9**	**1.9**	**26.1**	**2.9**

Table 10. Savings and B/C Ratio for Cherry Hill Yard Zones

Savings-Performance Measures	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
Delay (veh-hrs)	4,679	30,251	14,917	7,057	4,703	6,739	10,446
Fuel Consumption (gal)	7,058	45,631	22,502	10,646	7,094	10,166	15,757
Emissions							
ROG (kg)	589	3,809	1,878	889	592	848	1,315
CO (kg)	31	201	99	47	31	45	69
NOx (kg)	131	848	418	198	132	189	293
Cost Effectiveness							
Delay Benefits ($)	127,266	822,814	405,753	191,962	127,918	183,310	284,138
Fuel Benefits ($)	25,267	163,358	80,556	38,111	25,396	36,393	56,411
Total Benefits ($)	152,533	986,171	486,310	230,073	153,314	219,703	340,549
Driver Cost of the SSP Service ($)	55,772	111,544	111,544	55,772	111,544	111,544	55,772
B/C Ratio	**2.7**	**8.8**	**4.4**	**4.1**	**1.4**	**2.0**	**6.1**

7.2 Sensitivity Analysis

Two different analyses were performed in order to ascertain the impact of changes in parameter values on the B/C ratio.

The first analysis dealt with the variation in meant incident response time. Since the mean response incident time in case if no SSP service was operating was unknown, a sensitivity analysis was performed where mean response time was varied. To determine the sensitivity of results and if the efficiency of the SSP was preserved, the mean response time for the case without the SSP Service being present was varied from 10 to 60 minutes and the resulting B/C Ratios calculated. They are shown in Table 11 and Table 12. The B/C Ratio is over 1 for Harding Yard Zones 1,2,3,5,6,11 and Cherry Hill Yard Zone 2 even if the mean response time is 10 minutes. This means that the SSP Service was very efficient in providing assistance in clearing incidents.

Table 11. Change in Benefit-Cost Ratio for Harding Yard

	Mean Response Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Zone 1	1.1	2.4	3.6	6.0	8.5	11.5	14.6	17.6	20.6	23.6	26.5
Zone 2	1.2	2.4	4.8	7.2	10.2	13.3	16.4	19.4	22.4	25.5	28.5
Zone 3	1.5	3.8	6.1	10.1	14.1	18.1	22.2	26.1	30.1	34.0	38.0
Zone 4	0.4	0.9	1.6	2.3	3.0	3.6	4.3	5.0	5.6	6.2	6.8
Zone 5	1.1	2.5	4.6	7.7	11.4	15.6	19.7	24.3	28.8	33.8	38.6
Zone 6	1.1	2.4	4.5	7.3	11.0	14.8	18.8	23.0	27.3	31.8	36.5
Zone 7	0.2	0.3	0.6	1.0	1.5	2.0	2.5	3.1	3.7	4.2	4.9
Zone 8	0.2	0.5	0.9	1.3	2.0	2.7	3.4	4.2	4.9	5.8	6.6
Zone 9	0.6	1.0	2.0	3.5	4.9	6.7	8.4	10.2	11.9	13.6	15.4
Zone 10	0.2	0.4	0.9	1.3	1.9	2.4	3.0	3.6	4.2	4.8	5.4
Zone 11	2.6	6.6	12.1	19.1	26.1	33.1	40.2	47.4	54.5	61.7	68.8
Zone 12	0.3	0.7	1.3	1.9	2.9	4.0	5.0	6.1	7.3	8.4	9.6

Table 12. Change in Benefit-Cost Ratio for Cherry Hill Yard

	Mean Response Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Zone 1	0.2	0.6	1.2	1.9	2.7	3.6	4.4	5.3	6.3	7.3	8.3
Zone 2	1.0	2.2	4.0	5.9	8.8	11.9	15.0	18.1	21.2	24.4	27.6
Zone 3	0.3	0.9	1.9	2.9	4.4	6.1	8.1	10.0	12.0	14.0	16.2
Zone 4	0.5	0.8	1.7	2.6	4.1	5.4	7.0	8.6	10.2	11.9	13.5
Zone 5	0.2	0.3	0.6	0.9	1.4	1.8	2.3	2.9	3.4	3.9	4.5
Zone 6	0.2	0.5	0.8	1.4	2.0	2.9	3.8	4.7	6.0	6.8	8.4
Zone 7	0.6	1.5	2.7	4.3	6.1	7.9	9.8	11.7	13.8	15.9	18.1

Appendix G shows the results of the sensitivity analysis for each SSP zone.

The second analysis dealt with ascertaining a change in B/C ratio if the labor cost was increased by the fringe benefit.

If assumed that the fringe benefit rate for fiscal Year 2011- 2012 for New Jersey State worker was 39 %, **the average benefit and cost ratio for the entire SSP program is approximately 4.7.** Table 13 show the B/C ratios for Harding and Cherry Hill yards if the fringe benefits are included into SSP driver wage. The B/C Ratio varies from 1 (Zone 5 in Cherry Hill Yard) to 18.8 for Zone 11 in Harding Yard.

Table 13. The B/C Ratios for Harding and Cherry Hill Yards (wage with fringe benefits)

ZONE\YARD	B/C RATIO	
	HARDING	CHERRY HILL
1	6.1	2.0
2	7.3	6.4
3	10.1	3.1
4	2.1	3.0
5	8.2	1.0
6	7.9	1.4
7	1.1	4.4
8	1.4	
9	3.5	
10	1.3	
11	18.8	
12	2.1	

Chapter 8.

CONCLUSIONS

The purpose of this study was to evaluate the SSP Program after it has been reorganized in 2012. The results of the study show that NJDOT SSP Operation provides an important service in identifying incidents, clearing obstructions such as debris and disabled vehicles from roadways, and assisting the law enforcement with traffic control at incident locations. All this leads towards reduction of incident duration and subsequently significant monetary savings for the traveling public and the society. The results show that reorganized service is more effective (reduced incident duration) than its predecessor ESP, and that the service is cost-effective.

The findings of this study are summarized below:

- In 2011, 2,424 incidents were recorded on a roadway network patrolled by the ESP. In 2012, there were 1,832 incidents recorded on a roadway network previously patrolled by the ESP. Out of the 1,832 incidents, 1,750 occurred on the roadway network patrolled by SSP. This means that even after the network coverage decreased by 28 %[11], 95.5 %[12] of incidents occurred within the realigned SSP network. Therefore, the SSP has been patrolling the sections of the New Jersey highway network where the need for its service is the highest.

- The realigned roadway network has higher incident rate and incident per mile rat. These higher rates could be interpreted to mean that the realigned network needs more attention as it is “risker” – more likely to contain incident location. By redirecting the SSP to this network, NJDOT is doing the right thing as it allocates its resources to the area that is most in need.

- Consequently, as a result of restructured service, the incident duration was reduced on average by approximately 9%.

- The average incident duration was reduced the most on NJ 55. The reduction was 36%. This was followed by a reduction at I-195 of 30 %. The average incident duration was reduced by 22% on I-78.

- The only portion of the network that had higher average incident duration was NJ 29. It (increased by 12 %. Perhaps, additional patrol can be added to this road to bring this increase down.

---

[11] (396-225+57.8)/396

[12] 1,750/1,832

- Incident Analysis shows that 73 % of all incidents fall within type category: accident. It is followed by breakdowns events with 24 %, and debris with 3 %.

- The SSP is cost effective. The Benefit Cost Ratio is 6.2. The Benefit Cost Ratio for individual SSP zones ranged from 1.4 to 26.1.

- The 1.4 ratio translates into a minimum return of $1.4 (for Cherry Hill Yard Zone 1 and 5) in fuel, time end emission for each dollar invested in the SSP program.

- The 26.1 ratio translates into a maximum return of $26.1 (for Harding Yard Zone 11) in benefits for each dollar invested in the SSP Program.

In reality, the mean response time for the situation that would have existed had the SSP not been operational was not known. The literature advised that a mean time of 30 minutes be adopted. A sensitivity analysis was performed where the mean response to incident time is varied. The mean response time was varied between 10-60 minutes with an interval of 5 minutes, and the resulting B/C Ratio is recorded. The B/C ratio for the Harding Yard Zones 1,2,3,5,6,and 11, and Cherry Hill Yard Zone 2 was over 1 if the mean response time without the SSP service was down to 10 minutes.

REFERENCES

1. Incident Management Successful Practice, A Cross-Cutting Study: Improving Mobility and Saving Lives. Report FHWA-JPO-99-018, FHWA, US DOT, 2000
2. Cuiciti P. and B. Janson. Incident Management via Courtesy Patrol: Evaluation of Pilot Program in Colorado, Transportation Research Record, 1494. Transportation Research Board, National Research Council, Washington DC, 1995.
3. Hawkins P. A. Evaluation of the South West Freeway Motorist Assistance Program in Houston. Report No. TX-94/1922-IF, Texas Transportation Institute, College Station, Texas, 1993
4. Skabardonis A. and M. Mauch. FSP Beat Evaluation and Predictor Models: User's Manual, Research. Report No. UCB-ITS-RR-2005-XX, Institute of Transportation Studies, University of California-Berkley, California, 2005
5. PB Farradyne. Traffic Incident Management Handbook. Report USDOT-13286. US DOT, 2000.
6. Carter, M. Metropolitan Model Deployment Initiative, San Antonio Evaluation Report. Report FHWA-OP-00-017, FHWA, US DOT 2000.
7. Nee, J. and M. Hallenbeck. Evaluation of the Service Patrol Program in the Puget Sound Region. Report T1803, TRAC, Washington State Transportation Commission, 2001
8. Khattak, A., J. Schofer, and M. Wang. A Simple Time Sequential Procedure forPredicting Freeway Incident Duration. IVHS Journal. Vol.2, No.2. 1995
9. Regional Traffic Incident Management Programs. Report FHWA-OP-01-002. FHWA, US DOT, 2001
10. Fenno D. and M. Ogden. Freeway Service Patrols: A State of the Practice. Transportation Research Record 1634, Transportation Research Board, National Research Council, Washington DC, 1998, pp 28-38
11. Goolsby, M. Influence of Incidents on Freeway Quality of Service. HighwayResearch Record, No. 349, Transportation Research Board, Washington DC, 1971
12. Smith, B., L. Qin and R. Venkatanarayana. Characterization of Freeway Capacity Reduction Resulting From Traffic Accidents. Journal of Transportation Engineering, 2003
13. Garib A., A. E. Radwan, H. Al-Deek. Estimating Magnitude and Duration of Incident Delays. Journal of Transportation Engineering, Vol. 139, 1997
14. Morales J. Analytical Procedures for Estimating Freeway Traffic Congestion. ITE Journal of Transportation Engineering. Volume: 123, 1987
15. Sullivan, E. New Model For Predicting Freeway Incidents And Incident Delays. Journal of Transportation Engineering, Paper no. 13592, 1997
16. Guin, A., Porter, C., Smith B. and Holmes, C., 2007. Benefits Analysis for an Incident Management Program Integrated with Intelligent Transportation Systems Operations: A Case Study. Transportation Research Board Annual Meeting CR-ROM
17. Hagen, L., Zhou, H. and Singh. H., 2005. Road Ranger Benefit Cost Analysis. Florida Department of Transportation.
18. Dougald, L.E. and Demetsky, M.J., 2008. Assessing the Return on Investment of Freeway Service Patrol Program. Transportation Research Board Annual Meeting CR-ROM

19. Al-Deek, H. M., A. Garib, and A.E. Radwan. New Method for Estimating Freeway Incident Congestion (1995). In Transportation Research Record: Journal of the Transportation Research Board, No. 1494, Transportation Research Board of the National Academies, Washington, D.C., pp. 30-39
20. Pierce R., C. Sun and J. Lemp. Incident Delay Modeling with the Use of Video Re-identification. CD-ROM. Transportation Research Board, Annual Meeting, Washington D.C., 2005
21. MNDOT, 2004. Minnesota Department of Transportation - FIRST Program Evaluation. Minnesota Department of Transportation
22. Latoski S., R. Pal, and K. Sinha. A Cost Effectiveness Evaluation of the Hoosier Helper Freeway Service Patrol. Final Report, Phase 1 FHWA/IN/JTRP. September, 1998
23. Haghani, A., Iliescu, D., Hamedi, M. and Yang, S., 2006. Methodology for Quantifying the Cost Effectiveness of Freeway Service Patrol Programs: A Case Study. University of Maryland
24. Moss, Sam Dallas, "A Benefit Cost Model for Traffic Incident Management. " Master's Thesis, University of Tennessee, 2012.
25. Pranav, Koshiya, ”A Benefit-Cost Analysis of a Freeway Service Patrol Program in Chicago”, 2010
26. Schrank, D., T. Lomax, B. Eisele. “TTI’s 2011 Urban Mobility Report-Powered by INRIX Traffic Data”. Texas Transportation Institute, The Texas A&M University System, College Station, TX, (2011).
27. Skabardonis A., Petty K.,Varaiya P.,Bertini R. Evaluation of the Freeway Service Patrol (FSP) in Los Angeles. California PATH Program, 1998.

APPENDIX A. ESP vs. SSP ROADWAY COVERAGE

Table 14. Comparison Between ESP and SSP Roadway Coverage

	ESP Coverage vs. SSP Coverage									
	ESP Coverage			**SSP Coverage**			**SSP Extended Coverage (i.e. emergency resulting in a lane closure)**			
Route	**Beg_MP**	**End_MP**	**Total**	**Beg_MP**	**End_MP**	**Total**	**Beg_MP**	**End_MP**	**Total**	**Zone**
I-78	3.8	58.32	54.52	27.11	58.32	31.21	17.6	27.11	9.51	North
I-80	0.5	68.1	67.6	35.3	68.1	32.8	27.19	68.1	8.11	North
I-280	0	17	17	0	17	17				North
I-287	0	67.5	67.5	0	45	45	45	53.14	8.14	North
NJ 440	0	5.15	5.15	0	5.15	5.15				North
Rt. 24	0	10	10	N/A	N/A		N/A	N/A		
Total North	**-**	**-**	***221.77***	-	-	***131.16***	-	-	***25.76***	-
I-295	0	68	68	16.42	67.79	51.37	0	16.42	16.42	South
I-95	0	8.8	8.8	0	8.77	8.77				South
I-195	0	34	34	0	7.3	7.3	7.3	16.71	9.41	South
I-76	0	2.2	2.2	0	2.2	2.2				South
I-676	0	3.7	3.7	0	3.7	3.7				South
NJ 29	0	9	9	0	2.94	2.94	2.94	9.13	6.19	South
NJ 42	6.2	14.3	8.1	6.2	14.28	8.08				South
NJ 55	20	60.5	40.5	50.5	60.49	9.99				South
Total South			***174.3***			***94.35***			***32.2***	
Statewide Total			***396.07***			***225.51***			***57.78***	

APPENDIX B. 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

APPENDIX C. INCIDENT FREQUENCY AND CHARACTERISTICS

Incidents include vast array of events, from most severe such as accident with injuries, to breakdowns, spills, debris on the road and shoulder that disrupts the normal flow of traffic. The incidents from the SWIFT/OpenRach database are grouped into three major categories: accidents, breakdowns and debris and their frequency is presented in Table 16.

Table 15. Events by Category and Their Frequency

	Within ESP Coverage Area		Within SSP Coverage Area	
ACCIDENT	Number of Incidents	Percent of Total (%)	Number of Incidents	Percent of Total (%)
Accident	1,039	56.7%	1,007	55.0%
Accident investigation	24	1.3%	22	1.2%
Accident with Injuries	38	2.1%	37	2.0%
Jack-knifed tractor trailer	12	0.7%	7	0.4%
Overturned Dump Truck	1	0.1%	1	0.1%
Overturned tractor trailer	20	1.1%	16	0.9%
Overturned Truck	2	0.1%	2	0.1%
Overturned vehicle	45	2.5%	40	2.2%
Pedestrian accident	2	0.1%	1	0.1%
Police department activity	37	2.0%	30	1.6%
Truck fire	12	0.7%	12	0.7%
Vehicle fire	54	2.9%	52	2.8%
Vehicle off the roadway	25	1.4%	25	1.4%
Vehicle spun out	26	1.4%	25	1.4%
Total Accident	***1,337***	***73%***	***1,277***	***73%***
BREAKDOWN				
Disabled bus	13	0.7%	13	1%
Disabled tractor trailer	78	4.3%	77	4%
Disabled truck	35	1.9%	33	2%
Disabled vehicle	305	16.6%	299	16%
Total Breakdown	***431***	***23.5%***	***422***	***24.1%***
DEBRIS				
Debris spill	36	2.0%	33	1.8%
Downed tree	13	0.7%	6	0.3%
Fuel Spill	7	0.4%	5	0.3%
Street Light Knockdown	8	0.4%	7	0.4%
Total Debris	***64***	***3.5%***	***51***	***2.9%***

APPENDIX D. AVERAGE INCIDENT DURATION BY EVENT TYPE AND BY ROADWAY

Table 16. Average Incident Duration by Event Type and By Roadway (ESP Service)

	Average Incident Duration												
ACCIDENT	**I-78**	**I-80**	**I-280**	**I-287**	**NJ440**	**I-295**	**I-95**	**I-195**	**I-76**	**I-676**	**NJ 29**	**NJ 42**	**NJ 55**
Accident	0:36:18	0:31:49	0:22:26	0:32:29	0:38:28	0:32:29	0:31:09	0:45:48	0:37:44	0:30:25	0:37:19	0:28:24	0:35:03
Accident investigation	3:19:05	3:01:37	1:28:34	3:07:37	3:02:12	3:07:37	-	1:38:53	-	3:36:09	-	1:21:21	2:55:20
Accident with Injuries	0:44:33	0:42:39	0:32:25	0:25:39	0:19:56	0:25:39	-	-	1:04:07	0:35:58	-	-	0:33:51
Jack-knifed tractor trailer	1:56:25	0:49:27	0:43:33	1:06:12	-	1:06:12	-	-	-	-	-	-	1:04:56
Overturned Dump Truck	-	-	-	2:27:32	-	2:27:32	-	-	-	-	-	-	-
Overturned tractor trailer	5:15:36	5:12:13	4:03:55	5:29:57	2:48:13	5:29:57	-	2:06:57	-	-	-	-	2:09:28
Overturned Truck	1:06:05	-	-	-	-	-	-	-	3:02:35	-	-	-	-
Overturned vehicle	0:51:50	0:28:07	0:39:57	0:40:14	-	0:40:14	0:51:05	0:46:25	0:30:56	0:51:34	-	0:25:22	1:07:43
Pedestrian accident	-	1:30:21	2:55:38	-	-	-	-	-	-	-	-	-	-
Police department activity	2:42:05	0:57:12	-	0:07:02	-	0:07:02	-	3:46:31	-	0:55:49	0:19:57	0:53:56	0:48:21
Truck fire	0:37:04	1:27:43	1:12:57	1:45:15	-	1:45:15	-	-	-	-	-	-	0:08:35
Vehicle fire	0:29:34	0:33:50	0:19:35	0:30:24	-	0:30:24	-	-	0:34:48	0:26:57	-	0:16:38	0:30:53
Vehicle off the roadway	-	0:03:42	-	0:59:59	-	0:59:59	0:13:42	0:29:18	-	-	-	0:30:58	0:34:24
Vehicle spun out	0:04:18	0:08:49	-	0:53:49	-	0:53:49	-	-	0:16:40	0:46:01	1:17:05	0:05:58	0:27:49
BREAKDOWN	**Average Incident Duration**												
Disabled bus	0:42:28	-	0:13:26	-	-	-	0:22:08	-	1:30:58	-	0:14:16	-	-
Disabled tractor trailer	0:32:54	0:38:57	0:52:48	0:17:23	0:46:49	0:17:23	0:31:30	0:04:19	0:42:30	0:37:20	0:36:27	0:00:22	-
Disabled truck	0:29:36	0:24:45	0:37:24	0:18:17	-	0:18:17	-	1:47:17	0:08:31	0:40:10	0:21:32	0:04:17	0:52:21
Disabled vehicle	0:18:40	0:17:49	0:19:36	0:17:11	0:15:10	0:17:11	0:39:51	0:21:22	0:23:02	0:16:51	0:27:04	0:14:33	0:22:10

DEBRIS	Average Incident Duration												
Debris spill	2:17:40	0:52:05	0:17:40	0:40:54	0:55:18	0:40:54	-	-	0:18:01	0:16:08	-	0:05:09	-
Downed pole	-	-	-	-	-	-	-	-	-	-	-	-	-
Downed wires	-	-	-	-	-	-	-	-	-	-	-	-	-
Downed tree	1:24:13	1:21:03	-	0:53:48	-	0:53:48	-	0:39:50	-	-	0:33:16	-	4:22:09
Fuel Spill	-	4:56:55	-	2:01:40	-	2:01:40	-	-	-	-	-	-	-
Street Light Knockdown	2:35:53	0:51:37	0:02:21	-	-	-	1:53:49	-	-	-	0:59:38	-	-
Traffic Signal Down	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 17. Average Incident Duration by Event Type and By Roadway (SSP Service)

	Average Incident Duration												
ACCIDENT	**I-78**	**I-80**	**I-280**	**I-287**	**NJ440**	**I-295**	**I-95**	**I-195**	**I-76**	**I-676**	**NJ 29**	**NJ 42**	**NJ 55**
Accident	0:32:45	0:29:14	0:22:26	0:31:59	0:38:28	0:32:29	0:31:09	0:45:48	0:37:44	0:30:25	0:44:21	0:28:24	0:31:18
Accident investigation	3:19:05	3:16:49	1:28:34	3:07:37	3:02:12	3:07:37	-	1:38:53	-	3:36:09	-	1:21:21	-
Accident with Injuries	0:43:44	0:45:07	0:32:25	0:25:39	0:19:56	0:25:39	-	-	1:04:07	0:35:58	-	-	0:33:51
Jack-knifed tractor trailer	-	1:08:11	0:43:33	2:02:05	-	1:06:12	-	-	-	-	-	-	-
Overturned Dump Truck	-	-	-	2:27:32	-	2:27:32	-	-	-	-	-	-	-
Overturned tractor trailer	3:30:46	5:05:31	4:03:55	5:29:57	2:48:13	5:29:57	-	2:06:57	-	-	-	-	2:09:28
Overturned Truck	-	-	-	-	-	-	-	-	3:02:35	-	-	-	-
Overturned vehicle	0:52:25	0:28:32	0:39:57	0:31:39	-	0:40:14	0:51:05	0:43:39	0:30:56	0:51:34	-	0:25:22	1:23:56
Pedestrian accident	-	-	2:55:38	-	-	-	-	-	-	-	-	-	-
Police department activity	0:47:12	0:20:38	-	0:07:02	-	0:07:02	-	1:15:08	-	0:55:49	0:19:57	0:53:56	0:28:34
Truck fire	0:37:04	1:27:43	1:12:57	1:45:15	-	1:45:15	-	-	-	-	-	-	0:08:35
Vehicle fire	0:34:19	0:33:50	0:19:35	0:30:24	-	0:30:24	-	-	0:34:48	0:26:57	-	0:16:38	0:35:52
Vehicle off the roadway	-	0:03:42	-	0:59:59	-	0:59:59	0:13:42	0:29:18	-	-	-	0:30:58	0:34:24
Vehicle spun out	0:04:18	0:08:49	-	0:53:49	-	0:53:49	-	-	0:16:40	0:46:01	1:17:05	0:05:58	0:11:12

BREAKDOWN	**Average Incident Duration**												
Disabled bus	-	-	0:13:26	-	-	-	0:22:08	-	1:30:58	-	0:14:16	-	-
Disabled tractor trailer	0:32:11	0:38:57	0:52:48	0:17:23	0:46:49	0:17:23	0:31:30	0:04:19	0:42:30	0:37:20	0:36:27	0:00:22	-
Disabled truck	0:29:36	0:24:45	0:37:24	0:18:17	-	0:18:17	-	1:47:17	0:08:31	0:40:10	0:21:52	0:04:17	0:52:21
Disabled vehicle	0:19:02	0:17:49	0:19:36	0:17:11	0:15:10	0:17:11	0:39:51	0:21:22	0:23:02	0:16:51	0:30:28	0:14:33	0:24:43
DEBRIS	**Number of Incidents**												
Debris spill	0:01:32	0:44:03	0:17:40	0:38:46	0:55:18	0:40:54	-	-	0:18:01	0:16:08	-	0:05:09	-
Downed pole	-	-	-	-	-	-	-	-	-	-	-	-	-
Downed wires	-	-	-	-	-	-	-	-	-	-	-	-	-
Downed tree	1:24:13	2:34:42	-	0:53:48	-	0:53:48	-	0:39:50	-	-	-	-	-
Fuel Spill	-	5:21:36	-	2:05:57	-	2:01:40	-	-	-	-	-	-	-
Street Light Knockdown	-	0:51:37	0:02:21	-	-	-	1:53:49	-	-	-	-	-	-
Traffic Signal Down	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E. SSP SERVICE DESCRIPTION

Table 18. Harding Yard Hours of Operation and Staffing

Harding Yard			
	AM Shift (Mon – Fri)	**PM Shift (Mon – Fri)**	**Weekend Shift (Sat – Sun)**
Hours of Operation	04:00 AM to 12:30 PM	12:00 P.M. to 20:30 P.M.	10:00 A.M. to 20:30 P.M.
Trucks Per Shift	12	12	10
Staff per Truck	1	1	1

Table 19. Cherry Hill Yard Hours of Operation and Staffing

Cherry Hill Yard			
	AM Shift (Mon – Fri)	**PM Shift (Mon – Fri)**	**Weekend Shift (Sat – Sun)**
Hours of Operation	04:00 AM to 12:30 PM	12:00 P.M. to 20:30 P.M.	10:00 A.M. to 20:30 P.M.
Trucks Per Shift	11	8	10
Staff per Truck	1	1	1

APPENDIX F. DISTRIBUTION OF INCIDENT TYPES BY LOCATION AND AVERAGE INCIDENT DURATION

F.1. Harding Yard – Zone 1

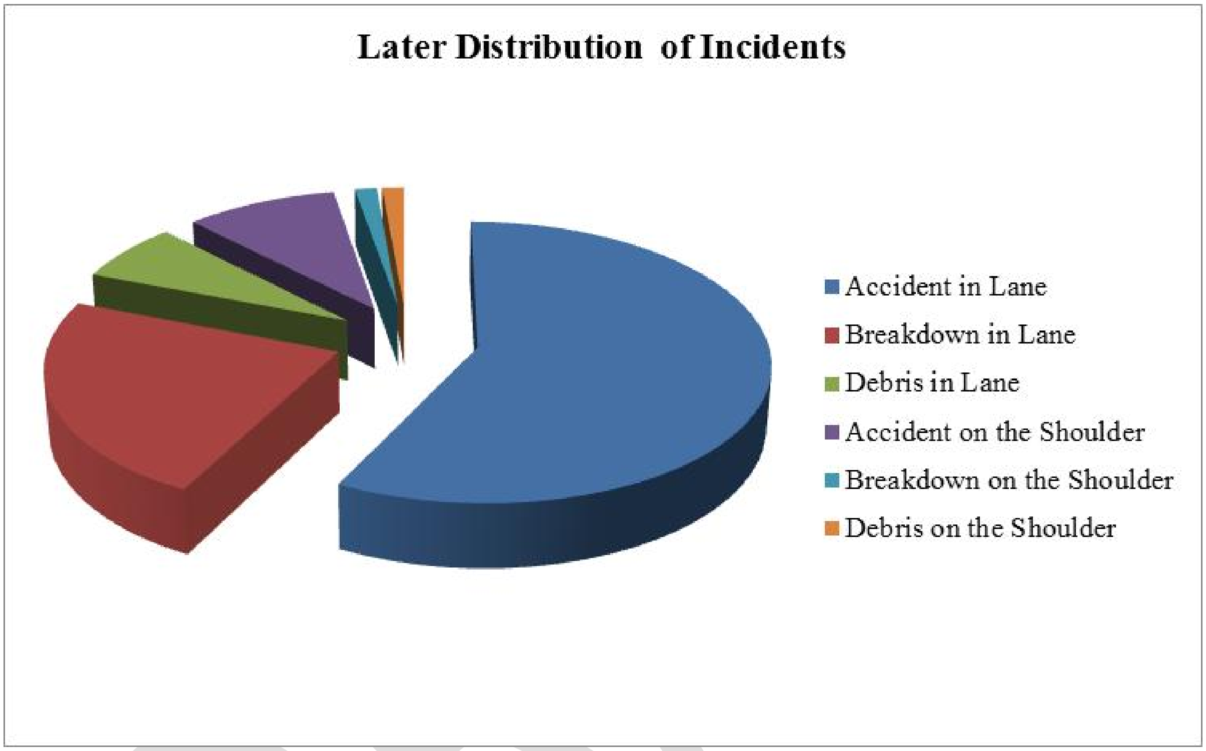

Figure 5. Distribution of Incident Types by Location in Zone 1 Harding Yard

Table 20. Average Incident Duration

	Lane	**Shoulder**
Accident	0:28:21	0:20:25
Breakdown	0:29:15	0:21:50
Debris	0:48:03	5:21:36

F.2. Harding Yard – Zone 2

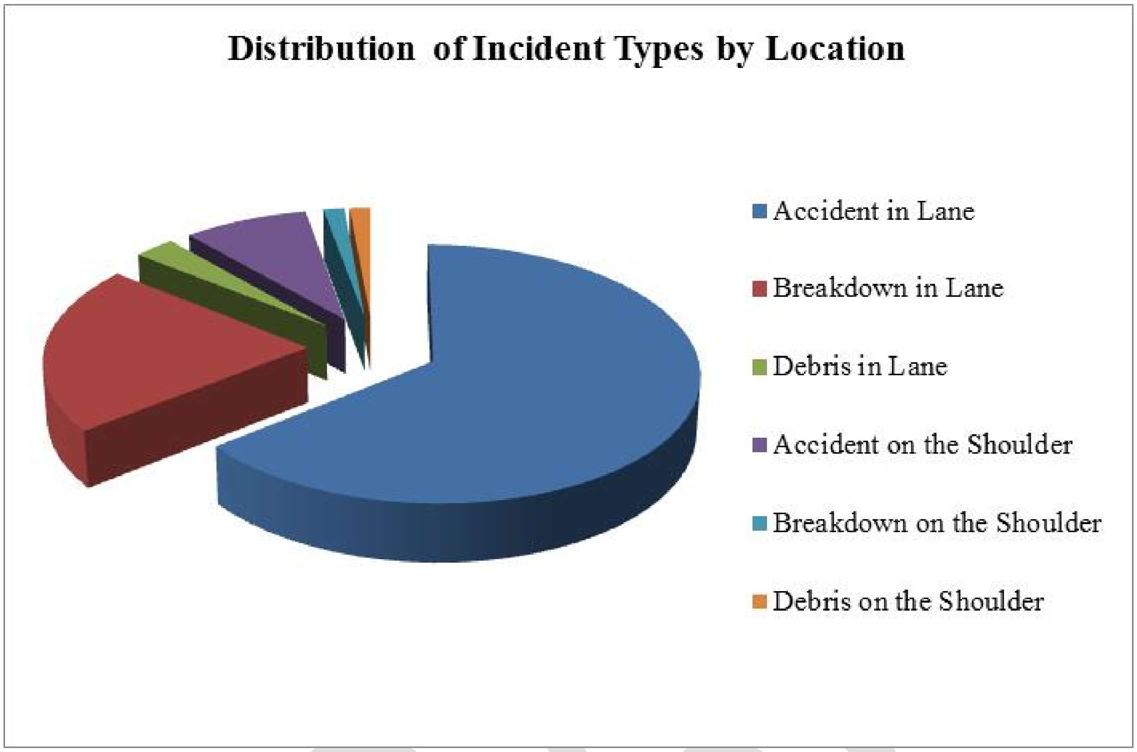

Figure 6. Distribution of Incident Types by Location in Zone 2 Harding Yard

Table 21. Average Incident Duration in Zone 2 Harding Yard

	Lane	**Shoulder**
Accident	0:50:11	0:27:46
Breakdown	0:28:33	-
Debris	0:15:30	5:21:36

F.3. Harding Yard – Zone 3

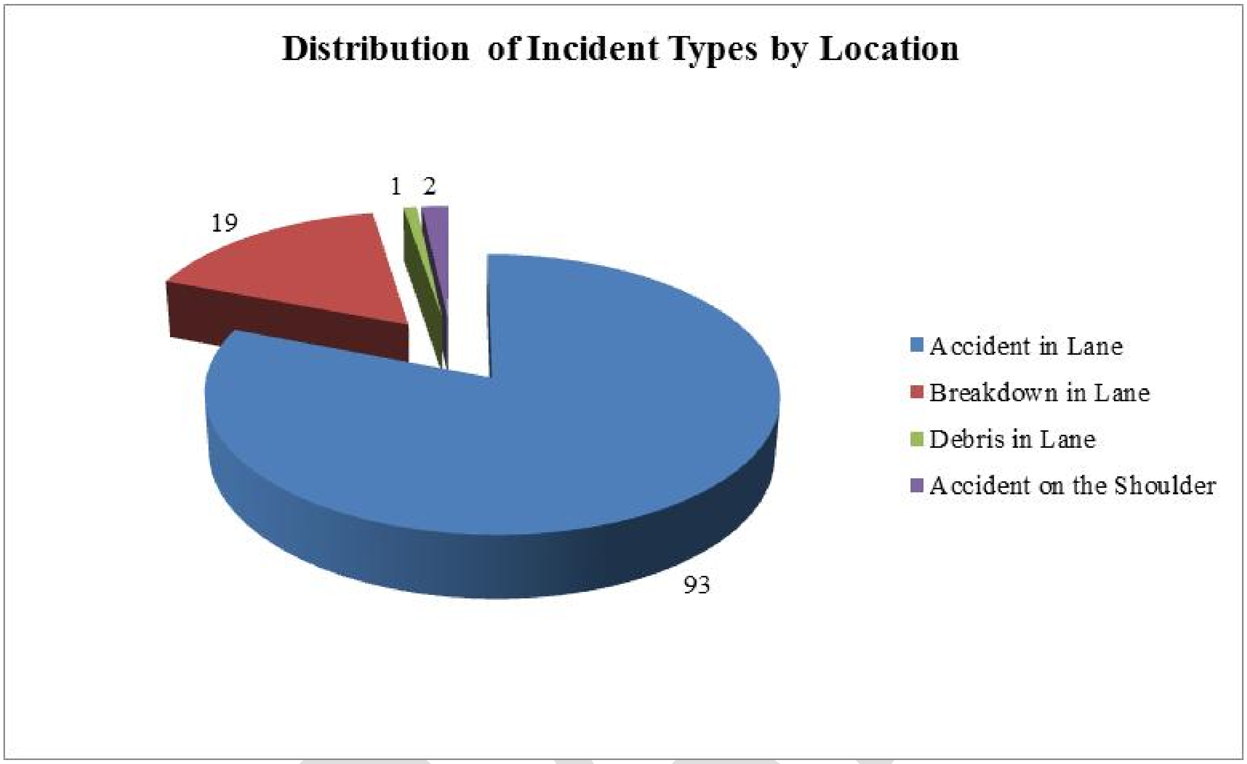

Figure 7. Distribution of Incident Types by Location in Zone 3 Harding Yard

Table 22. Average Incident Duration in Zone 3 Harding Yard

	Lane	**Shoulder**
Accident	0:41:35	0:35:54
Breakdown	0:15:29	-
Debris	1:38:21	-

F.4. Harding Yard – Zone 4

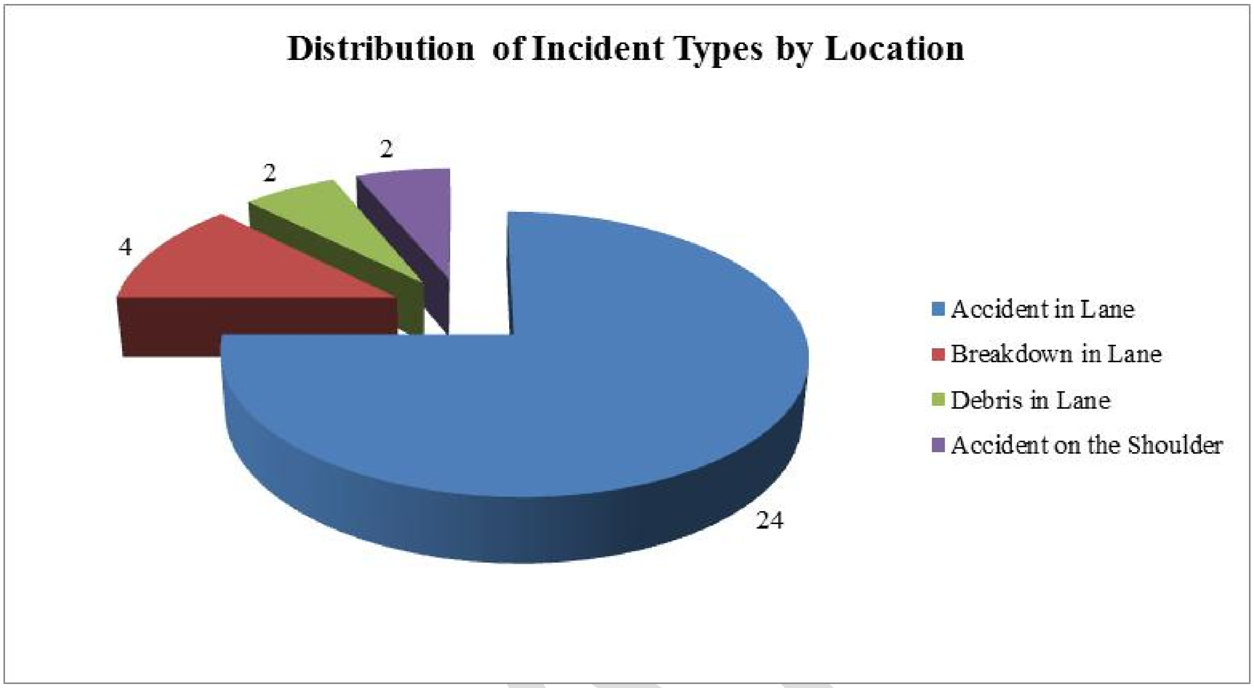

Figure 8. Distribution of Incident Types by Location in Zone 4 Harding Yard

Table 23. Average Incident Duration in Zone 4 Harding Yard

	Lane	**Shoulder**
Accident	0:40:54	1:23:14
Breakdown	0:42:13	-
Debris	0:06:52	-

F.5. Harding Yard – Zone 5

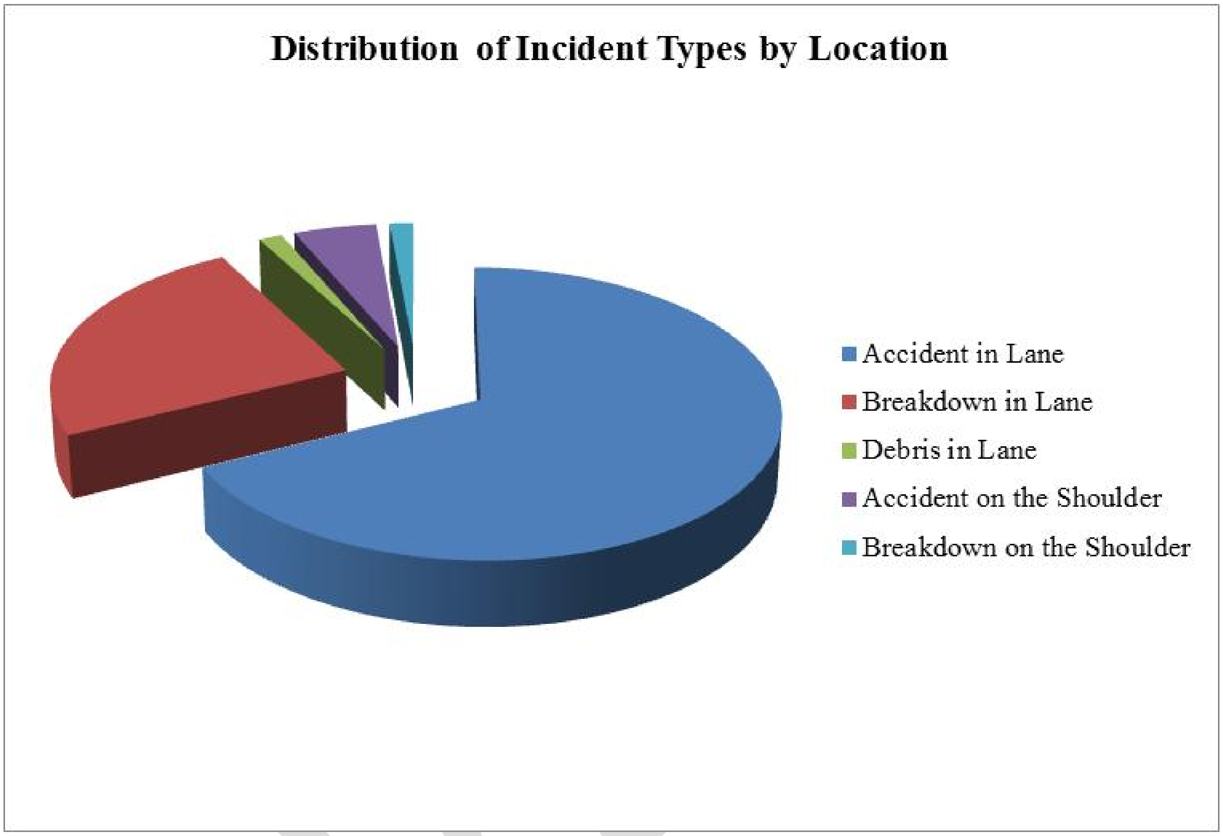

Figure 9. Distribution of Incident Types by Location in Zone 5 Harding Yard

Table 24. Average Incident Duration in Zone 5 Harding Yard

	Lane	Shoulder
Accident	0:26:27	0:52:12
Breakdown	0:19:24	2:27:00
Debris	0:10:01	-

F.6. Harding Yard – Zone 6

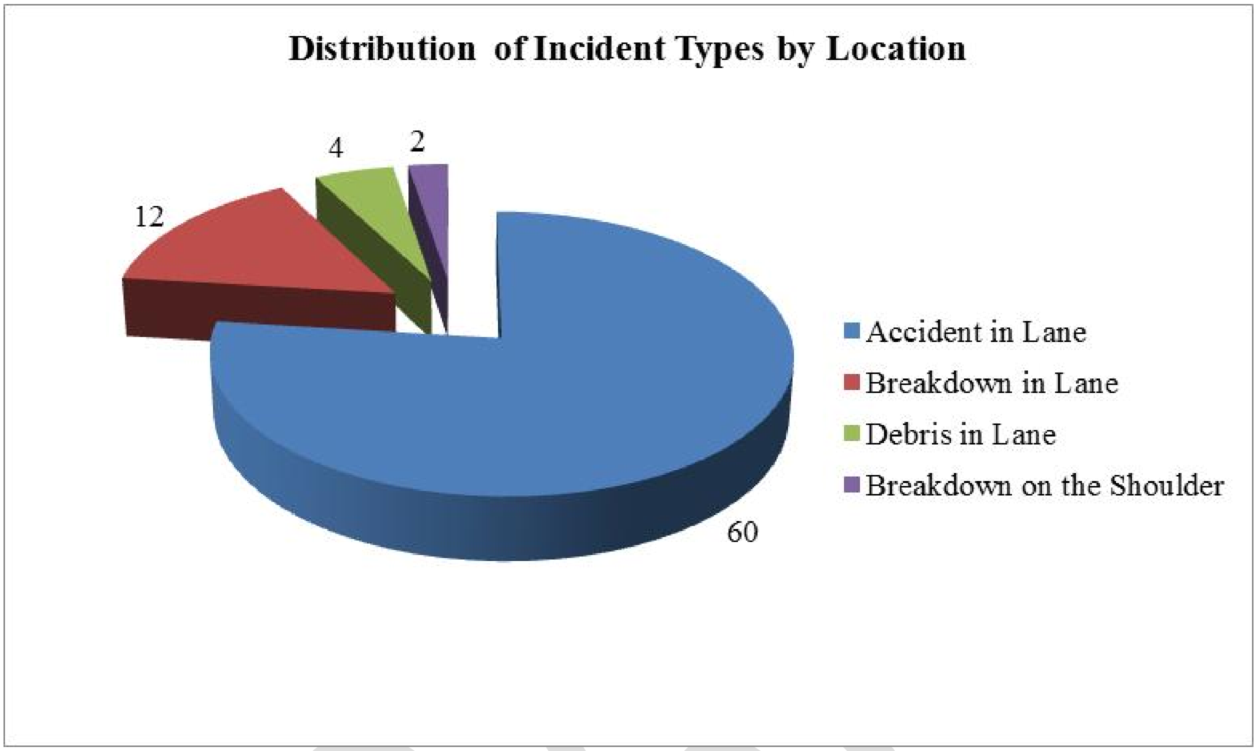

Figure 10. Distribution of Incident Types by Location in Zone 6 Harding Yard

Table 25. Average Incident Duration in Zone 6 Harding Yard

	Lane	**Shoulder**
Accident	0:41:25	-
Breakdown	0:13:20	1:01:42
Debris	1:01:01	-

F.7. Harding Yard – Zone 7

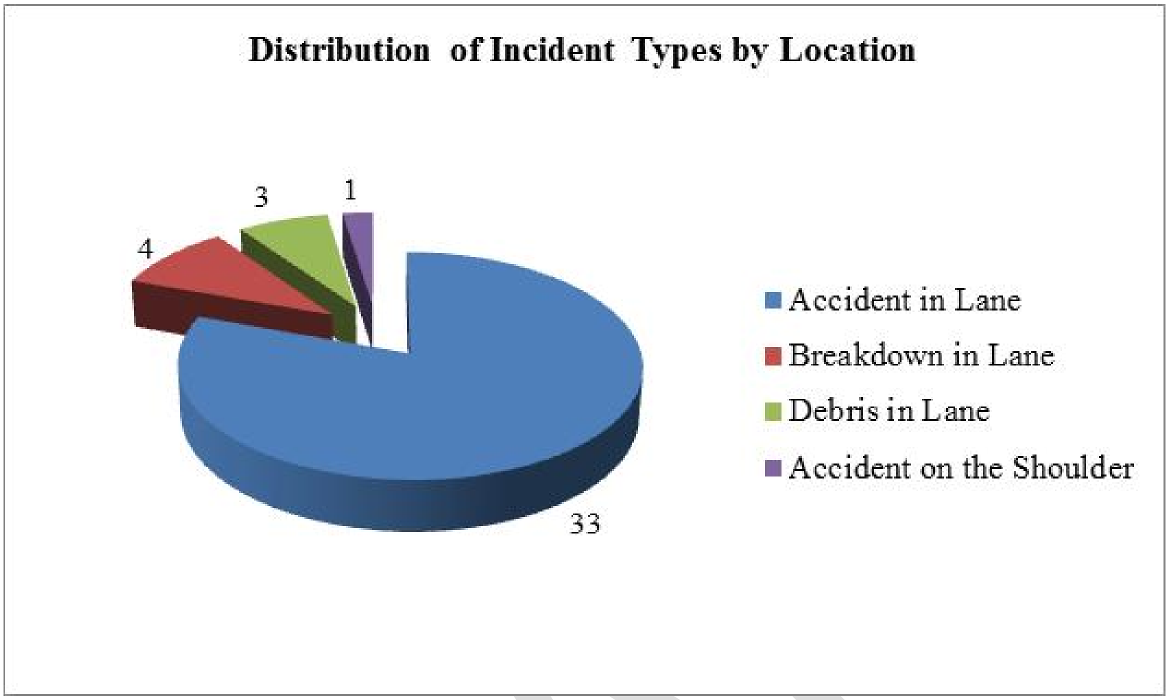

Figure 11. Distribution of Incident Types by Location in Zone 7 Harding Yard

Table 26. Average Incident Duration in Zone 7 Harding Yard

	Lane	**Shoulder**
Accident	0:43:24	0:05:26
Breakdown	0:14:02	-
Debris	0:55:06	-

F.8. Harding Yard – Zone 8

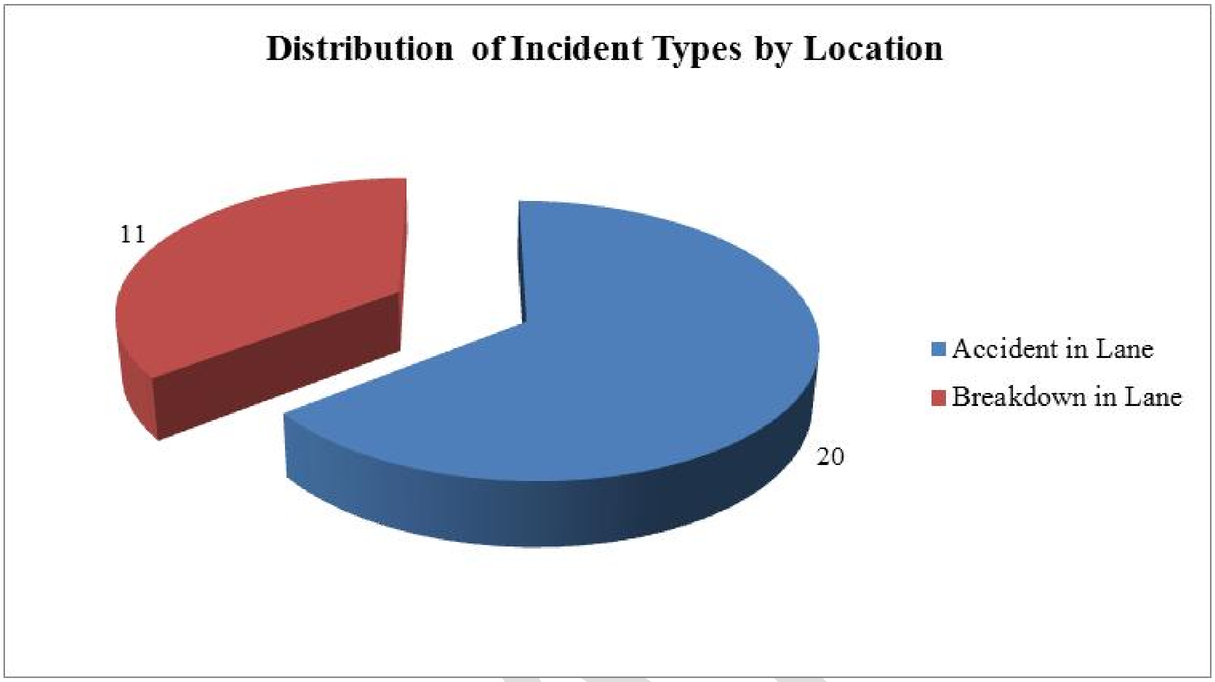

Figure 12. Distribution of Incident Types by Location in Zone 8 Harding Yard

Table 27. Average Incident Duration in Zone 8 Harding Yard

	Lane	**Shoulder**
Accident	0:56:31	-
Breakdown	0:21:37	-
Debris	-	-

F.9. Harding Yard – Zone 9

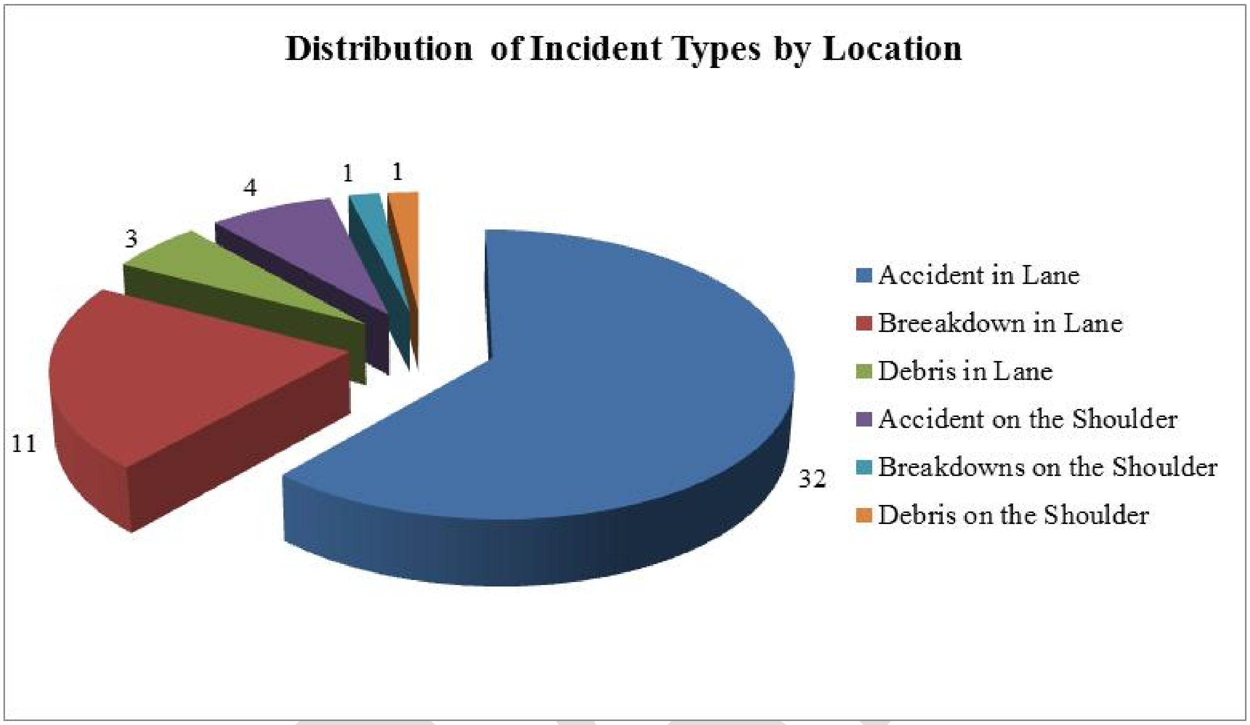

Figure 13. Distribution of Incident Types by Location in Zone 9 Harding Yard

Table 28. Average Incident Duration in Zone 9 Harding Yard

	Lane	**Shoulder**
Accident	0:50:00	0:48:42
Breakdown	0:16:58	0:20:40
Debris	0:33:23	1:45:27

F.10. Harding Yard – Zone 10

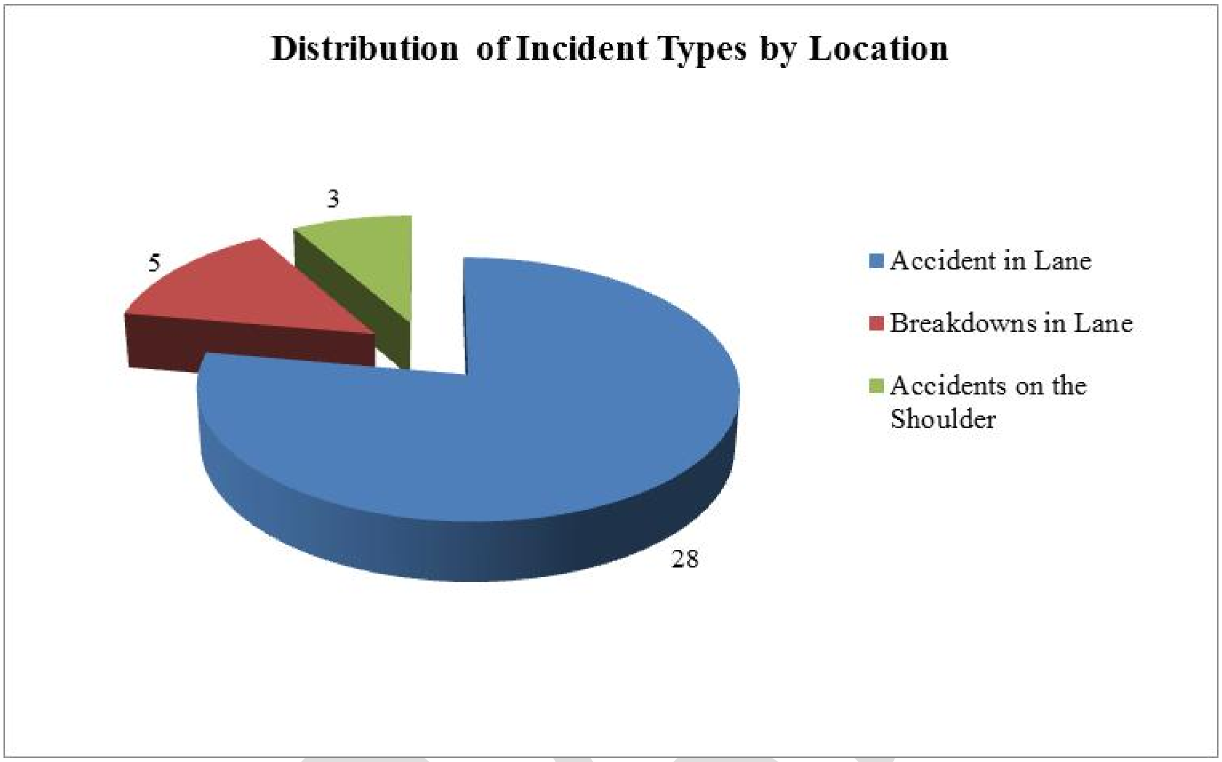

Figure 14. Distribution of Incident Types by Location in Zone 10 Harding Yard

Table 29. Average Incident Duration in Zone 10 Harding Yard

	Lane	**Shoulder**
Accident	0:50:21	0:29:59
Breakdown	0:09:14	-
Debris	-	-

F.11. Harding Yard – Zone 11

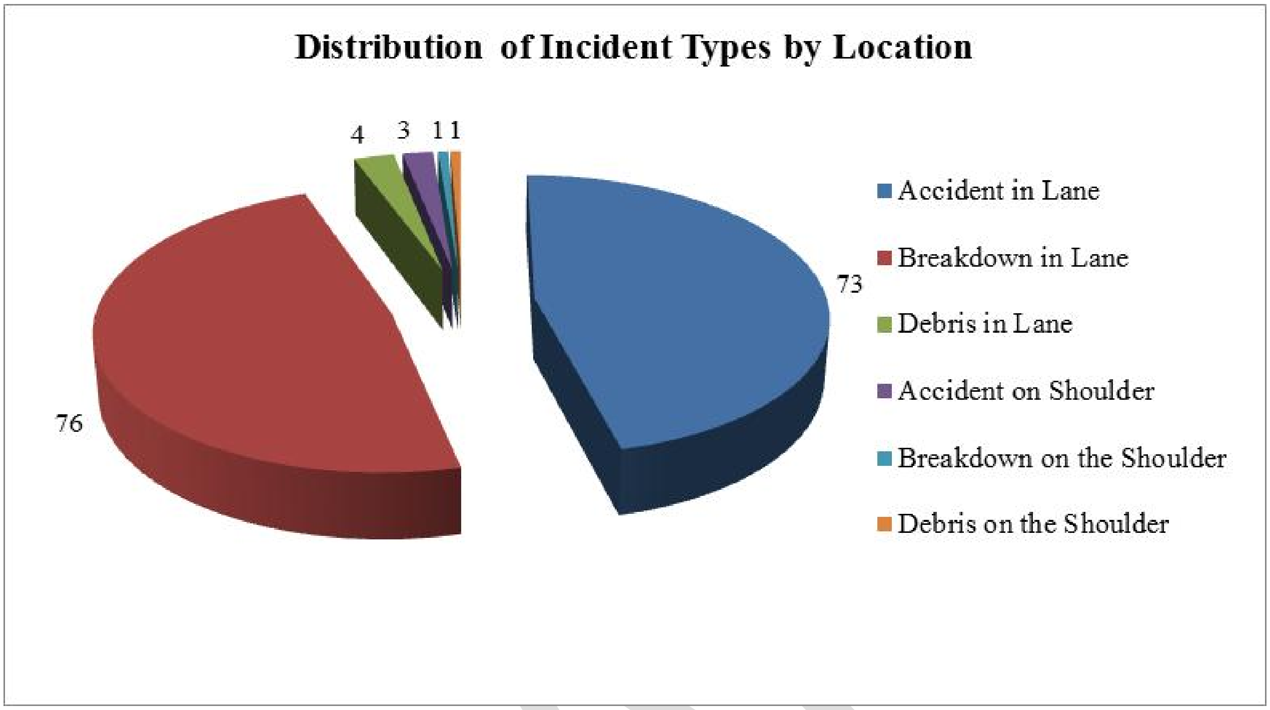

Figure 15. Distribution of Incident Types by Location in Zone 11 Harding Yard

Table 30. Average Incident Duration in Zone 11 Harding Yard

	Lane	**Shoulder**
Accident	0:40:05	0:37:58
Breakdown	0:24:08	0:00:22
Debris	3:04:08	1:29:10

F.12. Harding Yard – Zone 12

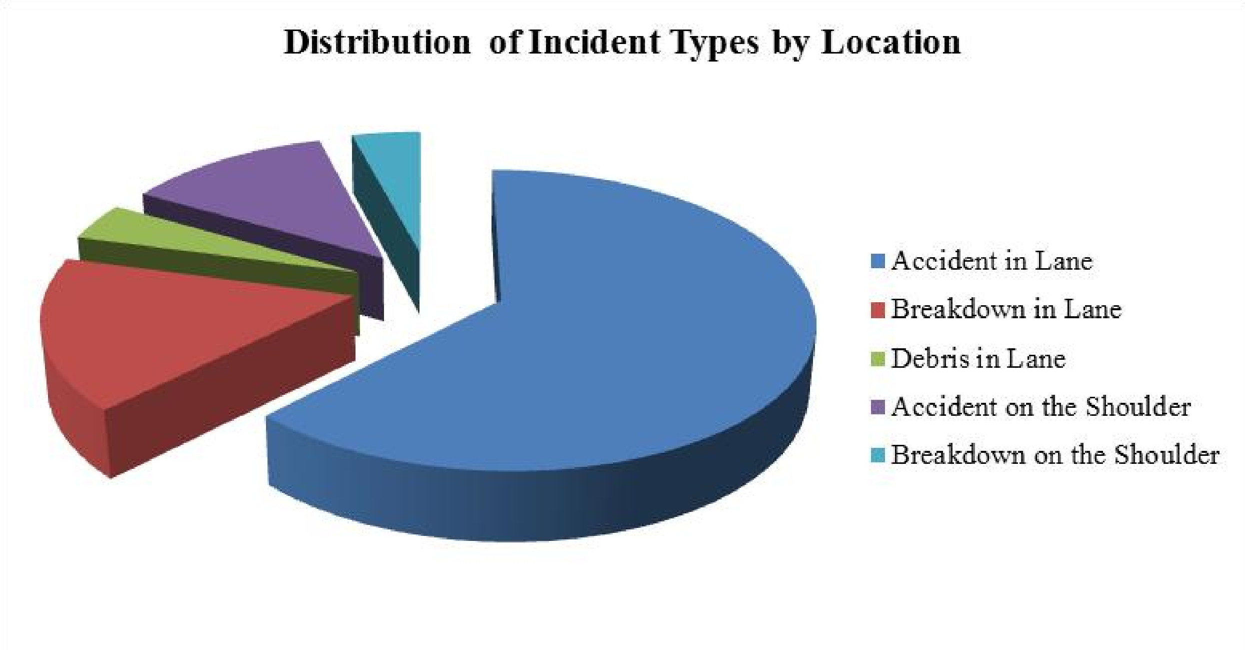

Figure 16. Distribution of Incident Types by Location in Zone 12 Harding Yard

Table 31. Average Incident Duration in Zone 12 Harding Yard

	Lane	**Shoulder**
Accident	1:08:13	4:10:10
Breakdown	0:27:57	0:01:54
Debris	4:33:48	-

F.13. Cherry Hill Yard – Zone 1

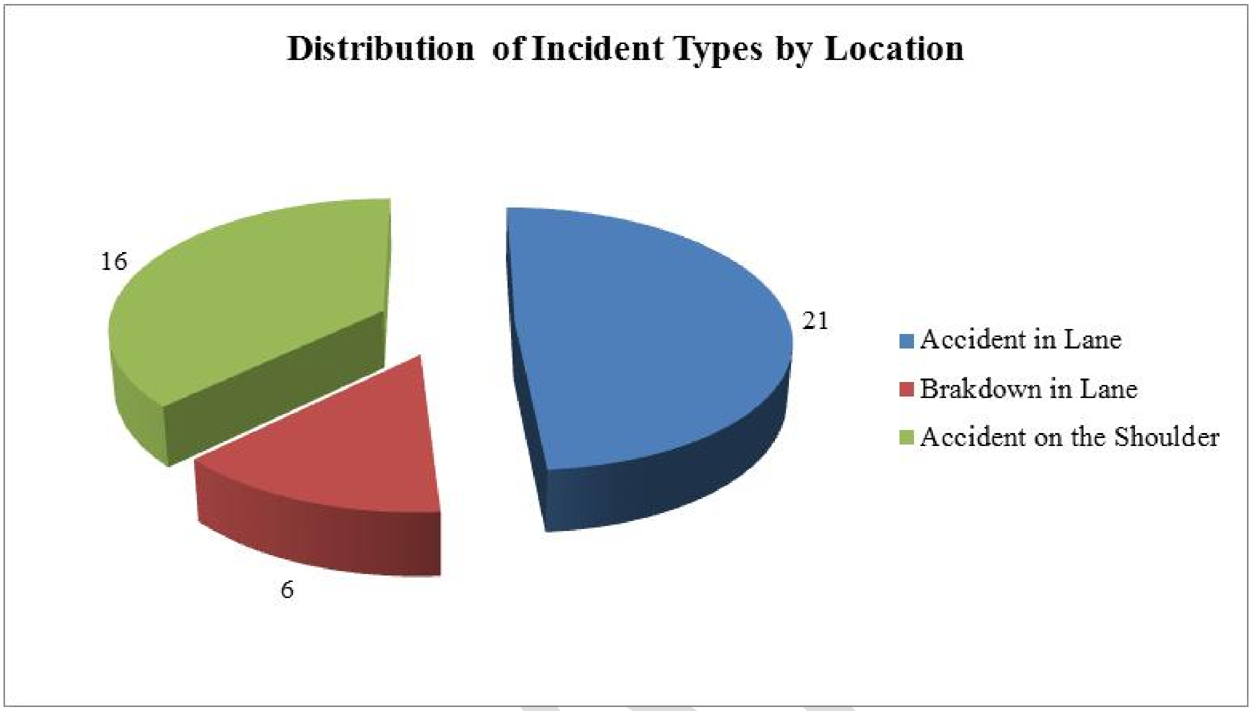

Figure 17. Distribution of Incident Types by Location in Zone 1 Cherry Hill Yard

Table 32. Average Incident Duration in Zone 1 Cherry Hill Yard

	Lane	**Shoulder**
Accident	0:35:04	0:37:57
Breakdown	0:29:20	-
Debris	-	-

F.14. Cherry Hill Yard – Zone 2

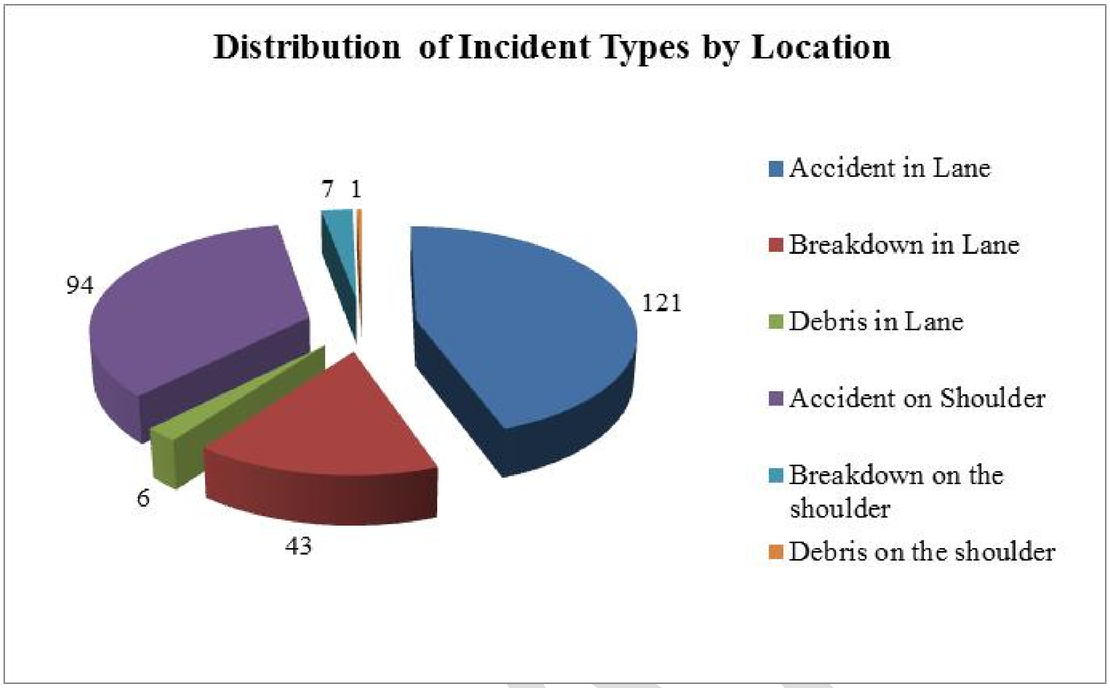

Figure 18. Distribution of Incident Types by Location in Zone 2 Cherry Hill Yard

Table 33. Average Incident Duration in Zone 2 Cherry Hill Yard

	Lane	**Shoulder**
Accident	0:36:32	0:30:16
Breakdown	0:16:16	0:51:38
Debris	0:10:58	0:30:47

F.15. Cherry Hill Yard – Zone 3

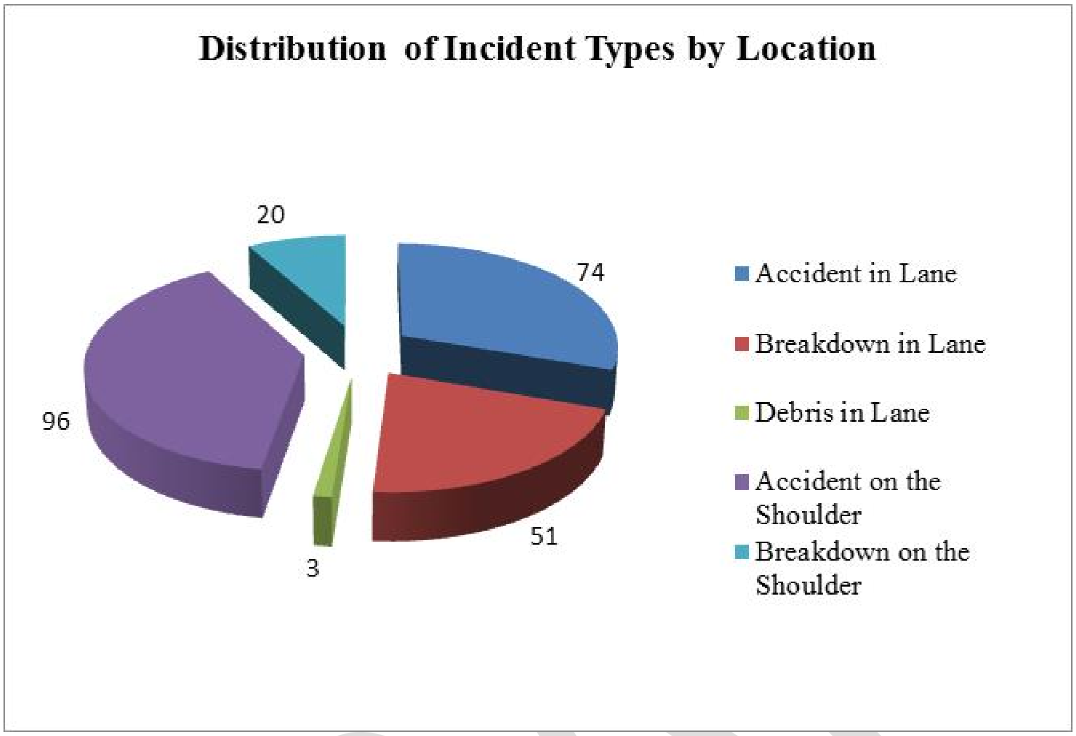

Figure 19. Distribution of Incident Types by Location in Zone 3 Cherry Hill Yard

Table 34. Average Incident Duration in Zone 3 Cherry Hill Yard

	Lane	**Shoulder**
Accident	0:42:17	0:33:01
Breakdown	0:19:27	1:14:36
Debris	1:28:57	-

F.16. Cherry Hill Yard – Zone 4

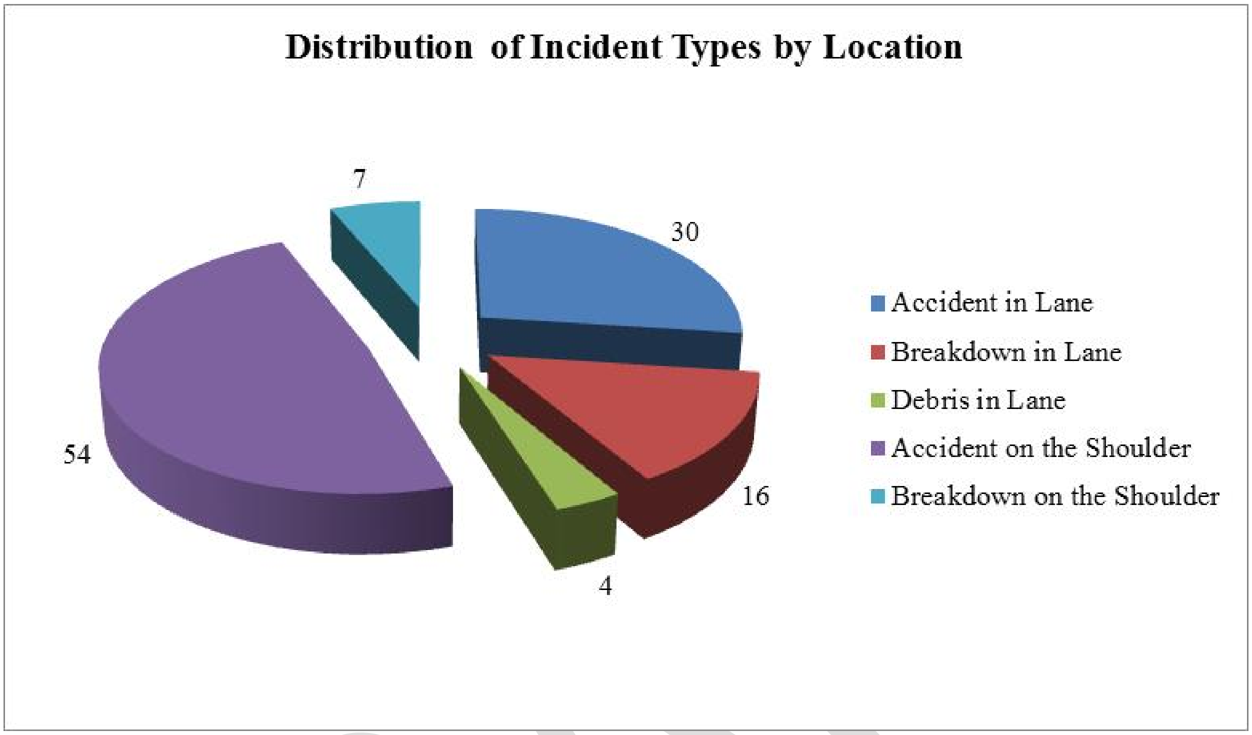

Figure 20. Distribution of Incident Types by Location in Zone 4 Cherry Hill Yard

Table 35. Average Incident Duration in Zone 4 Cherry Hill Yard

	Lane	**Shoulder**
Accident	1:12:29	0:41:54
Breakdown	0:23:17	0:43:03
Debris	0:52:15	-

F.17. Cherry Hill Yard – Zone 5

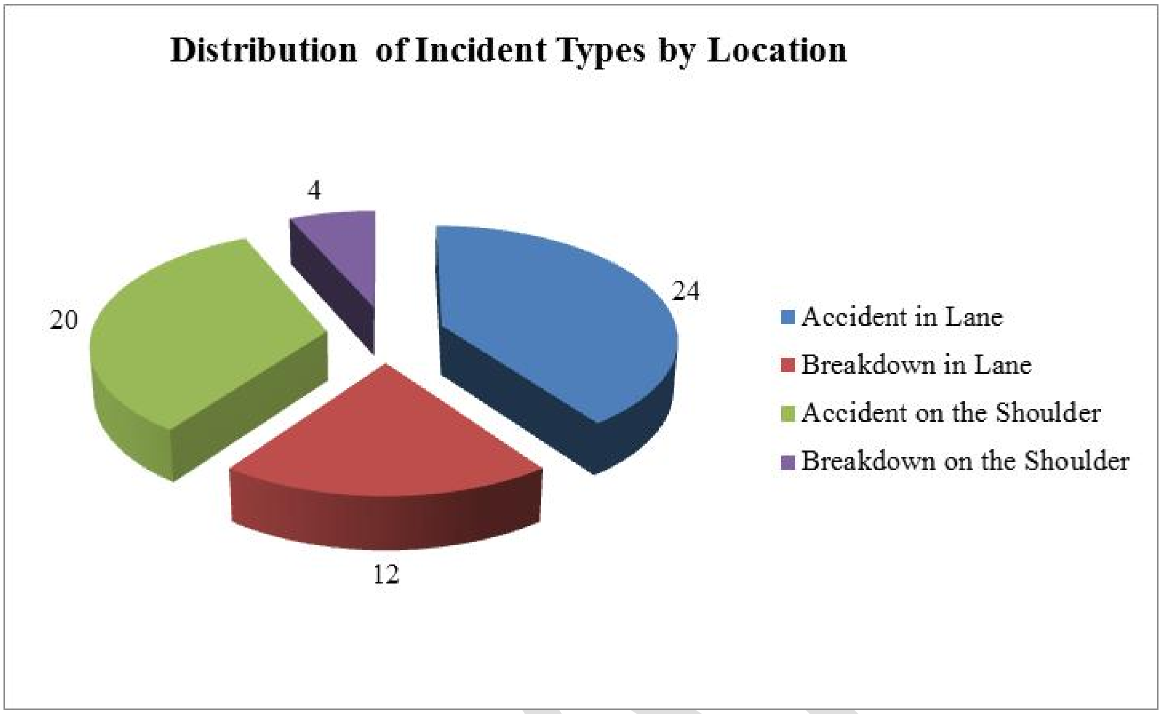

Figure 21. Distribution of Incident Types by Location in Zone 5 Cherry Hill Yard

Table 36. Average Incident Duration in Zone 5 Cherry Hill Yard

	Lane	**Shoulder**
Accident	1:04:00	0:34:33
Breakdown	0:36:04	0:22:04
Debris	-	-

F.18. Cherry Hill Yard – Zone 6

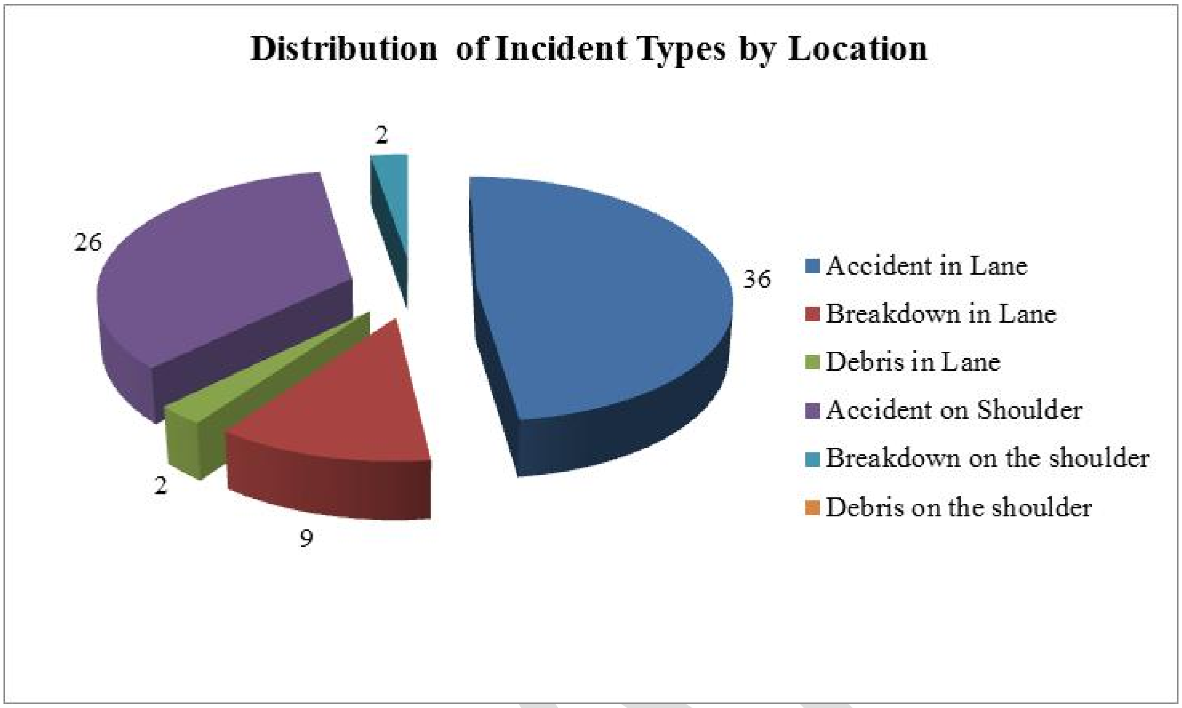

Figure 22. Distribution of Incident Types by Location in Zone 6 Cherry Hill Yard

Table 37. Average Incident Duration in Zone 6 Cherry Hill Yard

	Lane	**Shoulder**
Accident	0:28:05	0:35:47
Breakdown	0:35:33	0:52:53
Debris	1:10:41	-

F.19. Cherry Hill Yard – Zone 7

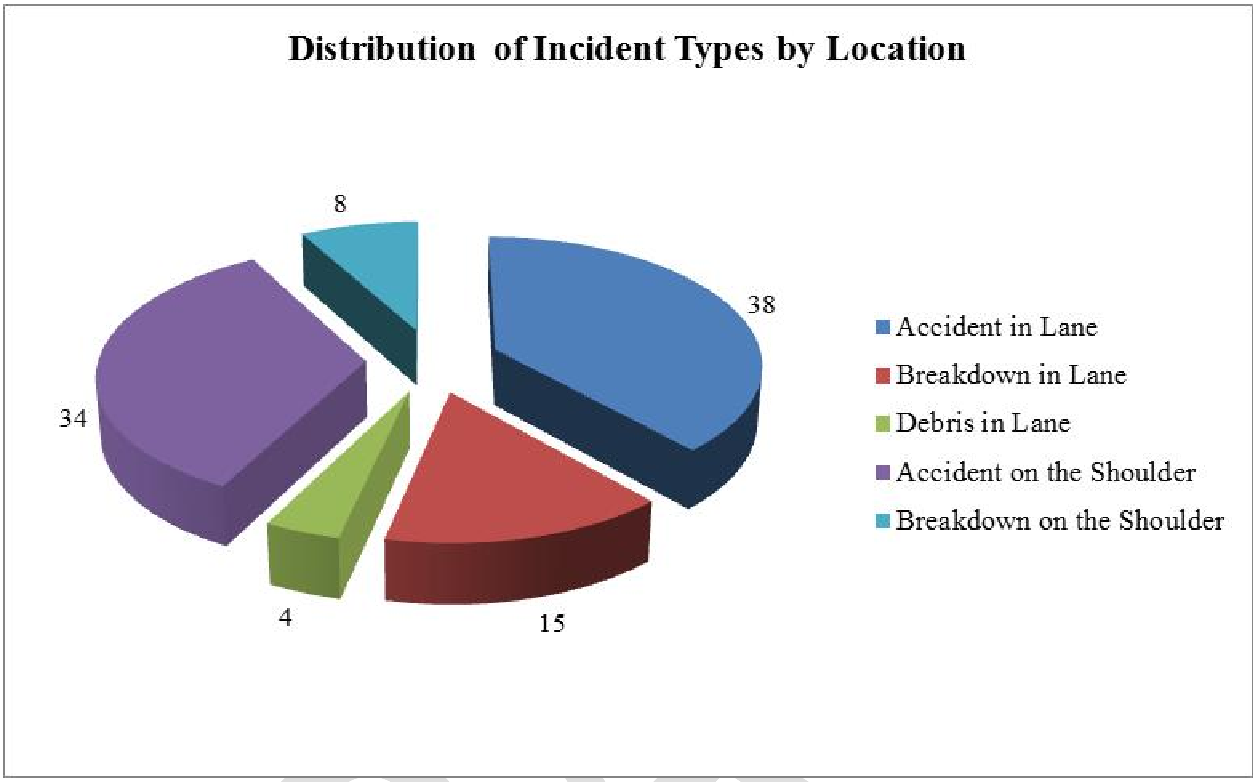

Figure 23. Distribution of Incident Types by Location in Zone 7 Cherry Hill Yard

Table 38. Average Incident Duration in Zone 7 Cherry Hill Yard

	Lane	**Shoulder**
Accident	0:53:27	0:35:25
Breakdown	0:24:39	0:32:26
Debris	0:43:08	-

APPENDIX G. SENSITIVITY ANALYSIS RESULTS

Harding Yard – Zone 1

Figure 24. Annual Savings and B/C Ratio for Harding Yard Zone 1

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	1959	4029	6136	10295	14492	19743	24964	30150	35301	40390	45390
Fuel Consumption (gal)	2956	6078	9255	15529	21861	29780	37657	45478	53249	60926	68467
Emissions											
ROG (kg)	247	507	772	1296	1825	2486	3143	3796	4444	5085	5715
CO (kg)	13	27	41	68	96	131	166	201	235	269	302
NOx (kg)	55	113	172	289	406	554	700	846	990	1133	1273
Cost Effectiveness											
Delay Benefits ($)	53296	109601	166887	280025	394190	536999	679030	820067	960196	1098620	1234604
Fuel Benefits ($)	10581	21760	33133	55595	78261	106613	134812	162812	190633	218115	245113
Total Benefits ($)	63877	131361	200021	335620	472451	643612	813842	982879	1150828	1316735	1479716
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	1.1	2.4	3.6	6.0	8.5	11.5	14.6	17.6	20.6	23.6	26.5

Harding Yard – Zone 2

Figure 25. Savings and B/C Ratio for Harding Yard Zone 2

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	2005	4077	8197	12329	17477	22737	27975	33194	38388	43568.64	48715
Fuel Consumption (gal)	3024	6150	12364	18598	26363	34297	42197	50071	57906	65720.79	73482
Emissions										0	
ROG (kg)	252	513	1032	1552	2200	2863	3522	4179	4833	5484.51	6133
CO (kg)	13	27	55	82	116	151	186	221	255	289.14	324
NOx (kg)	56	114	230	346	490	638	785	931	1077	1222.44	1366

Cost Effectiveness

Delay Benefits ($)	54528	110906	222951	335357	475381	618436	760907	902879	1044164	1185108	1325035
Fuel Benefits ($)	10826	22019	44264	66580	94380	122781	151067	179253	207304	235338	263066
Total Benefits ($)	65353	132925	267214	401937	569761	741218	911974	1082132	1251468	1420263	1588101
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	1.2	2.4	4.8	7.2	10.2	13.3	16.4	19.4	22.4	25.5	28.5

Harding Yard – Zone 3

Figure 26. Savings and B/C Ratio for Harding Yard Zone 3

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	2535	6439	10485	17194	24105	30939	37914	44700	51564	58247	65081
Fuel Consumption (gal)	3823	9712	15816	25936	36360	46670	57190	67426	77780	87861	98170
Emissions											
ROG (kg)	319	811	1320	2165	3035	3895	4773	5628	6492	7333	8194
CO (kg)	17	43	70	114	160	206	252	297	343	387	433
NOx (kg)	71	181	294	482	676	868	1063	1254	1446	1634	1825
Cost Effectiveness											
Delay Benefits ($)	68941	175130	285193	467682	655648	841548	1031247	1215837	1402534	1584306	1770213
Fuel Benefits ($)	13687	34769	56621	92851	130169	167077	204739	241387	278453	314541	351450
Total Benefits ($)	82628	209899	341814	560533	785817	1008626	1235986	1457224	1680987	1898847	2121663
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	1.5	3.8	6.1	10.1	14.1	18.1	22.2	26.1	30.1	34.0	38.0

Harding Yard – Zone 4

Figure 27. Savings and B/C Ratio for Harding Yard Zone 4

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	669	1575	2718	3878	5066	6241	7382	8476	9522	10593	11619
Fuel Consumption (gal)	1009	2376	4100	5850	7642	9415	11135	12786	14364	15979	17527
Emissions											
ROG (kg)	84	198	342	488	638	786	929	1067	1199	1334	1463
CO (kg)	4	10	18	26	34	42	49	56	63	70	77
NOx (kg)	19	44	76	109	142	175	207	238	267	297	326
Cost Effectiveness											
Delay Benefits ($)	18189	42848	73931	105493	137797	169766	200786	230555	259011	288135	316049
Fuel Benefits ($)	3611	8507	14678	20944	27358	33705	39863	45773	51423	57205	62747
Total Benefits ($)	21800	51355	88609	126437	165154	203471	240649	276328	310434	345341	378796
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	0.4	0.9	1.6	2.3	3.0	3.6	4.3	5.0	5.6	6.2	6.8

Harding Yard – Zone 5

Figure 28. Savings and B/C Ratio for Harding Yard Zone 5

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	1958	4295	7898	13125	19546	26683	33701	41594	49186	57822	65962
Fuel Consumption (gal)	2953	6479	11913	19798	29483	40249	50835	62742	74193	87221	99499
Emissions											
ROG (kg)	246	541	994	1652	2461	3359	4243	5237	6192	7280	8305
CO (kg)	13	29	53	87	130	177	224	277	327	385	439
NOx (kg)	55	120	221	368	548	748	945	1166	1379	1622	1850
Cost Effectiveness											
Delay Benefits ($)	53252	116833	214820	357007	531643	725779	916661	1131358	1337848	1572768	1794177
Fuel Benefits ($)	10572	23195	42649	70879	105550	144093	181990	224615	265610	312250	356208
Total Benefits ($)	63824	140028	257470	427885	637193	869872	1098650	1355972	1603458	1885018	2150385
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	**1.1**	**2.5**	**4.6**	**7.7**	**11.4**	**15.6**	**19.7**	**24.3**	**28.8**	**33.8**	**38.6**

Harding Yard – Zone 6

Figure 29. Savings and B/C Ratio for Harding Yard Zone 6

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	1961	4170	7656	12507	18749	25313	32173	39310	46716	54427	62451
Fuel Consumption (gal)	2958	6290	11549	18865	28281	38183	48530	59296	70467	82099	94203
Emissions											
ROG (kg)	247	525	964	1575	2360	3187	4050	4949	5881	6852	7863
CO (kg)	13	28	51	83	125	168	214	261	311	362	415
NOx (kg)	55	117	215	351	526	710	902	1102	1310	1526	1751
Cost Effectiveness											
Delay Benefits ($)	53335	113415	208253	340178	509972	688524	875093	1069229	1270666	1480406	1698671
Fuel Benefits ($)	10589	22517	41346	67537	101248	136696	173737	212280	252272	293913	337246
Total Benefits ($)	63923	135932	249598	407716	611219	825221	1048830	1281509	1522939	1774319	2035918
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	1.1	2.4	4.5	7.3	11.0	14.8	18.8	23.0	27.3	31.8	36.5

Harding Yard – Zone 7

Figure 30. Savings and B/C Ratio for Harding Yard Zone 7

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	264	555	1034	1671	2529	3381	4332	5244	6271	7241	8352
Fuel Consumption (gal)	399	837	1559	2520	3815	5100	6535	7911	9460	10923	12599
Emissions											
ROG (kg)	33	70	130	210	318	426	545	660	790	912	1052
CO (kg)	2	4	7	11	17	22	29	35	42	48	56
NOx (kg)	7	16	29	47	71	95	121	147	176	203	234
Cost Effectiveness											
Delay Benefits ($)	7187	15097	28113	45438	68796	91970	117831	142645	170581	196966	227181
Fuel Benefits ($)	1427	2997	5581	9021	13659	18259	23394	28320	33866	39105	45103
Total Benefits ($)	8613	18094	33694	54459	82455	110229	141225	170965	204447	236070	272284
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	0.2	0.4	0.7	1.1	1.7	2.3	3.0	3.6	4.3	5.0	5.7

Harding Yard – Zone 8

Figure 31. Savings and B/C Ratio for Harding Yard Zone 8

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	377	808	1469	2189	3340	4558	5786	7108	8422	9846	11228
Fuel Consumption (gal)	569	1219	2216	3301	5038	6875	8728	10722	12704	14851	16936
Emissions											
ROG (kg)	47	102	185	276	421	574	728	895	1060	1240	1414
CO (kg)	3	5	10	15	22	30	38	47	56	65	75
NOx (kg)	11	23	41	61	94	128	162	199	236	276	315
Cost Effectiveness											
Delay Benefits ($)	10255	21972	39958	59532	90848	123972	157380	193331	229088	267800	305396
Fuel Benefits ($)	2036	4362	7933	11819	18037	24613	31246	38383	45482	53168	60632
Total Benefits ($)	12291	26335	47891	71351	108885	148584	188626	231714	274570	320968	366028
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	0.2	0.5	0.9	1.3	2.0	2.7	3.4	4.2	4.9	5.8	6.6

Harding Yard – Zone 9

Figure 32. Savings and B/C Ratio for Harding Yard Zone 9

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	1105	1701	3504	5936	8383	11396	14388	17381	20374	23348	26286
Fuel Consumption (gal)	1666	2566	5286	8954	12645	17190	21704	26218	30733	35219	39650
Emissions											
ROG (kg)	139	214	441	747	1055	1435	1811	2188	2565	2940	3309
CO (kg)	7	11	23	39	56	76	96	116	136	155	175
NOx (kg)	31	48	98	166	235	320	404	487	571	655	737
Cost Effectiveness											
Delay Benefits ($)	30050	46266	95313	161455	228009	309977	391362	472767	554178	635068	714970
Fuel Benefits ($)	5966	9185	18923	32054	45268	61541	77699	93861	110024	126084	141947
Total Benefits ($)	36016	55452	114236	193509	273277	371519	469062	566628	664202	761152	856917
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	0.6	1.0	2.0	3.5	4.9	6.7	8.4	10.2	11.9	13.6	15.4

Harding Yard – Zone 10

Figure 33. Savings and B/C Ratio for Harding Yard Zone 10

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	343	715	1457	2214	3169	4143	5132	6130	7134	8145	9166
Fuel Consumption (gal)	517	1079	2197	3339	4781	6250	7742	9246	10761	12287	13826
Emissions											
ROG (kg)	43	90	183	279	399	522	646	772	898	1026	1154
CO (kg)	2	5	10	15	21	28	34	41	47	54	61
NOx (kg)	10	20	41	62	89	116	144	172	200	228	257
Cost Effectiveness											
Delay Benefits ($)	9322	19454	39619	60211	86210	112694	139604	166733	194035	221555	249306
Fuel Benefits ($)	1851	3862	7866	11954	17116	22374	27716	33102	38523	43987	49496
Total Benefits ($)	11173	23316	47485	72164	103325	135068	167320	199836	232557	265542	298802
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	0.2	0.4	0.9	1.3	1.9	2.4	3.0	3.6	4.2	4.8	5.4

Harding Yard – Zone 11

Figure 34. Savings and B/C Ratio for Harding Yard Zone 11

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	4407	11355	20745	32611	44636	56711	68829	81040	93296	105525	117769
Fuel Consumption (gal)	6647	17128	31293	49191	67330	85544	103824	122243	140729	159176	177646
Emissions											
ROG (kg)	555	1430	2612	4106	5620	7140	8666	10203	11746	13285	14827
CO (kg)	29	76	138	217	297	377	458	539	621	702	783
NOx (kg)	124	318	582	915	1252	1590	1930	2273	2616	2959	3303
Cost Effectiveness											
Delay Benefits ($)	119864	308851	564275	887007	1214097	1542537	1872150	2204297	2537640	2870274	3203324
Fuel Benefits ($)	23797	61318	112029	176102	241041	306248	371688	437631	503811	569851	635973
Total Benefits ($)	143661	370169	676304	1063109	1455139	1848785	2243839	2641928	3041451	3440125	3839297
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	2.6	6.6	12.1	19.1	26.1	33.1	40.2	47.4	54.5	61.7	68.8

Harding Yard – Zone 12

Figure 35. Savings and B/C Ratio for Harding Yard Zone 12

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	593	1233	2224	3266	4992	6775	8611	10499	12435	14417	16443
Fuel Consumption (gal)	895	1860	3354	4927	7530	10219	12989	15836	18757	21747	24803
Emissions											
ROG (kg)	75	155	280	411	628	853	1084	1322	1566	1815	2070
CO (kg)	4	8	15	22	33	45	57	70	83	96	109
NOx (kg)	17	35	62	92	140	190	241	294	349	404	461
Cost Effectiveness											
Delay Benefits ($)	16137	33542	60487	88844	135782	184273	234218	285562	338224	392134	447253
Fuel Benefits ($)	3204	6659	12009	17639	26957	36585	46501	56694	67150	77853	88796
Total Benefits ($)	19341	40202	72495	106483	162739	220858	280718	342256	405374	469987	536048
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	0.3	0.7	1.3	1.9	2.9	4.0	5.0	6.1	7.3	8.4	9.6

Cherry Hill Yard – Zone 1

Figure 36. Savings and B/C Ratio for Cherry Hill Yard Zone 1

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	407	1085	2057	3328	4679	6099	7585	9137	10748	12417	14144
Fuel Consumption (gal)	613	1637	3102	5020	7058	9200	11442	13782	16213	18731	21335
Emissions											
ROG (kg)	51	137	259	419	589	768	955	1150	1353	1563	1781
CO (kg)	3	7	14	22	31	41	50	61	71	83	94
NOx (kg)	11	30	58	93	131	171	213	256	301	348	397
Cost Effectiveness											
Delay Benefits ($)	11058	29510	55942	90522	127266	165901	206320	248517	292359	337753	384717
Fuel Benefits ($)	2189	5842	11106	17972	25267	32937	40962	49339	58044	67056	76380
Total Benefits ($)	13248	35353	67048	108494	152533	198838	247282	297856	350402	404809	461097
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	0.2	0.6	1.2	1.9	2.7	3.6	4.4	5.3	6.3	7.3	8.3

Cherry Hill Yard – Zone 2

Figure 37. Savings and B/C Ratio for Cherry Hill Yard Zone 2

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	3547	7378	13518	20018	30251	40723	51256	62033	72643	83515	94394
Fuel Consumption (gal)	5350	11130	20391	30195	45631	61427	77316	93572	109576	125976	142387
Emissions											
ROG (kg)	447	929	1702	2520	3809	5127	6453	7810	9146	10514	11884
CO (kg)	24	49	90	133	201	271	341	413	483	555	628
NOx (kg)	99	207	379	561	848	1142	1437	1740	2037	2342	2647
Cost Effectiveness											
Delay Benefits ($)	96469	200690	367693	544478	822814	1107662	1394162	1687299	1975878	2271601	2567527
Fuel Benefits ($)	19153	39844	73000	108098	163358	219910	276791	334989	392282	450993	509745
Total Benefits ($)	115622	240534	440694	652576	986171	1327572	1670953	2022287	2368160	2722595	3077272
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	2.1	4.3	7.9	11.7	17.7	23.8	30.0	36.3	42.5	48.8	55.2

Cherry Hill Yard – Zone 3

Figure 38. Savings and B/C Ratio for Cherry Hill Yard Zone 3

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	947	3021	6412	9966	14917	21023	27575	34090	41109	47990	55396
Fuel Consumption (gal)	1429	4557	9672	15032	22502	31711	41595	51422	62010	72389	83561
Emissions											
ROG (kg)	119	380	807	1255	1878	2647	3472	4292	5176	6042	6974
CO (kg)	6	20	43	66	99	140	183	227	273	319	368
NOx (kg)	27	85	180	279	418	590	773	956	1153	1346	1554
Cost Effectiveness											
Delay Benefits ($)	25766	82164	174404	271065	405753	571818	750035	927244	1118175	1305315	1506770
Fuel Benefits ($)	5116	16312	34625	53816	80556	113526	148909	184091	221997	259151	299147
Total Benefits ($)	30882	98476	209030	324881	486310	685344	898944	1111334	1340173	1564467	1805917
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	0.6	1.8	3.7	5.8	8.7	12.3	16.1	19.9	24.0	28.1	32.4

Cherry Hill Yard – Zone 4

Figure 39. Savings and B/C Ratio for Cherry Hill Yard Zone 4

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	904	1413	2898	4476	7057	9259	11949	14732	17494	20345	23155
Fuel Consumption (gal)	1364	2132	4371	6751	10646	13966	18025	22222	26388	30689	34928
Emissions											
ROG (kg)	114	178	365	563	889	1166	1504	1855	2202	2561	2915
CO (kg)	6	9	19	30	47	62	79	98	116	135	154
NOx (kg)	25	40	81	126	198	260	335	413	491	571	649
Cost Effectiveness											
Delay Benefits ($)	24595	38439	78815	121736	191962	251844	325020	400711	475833	553383	629816
Fuel Benefits ($)	4883	7632	15648	24169	38111	50000	64528	79555	94470	109866	125041
Total Benefits ($)	29478	46071	94462	145905	230073	301844	389548	480266	570303	663249	754857
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	0.5	0.8	1.7	2.6	4.1	5.4	7.0	8.6	10.2	11.9	13.5

Cherry Hill Yard – Zone 5

Figure 40. Savings and B/C Ratio for Cherry Hill Yard Zone 5

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	618	955	1949	2982	4703	6143	7944	9773	11624	13492	15378
Fuel Consumption (gal)	932	1440	2941	4498	7094	9266	11983	14742	17533	20352	23197
Emissions											
ROG (kg)	78	120	245	375	592	773	1000	1230	1463	1699	1936
CO (kg)	4	6	13	20	31	41	53	65	77	90	102
NOx (kg)	17	27	55	84	132	172	223	274	326	378	431
Cost Effectiveness											
Delay Benefits ($)	16803	25975	53024	81109	127918	167092	216081	265833	316160	366988	418284
Fuel Benefits ($)	3336	5157	10527	16103	25396	33174	42900	52777	62769	72860	83044
Total Benefits ($)	20138	31131	63552	97212	153314	200266	258981	318610	378929	439848	501328
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	0.4	0.6	1.1	1.7	2.7	3.6	4.6	5.7	6.8	7.9	9.0

Cherry Hill Yard – Zone 6

Figure 41. Savings and B/C Ratio for Cherry Hill Yard Zone 6

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	818	1743	2733	4699	6739	9783	12934	16183	20654	23377	28796
Fuel Consumption (gal)	1233	2630	4123	7088	10166	14756	19510	24410	31155	35263	43436
Emissions											
ROG (kg)	103	220	344	592	848	1232	1628	2037	2600	2943	3625
CO (kg)	5	12	18	31	45	65	86	108	137	155	192
NOx (kg)	23	49	77	132	189	274	363	454	579	656	808
Cost Effectiveness											
Delay Benefits ($)	22239	47423	74338	127812	183310	266085	351807	440169	561796	635865	783245
Fuel Benefits ($)	4415	9415	14759	25375	36393	52827	69846	87389	111536	126242	155502
Total Benefits ($)	26654	56838	89097	153187	219703	318913	421653	527558	673332	762107	938747
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	0.5	1.0	1.6	2.7	3.9	5.7	7.6	9.5	12.1	13.7	16.8

Cherry Hill Yard – Zone 7

Figure 42. Savings and B/C Ratio for Cherry Hill Yard Zone 7

	Mean Clearance Time w/o SSP (min)										
	10	15	20	25	30	35	40	45	50	55	60
Savings-Performance Measures											
Delay (veh-hrs)	958	2489	4680	7440	10446	13459	16789	20046	23674	27138	31023
Fuel Consumption (gal)	1445	3755	7060	11223	15757	20302	25325	30238	35710	40936	46795
Emissions											
ROG (kg)	121	313	589	937	1315	1695	2114	2524	2980	3417	3906
CO (kg)	6	17	31	49	69	90	112	133	157	181	206
NOx (kg)	27	70	131	209	293	377	471	562	664	761	870
Cost Effectiveness											
Delay Benefits ($)	26059	67704	127303	202372	284138	366090	456660	545246	643923	738158	843815
Fuel Benefits ($)	5174	13442	25274	40178	56411	72682	90663	108251	127842	146550	167527
Total Benefits ($)	31232	81145	152577	242550	340549	438772	547323	653496	771765	884708	1011343
Driver Cost of the SSP Service ($)	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772	55772
B/C Ratio	0.6	1.5	2.7	4.3	6.1	7.9	9.8	11.7	13.8	15.9	18.1