Performance Evaluation and Benefit Analysis for CHART

– Coordinated Highways Action Response Team –

in
Year 2012

(Final report)

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Performance Evaluation of CHART

- The Real-Time Incident Management System (Year 2012)

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EXECUTIVE SUMMARY

- **Objectives**

This report presents the performance evaluation study of the Coordinated Highways Action Response Team (CHART) for the Year 2012, including its operational efficiency and resulting benefits. The research team at the Civil Engineering Department of the University of Maryland, College Park (UM), has conducted the annual CHART performance analysis over the past fourteen years for the Maryland State Highway Administration (MSHA).

Similar to previous studies, the focus of this task was to evaluate the effectiveness of Maryland CHART's ability to detect and manage incidents on major freeways and highways. Assessing the benefits resulting from incident management was equally essential. In addition, this annual report has extended the analysis of incident duration distributions on major highways for better understanding of the incident characteristics and management.

The study consisted of two phases. Phase 1 focused on defining objectives, identifying the available data, and developing the methodology. The core of the second phase involved assessing the efficiency of the incident management program and estimating the resulting benefits using the 2012 CHART incident operations data. As some information essential for efficiency and benefit assessment was not available in the CHART-II database, this study presents only those evaluation results that can be directly computed from the incident management data or derived with statistical methods.

- **Available Data for Analysis**

Upon a request made by MSHA, COSMIS began evaluating CHART operations performance in 1996. During the initial evaluation, the 1994 incident management data from the Traffic Operations Center (TOC) were reviewed but for various reasons were not used. Thus, the conclusions drawn were based mostly on information either from other states or from nationwide averaged data published by the Federal Highway Administration.

To ensure better evaluation quality and also in view of the Statewide Operations Center (SOC) having opened in August of 1995, those associated with the evaluation study concluded that the analysis should be based on *actual performance data from the CHART program*. Hence, in 1996, the UM (Chang and Point-Du-Jour, 1998) was contracted to work jointly with MSHA staff to collect, and subsequently to analyze incident management data.

This original study and evaluation analysis inevitably faced the difficulty of having insufficient information for analysis, since this was the first time CHART had to collect all previous performance records for a scrupulous evaluation.

The 1997 CHART performance evaluation had the advantage of having relatively substantial information. The collected information comprised incident management records from the Statewide Operations Center (SOC), TOC-3 (positioned in the proximity of the Capital Beltway), and TOC-4 (sited near the Baltimore Beltway) over the entire year, as well as 1997 Accident Report Data from the Maryland State Police (MSP) for secondary incident analysis.

Unlike previous studies, the quality and quantity of data available for performance evaluation has increased considerably since 1999. This results from CHART realizing the need to keep an extensive operational record in order to justify its costs and to evaluate the benefits of the emergency response operations. Due to CHART's efficient data collection, documentation of lane-closure-related incidents increased from 2,567 in 1997 to 22,328 in 2012.

The table below shows the total number of emergency response operations that have been assiduously documented from 2006 to 2012:

Summary of Total Number of Emergency Responses from 2006 to 2012

	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Incidents only	21,055	21,236	21,586	23,585	19,309	22,534	22,328
Total *	44,043	42,321	56,200	55,563	49,008	60,105	63,571

* *Total* includes incidents and disabled vehicles (assistance to drivers)

It should be noticed that CHART may have responded to more emergency service requests than those reported in the database. This may be due to insufficient recording of incidents by control center operators, which should be tackled with the implementation of the upgraded CHART information system.

- **Evolution of the Evaluation Work**

CHART has consistently worked to improve its data recording for both major and minor incidents over the past fourteen years, which accounts for the substantial improvements in data quality and quantity. The evaluation work has also been advanced by the improved availability of data. It has also become imperative to assess the quality of data used and to use only reliable data in the benefit analysis. Thus, from 1999, the performance evaluation reports have included data quality analysis. This aims at ensuring continued advancement in the quality of incident-related data so as to reliably estimate all potential benefits of CHART operations.

From February 2001, all incident requests for emergency assistance have been recorded in the CHART-II information system, whether CHART responded or not, and this has significantly enriched the available data. In the current CHART database system, most incident-related data can be generated directly for computer processing, except that incident-location-related information remains documented in a text format that cannot be processed automatically with a data analysis program.

- **Distribution of Incidents**

The evaluation methodology was created to use all available data sets that are considered to be of acceptable quality. An analysis of incident characteristics by incident duration and number of blocked lanes was initially conducted.

The analysis results indicate that a total of 2,514 severe incidents in Year 2012 occurred that resulted in one-lane blockage, 3,424 severe incidents caused two-lane closures, and 2,225 severe incidents blocked more than two lanes. In addition, either disabled vehicles or minor incidents caused a total of 43,728 shoulder blockages. A comparison of lane-blockage incident/disabled vehicles data over the past seven years is summarized below:

List[1] of Incidents/Disabled vehicles by Lane Blockage Type from 2006 to 2012

	2006	2007	2008	2009	2010	2011	2012
Shoulder[2]	25,631	23,904	36,861	35,069	31,322	40,290	43,728
1 lane	2,989	2,937	3,032	3,474	2,023	2,881	2,514
2 lanes[3]	3,659	3,824	3,579	4,106	2,167	3,745	3,424
3 lanes[3]	1,245	1,331	1,238	1,486	711	1,322	1,215
≥ 4 lanes[3]	1,303	1,356	1,185	1,326	578	1,065	1,010

* Note: 1. This analysis is based only on the samples with complete information for the lane blockage status.
2. *Shoulder Lane Blockages* include those events of having disabled vehicles (assistance to drivers)
3. A shoulder lane blockage is counted as one lane blockage (e.g., 2-lane blockage can either be two travel lanes or one travel lane and one shoulder blockage).

Most of those incidents/disabled vehicles were distributed along six major commuting corridors: I-495/95, which experienced a total of 5,383 incidents/disabled vehicles in 2012; I-695, I-95, US-50, I/MD-295, and I-270 with 8,345, 19,594, 5,209, 3,315, and 3,261 incidents/disabled vehicles, respectively. CHART managed an average of 54 emergency requests per day on I-95 alone, and 15, 23, 14, 9, and 9 responses per day for I-495/95, I-695, US-50, I/MD-295, and I-270, respectively. The distribution of incidents/disabled vehicles on those major commuting corridors between 2006 and 2012 is tabulated below:

Summary* of Incidents/Disabled vehicles Distribution on Major Freeway Corridors

	2006	2007	2008	2009	2010	2011	2012
I-495/95	7,881	7,667	6,147	6,929	5,362	5,702	5,383
I-695	10,009	7,592	7,359	7,159	6,294	8,088	8,345
I-270	1,536	2,168	2,417	2,865	2,378	3,059	3,261
I-95	4,024	4,804	17,794	16,472	17,551	19,411	19,594
US-50	4,273	5,197	5,343	3,214	4,600	5,069	5,209
I/MD-295	1,417	1,418	2,239	1,570	1,441	1,815	3,315

* This analysis is based on incidents and disabled vehicles (assistance to drivers) which have recorded the event location.

However, it should be mentioned that most incidents/disabled vehicles on the major commuting freeways did not block traffic for more than one hour. For instance, the ratio of incidents/disabled vehicles that had durations shorter than 30 minutes was about 84 percent in 2012. This observation can be attributed to the nature of the incidents and, more probably, to the efficient response of CHART. The distribution of incidents/disabled vehicle duration from 2006 to 2012 is summarized below:

Distribution* of Incidents/Disabled Vehicle Duration from 2006 to 2012

Duration(Hrs)	2006	2007	2008	2009	2010	2011	2012
D < 0.5	80%	78%	83%	81%	83%	83%	84%
0.5 ≤ D < 1	11%	13%	10%	11%	11%	9%	9%
1 ≤ D < 2	4%	5%	4%	5%	4%	5%	4%
2 ≤ D	5%	4%	3%	3%	3%	3%	3%

* This analysis is based on incidents and disabled vehicles (assistance to drivers) which have complete information for the event duration.

In brief, it is apparent that the highway networks served by CHART remain plagued by a high frequency of incidents with durations ranging from 10 to over 120 minutes. Those incidents were one of the primary contributors to traffic congestion in the entire region, especially on the major commuting highway corridors, such as I-95, I-270, I-495/95, and I-695.

- **Efficiency of Operations**

Detection, response and traffic recovery are the three vital features associated with the efficiency of an incident management program. Unfortunately, data needed for the execution of detection and response time analysis are not yet available under the CHART data system. MSHA patrols and MSP remain the main sources of incident detection and response data.

The average response time is the average time elapsing from the receiving of an emergency request to the arrival of the emergency response unit. The table below shows the average response times of 12.22, 12.67, 5.64, 16.40, 12.87, 6.72 and 6.43 minutes for TOC-

3, TOC-4, TOC-5, TOC-6, TOC-7, SOC and AOC, respectively, in 2012 data. Please note that incidents/disabled vehicles included in this analysis are responded by various units including CHART and non-CHART agencies:

Evolution of Response Times* by Center from 2008 to 2012

Response Time (mins)	2008	2009	2010	2011	2012		
					During OH	After OH	Overall
TOC-3	11.44	11.41	11.43	11.70	12.18 (4,072)	15.19 (49)	12.22 (4,121)
TOC-4	14.56	14.41	14.38	12.83	12.69 (3,578)	7.57 (19)	12.67 (3,597)
TOC-5	5.72	3.50	N/A	2.67	5.99 (13)	5.44 (23)	5.64 (36)
TOC-6	4.25	7.87	5.94	4.43	17.93 (10)	1.12 (1)	16.40 (11)
TOC-7	11.99	12.83	12.23	12.17	12.84 (1,429)	14.55 (24)	12.87 (1,453)
SOC	9.11	6.04	7.01	6.73	6.17 (1,951)	7.91 (921)	6.72 (2,872)
AOC	5.19	5.81	6.41	6.55	6.54 (2,785)	6.18 (1,303)	6.43 (4,088)
OTHER	7.36	4.60	5.23	4.42	4.81 (11)	6.62 (31)	6.15 (42)
Weighted Average	**9.99**	**9.91**	**10.15**	**9.87**	**10.39 (13,849)**	**7.13 (2,371)**	**9.92 (16,220)**

* Note: 1. This analysis is based on the data of incidents and disabled vehicles (assistance to drivers) which have indicated the responsible operation center and response times.
2. This analysis includes those sample data which have response times between 1 minute and 60 minutes.
3. Events included in this analysis were responded by various units including CHART, fire boards, state/local polices, private towing companies, etc.
4. OH stands for Operational Hours, 5 a.m. – 9 p.m. Monday through Friday.
5. The number in each parenthesis indicates the available samples with acceptable quality for analysis.
6. TOC-5 and TOC-6 operate on the seasonal basis.

CHART currently operates during 5 a.m. – 9 p.m. Monday through Friday. The table below presents that incidents are likely to be responded more prompt than disabled vehicles during operational hours:

Comparisons* of CHART Response Performance during and after Operational Hours

Response Time (mins)	Operational Hours		Non-operational Hours		Total		
	Inciden t	Disabled Vehicle	Inciden t	Disabled Vehicle	Incident	Disabled Vehicle	Sub-total
TOC-3	12.96 (2,759)	13.71 (1,282)	15.59 (48)	21.08 (4)	13.01 (2,807)	13.73 (1,286)	13.24 (4,093)
TOC-4	12.35 (1,921)	13.76 (1,777)	8.01 (15)	7.07 (5)	12.32 (1,936)	13.74 (1,782)	13.00 (3,718)
TOC-5	7.61 (10)	6.94 (3)	5.93 (15)	6.91 (9)	6.60 (25)	6.92 (12)	6.70 (37)
TOC-6	32.13 (6)	-	1.28 (1)	-	27.72 (7)	-	27.72 (7)
TOC-7	12.91 (1,070)	16.53 (331)	12.19 (14)	25.38 (5)	12.91 (1,084)	16.67 (336)	13.80 (1,420)
SOC	11.00 (835)	5.90 (910)	17.51 (507)	9.97 (189)	13.46 (1,342)	6.60 (1,099)	10.37 (2,441)
AOC	7.89 (999)	11.22 (768)	7.38 (519)	10.24 (373)	7.71 (1,518)	10.90 (1,141)	9.08 (2,659)
OTHER	7.19 (8)	3.18 (3)	7.26 (19)	6.44 (14)	7.24 (27)	5.86 (17)	6.70 (44)
Weighte d Average	**11.92 (7,608)**	**12.12 (5,074)**	**12.28 (1,138)**	**10.19 (599)**	**11.97 (8,746)**	**11.92 (5,673)**	**11.95 (14,419)**

* Note: 1. This analysis is based on the dataset of incidents and disabled vehicles (assistance to drivers) which have indicated responsible operation center and response times.
2. This analysis includes those sample data which have response times between 1 minute and 60 minutes.
3. Events included in this analysis were responded by CHART
4. Operational Hours are 5 a.m. – 9 p.m. Monday through Friday.
5. The number in each parenthesis indicates the data availability.
6. TOC-5 and TOC-6 operate on the seasonal basis.

Also, 2012 data show that the CHART response operations are more prompt when incidents are more severe and cause lane blockages. On the other hand, for the severe incidents such as a fatality or heavy vehicle-involved incidents, the clearance times become longer. The weather turns out to be another significant factor affecting the CHART incident management performance. In inclement weather, the response times by CHART are likely to be shorter, whereas the clearance times are longer.

To better understand the contribution of the incident management program, the study compared the average duration of incidents to which CHART responded and those managed by other agencies. For example, for one-lane-blockage incidents to which the SHA Patrol did not respond, the average incident duration was about 6.53 minutes more than the ones to which they responded.

The duration of incidents managed by CHART response units averaged 21.95 minutes, shorter than the average duration of 28.95 minutes for those incidents managed by other agencies. On average, CHART operations in Year 2012 reduced the average incident duration by about 24 percent.

Performance improvement of CHART operations from years 2006 to 2012 is summarized below:

Comparison of Average Incident Duration* with and without CHART Response

Year	With CHART (mins)	Without CHART (mins)
2006	22.89	32.45
2007	25.06	35.15
2008	24.95	34.56
2009	28.35	41.12
2010	27.60	47.06
2011	22.14	29.44
2012	21.95	28.95

* This analysis is based on incidents which have included the information of event duration, lane blockage, and response units.

- **Analysis of Incident Durations**

For effective and efficient traffic management after incidents, responsible agencies can convey the information to travelers by updating the variable message signs; they can also estimate the resulting queue length and assess the need to implement detour operations and any other control strategies to mitigate congestion. To maximize the effectiveness of these operational strategies, reliably predicted/estimated incident durations will certainly play an essential role.

This study conducted a statistical analysis of incident durations, which provides fundamental insight into the characteristics of incident durations under various conditions. In this analysis, the distributions of average incident duration are identified by a range of categories, including Nature, County, County and Nature, Weekdays and Weekends, Peak and Off-Peak Hours, CHART Involvement, and Roads.

The average duration of incidents involving fatalities was 78.48 minutes, while incidents with property damage and personal injuries lasted, on average, 27 and 40 minutes, respectively. The average duration of disabled vehicle incidents was 18 minutes, shorter than that of any other incident natures (e.g., debris, vehicles on fire, police activities, etc.), the average incident duration of which turned out to be approximately 23 minutes.

- **Resulting Benefits**

The benefits attributed to CHART operations that were estimated directly from the available data include assistance to drivers and reductions in driver delay times, fuel consumption, emissions, and secondary incidents. CHART responded to a total of 22,328 lane blockage incidents in 2012 and assisted 41,243 highway drivers who may otherwise have caused incidents or rubbernecking delays to highway traffic. CHART's contribution to shortening incident duration also reduced potential secondary incidents by 218. In addition, efficient removal of stationary vehicles and large debris from travel lanes by CHART patrol units may have prevented 429 potential lane-changing-related collisions in 2012, as approaching vehicles under those conditions would have been forced to perform unsafe mandatory lane changes.

CORSIM, a traffic simulation program produced by the Federal Highway Administration (FHWA), was used to estimate the direct benefits of reductions in delay time, and it was discovered that various factors, including traffic and heavy vehicle volumes, the number of lane closures, the number of incident responses, and incident durations, affect the delay. Analysis determined that CHART's services in 2012 reduced delays by 28.47 million vehicle-hours, as well as reducing fuel consumption by 5.79 million gallons. A comparison of direct benefits from reductions in delay time, fuel consumptions, and emissions, from 2006 to 2012, is summarized below:

Comparison of Direct Benefits from 2006 to 2012

	Total Direct Benefits (million)[1,2,3,4]	# of Incidents Eligible for the Benefit Estimate[5]
2006	$1,092.35	21,055
2007	$1,118.55	21,236
2008	$981.06	21,586
2009	$1,006.50	23,585
2010	$1,375.52	18,045
2011	$1,096.61	20,547
2012	$961.69[5]	19,920

* Note: 1. Results are based on the data of the corresponding year from the U.S Census Bureau and Energy Information Administration.
2. The direct benefits represent reductions from delay time, fuel consumptions, and emissions due to the CHART effective operations.
3. The direct benefits rely on numerous factors (i.e., traffic and heavy vehicle volumes, the number of lane blockages, the number of incidents responded, and incident durations).
4. The direct benefits are estimated based on the car delay reduction occurring over all roads covered by CHART and the truck delay reduction only occurring along major roads.
5. The direct benefits are estimated only based on the incidents causing travel lane closure(s).

- **Conclusions and Recommendations**

Building from the earlier research, this study has conducted a rigorous evaluation of CHART's performance in 2012 and its resulting benefits under the constraints of data availability and quality. Overall, CHART has made significant progress in recording more reliable incident reports, especially after implementation of the CHART-II Database.

However, much remains to be done in terms of collecting more data and extending operations to major local arterials, if resources are available to do so. For example, data regarding the potential impacts of major incidents on local streets have not been collected by CHART. Without such information, one may substantially underestimate the benefits of CHART operations, as most incidents causing lane blockages on major commuting freeways are likely to spill congestion back to neighboring local arterials if traffic queues form more quickly than incidents are cleared. Similarly, a failure to respond to major accidents on local arterials, such as MD-355, may also significantly degrade traffic conditions on I-270. Effectively coordinating with county agencies on both incident management and operational data collection is one of CHART's major tasks.

With respect to performance, CHART has maintained nearly the same level of efficiency in responding to incidents and driver assistance requests in recent years. The average response time in Year 2012 was 9.92 minutes. In view of the worsening congestion and the increasing number of incidents in the Washington-Baltimore region, it is commendable that CHART can maintain its performance efficiency with approximately the same level of resources.

This study's main recommendations, based on the performance of CHART in 2012, are listed below:

- Allocate more resources to CHART for incident response and traffic management to improve the performance of the response teams so that they can effectively contend with the ever-increasing congestion and accompanying incidents.
- Coordinate with county traffic agencies to extend CHART operations to major local routes and include data collection as well as performance benefits in the annual CHART review.
- Make CHART's quality evaluation report available to the operators for continuous improvement of their response operations.
- Implement training sessions to educate operators on how to effectively record critical performance-related data.
- Improve the data structure used in the CHART-II system for recording incident locations to eliminate the current laborious and complex procedures.
- Reduce the average response time by increasing freeway service patrols and assigning patrol locations based on both the spatial distribution of incidents along freeway segments and the probability of an incident occurring.

- Integrate police accident data efficiently with the CHART-II incident response database to have a complete representation of statewide incident records.
- Incorporate the delay and fuel consumption benefits from the reduced potential secondary incidents in the CHART benefit evaluation.

Please note that comprehensive evaluation results of CHART performance over the past six years are available on the website (http://chartinput.umd.edu).

CHAPTER 1

INTRODUCTION

CHART (Coordinated Highways Action Response Team) is the highway incident management system of the Maryland State Highway Administration (MSHA). Initiated in the mid-80s as "The Reach the Beach Program," it was subsequently expanded as a statewide program. The Statewide Operations Center (SOC), an integrated traffic control center for the state of Maryland, has its headquarters in Hanover, Maryland. The SOC is supported by four satellite Traffic Operations Centers (TOCs), of which one is seasonal. CHART's current network coverage consists of statewide freeways and major arterials.

CHART has five major functions: traffic monitoring, incident response, traveler information, traffic management, and severe weather and emergency operations. Incident response and traveler information systems have received increasing attention from the general public, media, and transportation experts.

In 1996, incident data were collected and used in the pilot evaluation analysis conducted by the University of Maryland in conjunction with MSHA staff (Chang and Point-Du-Jour, 1998). As this was the first time that previous records were to be analyzed, researchers were inevitably faced with the difficulty of having a database with insufficient information.

The 1997 CHART performance evaluation was far more extensive. The researchers were able to obtain a relatively richer set of data, obtained from incident management reports gathered over twelve months from the SOC, TOC-3 (located near the Capital Beltway), and TOC-4 (situated near the Baltimore Beltway). In addition to these data, accident reports from the Maryland State Police (MSP) were also available for secondary incident analysis.

The data used for the evaluations have improved incredibly since 1999 because CHART recognized the need to keep an extensive operational record in order to justify the costs and to evaluate the benefits of the emergency response operation. The data available for analysis of lane closure incidents increased from 5,000 reports in 1999 to 22,328 reports in 2012. A summary of total emergency response operations documented from 2005 to 2012 is presented in Table 1.1.

Table 1.1 Total Number of Emergency Response Operations

Records	2005	2006	2007	2008	2009	2010	2011	2012
Incidents	20,515	21,055	21,236	21,586	23,585	19,309	22,534	22,328
Disabled Vehicles	20,681	22,988	21,085	34,614	31,978	29,699	37,571	41,243
Total	41,196	44,043	42,321	56,200	55,563	49,008	60,105	63,571

The objective of this study is to evaluate the effectiveness of CHART's incident detection, response, and traffic management operations on interstate freeways and major arterials. This assessment also includes an estimation of CHART benefits, an essential part of the study, since support of MSHA programs from the general public and state policymakers largely depends on the benefits the state obtains from its ongoing programs. In order to conduct a comprehensive analysis using available data to ensure the reliability of the evaluation results, the evaluation study has been divided into the following three principal tasks:

Task 1: Assessment of Data Sources and Data Quality — involves identifying data sources, evaluating their quality, analyzing available data, and classifying missing parameters.

Task 2: Statistical Analysis and Comparison — entails performing comparisons based on data available in 2011 and 2012, with an emphasis on these target areas: incident characteristics, efficiency of incident detection, distribution of detection sources, efficiency of incident response, and effectiveness of incident traffic management.

Task 3: Benefits Analysis — entails the analysis of the reduction in total delay times, fuel consumption, emissions, and secondary incidents due to CHART/SHA operations, as well as the reduction in potential accidents due to efficient removal of stationary vehicles in travel lanes by the CHART/SHA response team.

The subsequent chapters are structured as follows:

Chapter 2 assesses the quality of data available for the 2012 CHART performance evaluation. This includes the total available incident reports, the percentage of missing data for each critical performance parameter, and a comparison of 2012 data quality with that of 2011.

Chapter 3 outlines the statistical analysis of incident data characteristics, such as distributions of incidents and disabled vehicles by road name, by location on road, by weekday and weekend, by lane-blockage type, and by lane-blockage duration. The analysis also includes a comparison of the average incident duration caused by different types of incidents.

Chapter 4 provides a detailed report on the efficiency and effectiveness of incident detection. Issues discussed are the detection rate, the distribution of detection sources for various types of incidents, and driver requests for assistance. The chapter also touches on an evaluation of incident response efficiency. The efficiency rate is based on the difference between the incident report time and the arrival time of emergency response units. Also, the assessment of incident clearance efficiency is based on the difference between the arrival time of the emergency response units and the incident clearance time.

Chapter 5 discusses a statistical analysis of response times, which provides fundamental insight into the characteristics of response times under various conditions. In this analysis, the distributions of the average response time are identified by a range of categories, including the time of day, the incident nature, the pavement conditions, the lane blockage status, the involvement of heavy vehicles, and the involved regions.

Chapter 6 performs a statistical analysis of incident durations, similar to Chapter 5. In this analysis, the distributions of the average incident duration are identified by a range of categories, including nature, county, county and nature, weekdays and weekends, peak and off-peak hours, CHART Involvement, pavement conditions, the involvement of heavy vehicles, and the roads.

Chapter 7 estimates the direct benefits associated with CHART's operations. Parameters used for the estimates are the reductions in fuel consumption, delays, emissions, secondary incidents, and potential accidents. CHART patrol units also respond to a significant number of driver assistance requests, and these services provide direct benefits to drivers and minimize potential rubbernecking delays on highways.

Finally, Chapter 8 offers concluding comments and recommendations for future evaluations.

CHAPTER 2
DATA QUALITY ASSESSMENT

This chapter assesses the quality of data available for the CHART 2012 performance evaluation and compares it with the data from CHART 2011.

2.1 Analysis of Data Availability

In 2012, CHART recorded a total of 63,571 emergency response cases. These are categorized into two groups: incidents and disabled vehicles. A summary of the total available incident reports for the years 2010, 2011 and 2012 is shown in Table 2.1.

Table 2.1 Comparison of Available Data for 2010, 2011, and 2012

Available Records		**2010**		**2011**		**2012**	
		Records	Total (%)	Records	Total (%)	Records	Total (%)
CHART II Database	Disabled Vehicles	29,699	60.6	37,571	62.5	41,243	64.9
	Incidents	19,309	39.4	22,534	37.5	22,328	35.1
Total		49,008	100	60,105	100	63,571	100

2.2 Analysis of Data Quality

More than 10 million records in 24 tables from the CHART II database have been filtered to obtain key statistics for a detailed evaluation of the data quality. Figures 2.1 and 2.2 illustrate the comparison of the quality of data recorded in 2011 and 2012.

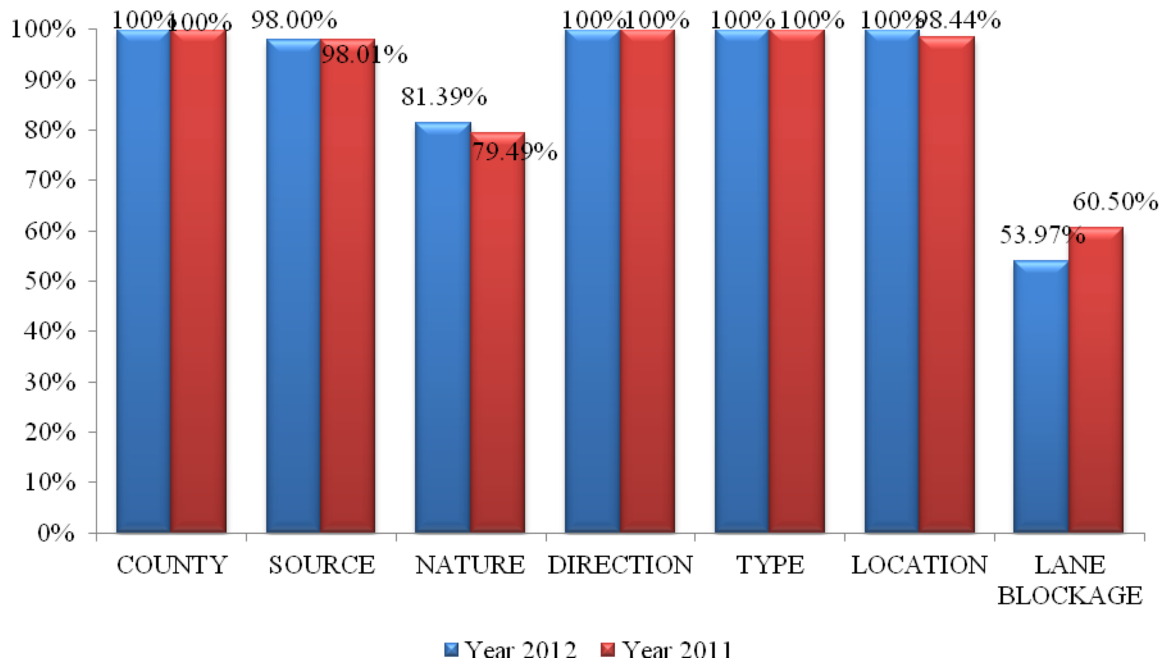


Figure 2.1 Summary of Data Quality for Critical Indicators

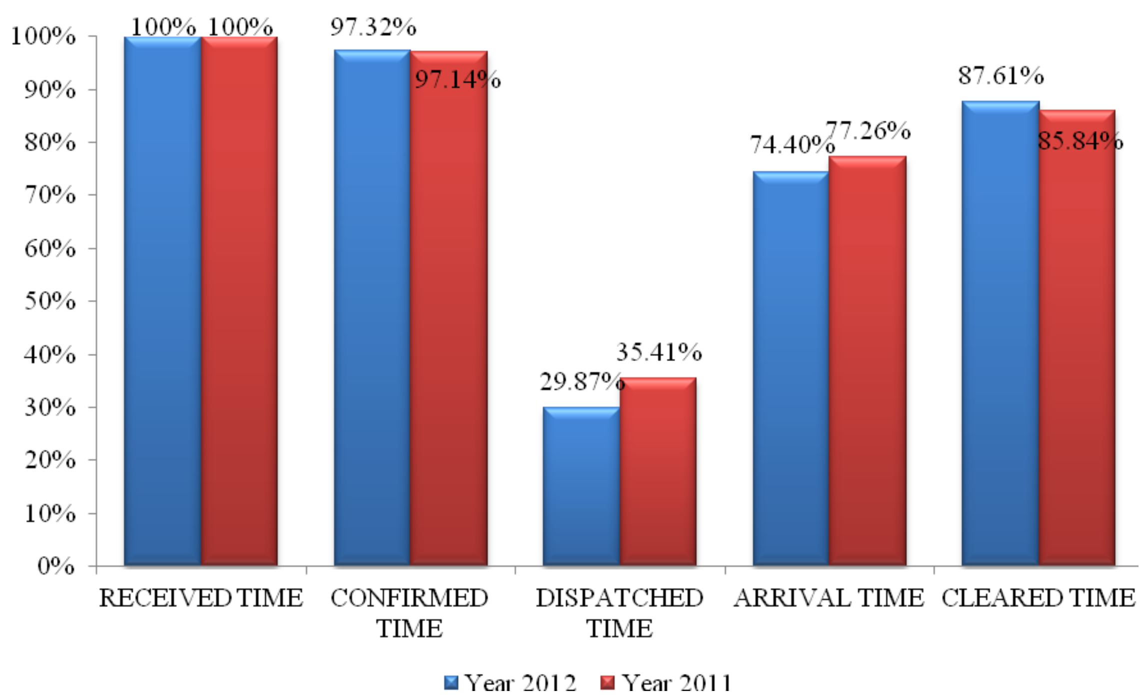


Figure 2.2 Summary of Data Quality for Time Indicators

Nature of Incidents/Disabled Vehicles

Data were classified based on the nature of the incidents, such as vehicle on fire, collision-personal injury, and collision-fatality. CHART's records for disabled vehicles are also categorized as abandoned vehicles, tire changes, and gas shortage. As shown in Figure 2.1, about 80 percent of emergency responses reported in 2012 recorded the nature of incidents.

Detection Sources

As Figure 2.1 shows, about 98 percent of all emergency responses recorded in 2012 contained the source of detection, which is almost the same as the previous year's data. In 2012, about 95.42 percent of incidents reported and 99.40 percent of the disabled vehicles reported had a definite detection source.

Operational Time-Related Information

To evaluate the efficiency and effectiveness of emergency response operations, CHART in 2012 used five time parameters for performance measurements: "Received Time," "Dispatched Time," "Arrival Time," "Cleared Time," and "Confirmed Time." Figure 2.2 illustrates the data quality analysis with respect to these performance parameters. The figure indicates that the quality of data for "Received Time" and "Confirmed Time" is sufficient for reliable analysis, while the data of "Dispatched Time," "Arrival Time," and "Cleared Time" still require improvement for reliable analysis.

Type of Reports

The total number of incidents/disabled vehicles managed by each operation center in 2012 is summarized in Table 2.2. Overall, CHART responded to a total of 22,328 incidents in 2012. Over the same period, the response team also attended to 41,243 disabled vehicle requests.

Table 2.2 Emergency Assistance Reported in 2012

Operation Center	TOC3	TOC4	SOC	TOC6	TOC7	AOC	OTHER	TOTAL
Disabled Vehicles	6,147	10,757	6,959	6	3,124	4,172	10,078	41,243 (37,571)
Incidents	5,466	3,873	4,928	103	2,229	4,625	1,104	22,328 (22,534)
Total	11,613	14,630	11,887	109	5,353	8,797	11,182	63,571 (60,105)

Note: numbers in each parenthesis are the corresponding data from 2011

Location and Road Name Associated with Each Response Operation

The location and road name information associated with each emergency response operation was used to analyze the spatial distribution of incidents/disabled vehicles and to identify freeway segments that experience frequent incidents. As shown in Figure 2.1, all incident response reports have documented location information. This feature has always been properly recorded over the years. However, the location information associated with each response operation is structured in a descriptive text format that cannot be processed automatically with a computer program. Hence, road names and highway segments must be manually located and entered into the evaluation system.

Table 2.3 shows the percentage of data with valid road names and highway segment location information (i.e., exit numbers) for incidents and disabled vehicles in the CHART II Database for 2012. Note that road names can be identified for 99.95 percent of incidents in which the database specifies the highway segments where the incidents occurred. For the remaining 0.05 percent of incidents, the location information is either unclear or not specified, and therefore cannot be used for reliable performance analysis.

Table 2.3 Data Quality Analysis with Respect to Road and Location

Data Quality	Incident	Disabled Vehicles	Total
Road	99.29%	99.78%	99.61%
Location	99.94%	99.95%	99.95%

Lane/Shoulder Blockage Information

To compute additional delays and fuel consumption costs caused by each incident requires knowing the number of lanes (including shoulder lanes) blocked as a result of the incident. The analysis of all available data in 2012 shows that up to 53.97 percent of emergency response reports involved lane/shoulder blockage. This value is slightly lower than the 60.50 percent in 2011.

In summary, in 2012, improvements have been made in documenting CHART's performance and recording operations-related information. The use of the CHART II Database has had a noticeable positive impact on data quality improvement, but room for improvement still exists, as shown in the above statistics on evaluating data quality. Finally, CHART operators should be made aware of their contribution to mitigation of traffic congestion, driver assistance, and overall improvement of the driving environment.

CHAPTER 3

ANALYSIS OF DATA CHARACTERISTICS

The evaluation study began with a comprehensive analysis of the spatial distribution of incidents/disabled vehicles and their key characteristics to improve the efficiency of incident management.

3.1 Distribution of Incidents and Disabled Vehicles by Day and Time

The research team analyzed the differences between the distribution of incidents/disabled vehicles during weekdays and weekends. As shown in Table 3.1, a large number (about 87 percent) of incidents/disabled vehicles in 2012 occurred on weekdays. Thus, more resources and personnel are required on weekdays than on weekends to manage the incidents/disabled vehicles more effectively.

Table 3.1 Distribution of Incidents/Disabled Vehicles by Day

Center	TOC3		TOC4		TOC5		TOC6		TOC7	
Year	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011
Weekdays	99%	99%	100%	100%	19%	3%	99%	100%	99%	99%
Weekends	1%	1%	0%	0%	81%	97%	1%	0%	1%	1%

Center	SOC		AOC		Other*		Total	
Year	2012	2011	2012	2011	2012	2011	2012	2011
Weekdays	78%	55%	75%	74%	19%	27%	87%	85%
Weekends	22%	45%	25%	26%	81%	73%	13%	15%

* Includes RAVENS TOC and REDSKINS TOC

As defined by the 1999 CHART performance evaluation, peak hours in this study are from 7:00 a.m. to 9:30 a.m. and from 4:00 p.m. to 6:30 p.m. Table 3.2

illustrates that 35 percent of incidents/disabled vehicles reported in 2012 occurred during peak hours, which is slightly higher than the one in 2011.

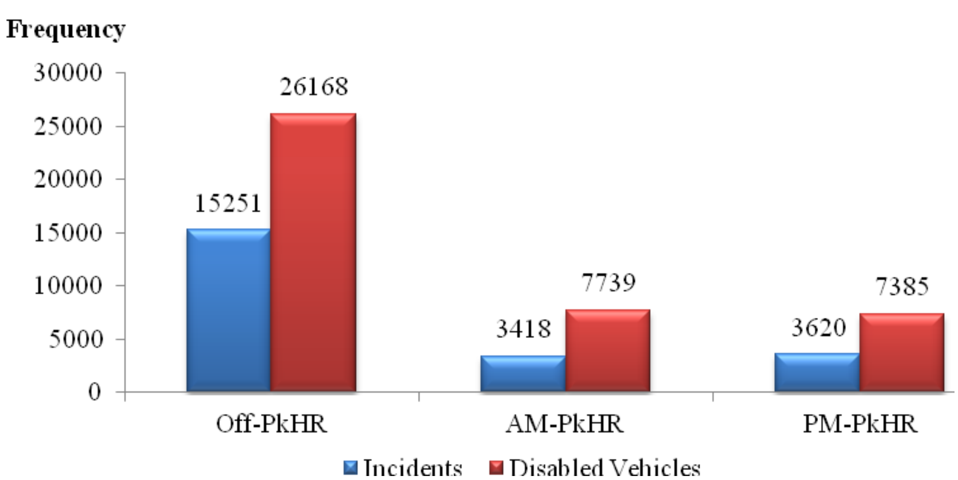
Table 3.2 Distribution of Incidents/Disabled Vehicles by Peak and Off-Peak Periods

Center	TOC3		TOC4		TOC5		TOC6		TOC7	
Year	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011
Peak**	37%	38%	47%	45%	8%	1%	23%	25%	48%	46%
Off-Peak	63%	62%	53%	55%	92%	99%	77%	75%	52%	54%

Center	SOC		AOC		Other*		Total	
Year	2012	2011	2012	2011	2012	2011	2012	2011
Peak**	29%	18%	26%	26%	1%	6%	35%	34%
Off-Peak	71%	82%	74%	74%	99%	94%	65%	66%

* Includes RAVENS TOC and REDSKINS TOC

** 7:00 a.m. ~ 9:30 a.m.and 4:00 p.m. ~ 6:30 p.m.



* Off-PkHR, AM-PkHR, and PM-PkHR stand for Off-Peak hours, AM-Peak hours, and PM-Peak hours, respectively.

Figure 3.1 Distributions of Incidents/Disabled Vehicles by Time of Day in 2012

Figure 3.1 illustrates the distributions of incidents/disabled vehicles by time of day in more detail. The frequency of incidents in off-peak hours is much higher than in morning or evening peak hours, since there are many more such hours. More detailed information regarding distributions by time of day is presented in the Appendix.

3.2 Distribution of Incident and Disabled Vehicles by Road and Location

Figure 3.2 compares the frequency distribution among roads between 2012 and 2011, and Figure 3.3 depicts the frequency distribution of incidents and disabled vehicles for 2012.

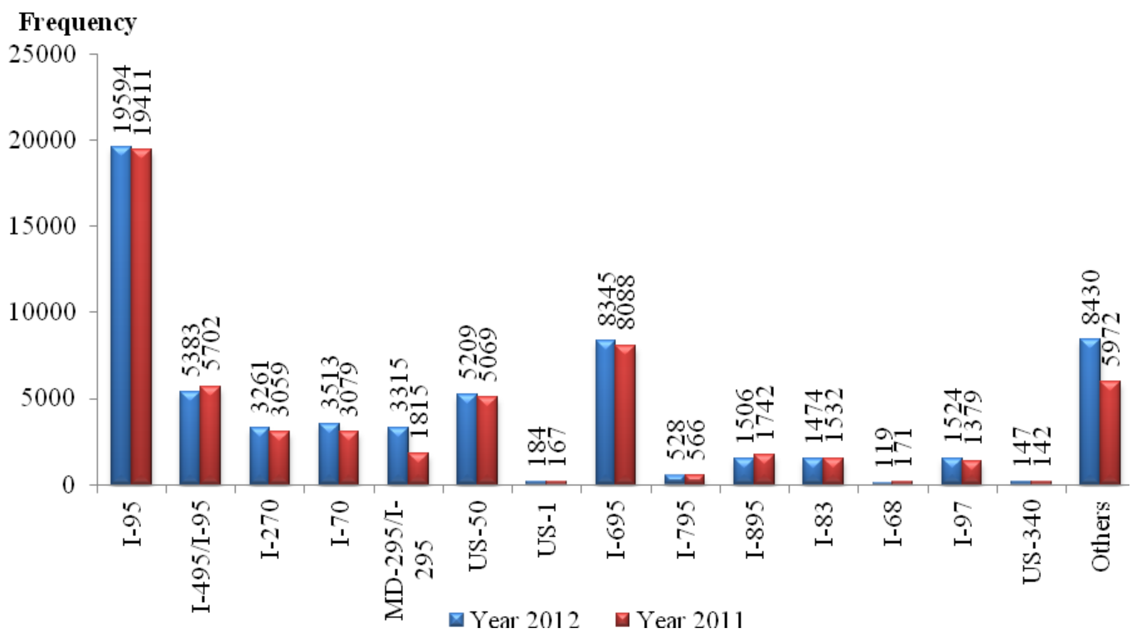


Figure 3.2 Distributions of Incidents/Disabled Vehicles by Road in 2012 & 2011

Based on the statistics shown above, the roadways with high incident frequencies for 2012 were I-95 (from the Delaware border to the Capital Beltway), I-695 (Baltimore Beltway), I-495/95 (Capital Beltway), US-50, I-70 and I/MD-295. I-95 experienced a total of 19,594 incidents/disabled vehicles in 2012, while I-695 had 8,345 incidents/disabled vehicles within the same period. I-495/95, US-50, I-70 and I/MD-295 had 5,383, 5,209, 3,513, and 3,315 incidents/disabled vehicles, respectively.

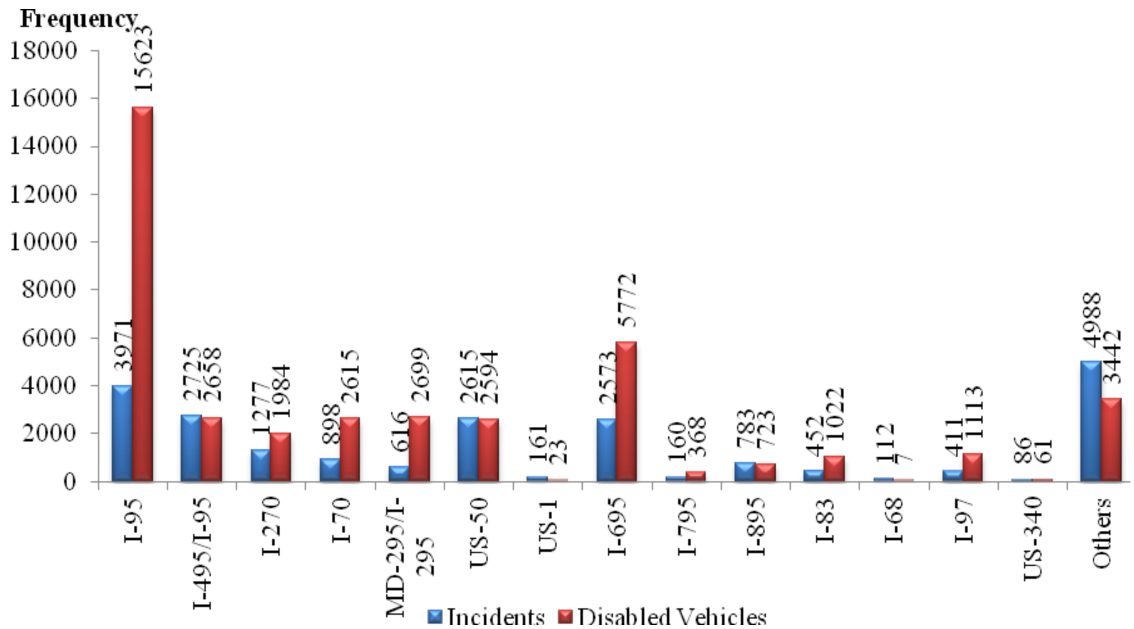


Figure 3.3 Distributions of Incidents/Disabled Vehicles by Road in 2012

Figures 3.4 and 3.5 present comparisons of frequency distributions by time of day on major roads in Maryland for incidents and disabled vehicles. As shown in these figures, somewhat more incidents occurred during a.m. peak hours than p.m. peak hours on I-95 and I-695.

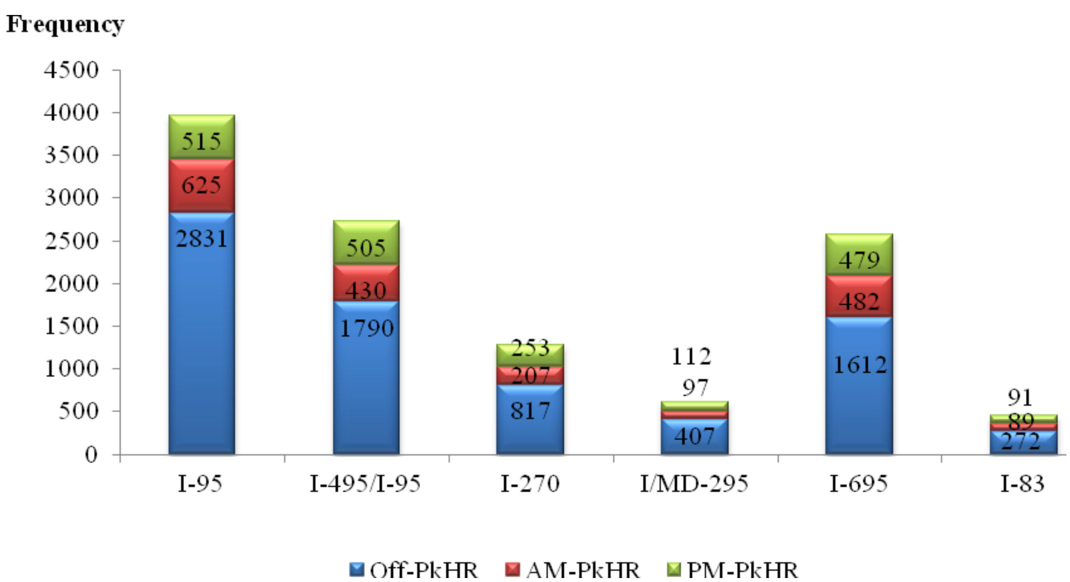


Figure 3.4 Distributions of Incidents by Time of Day on Major Roads in 2012

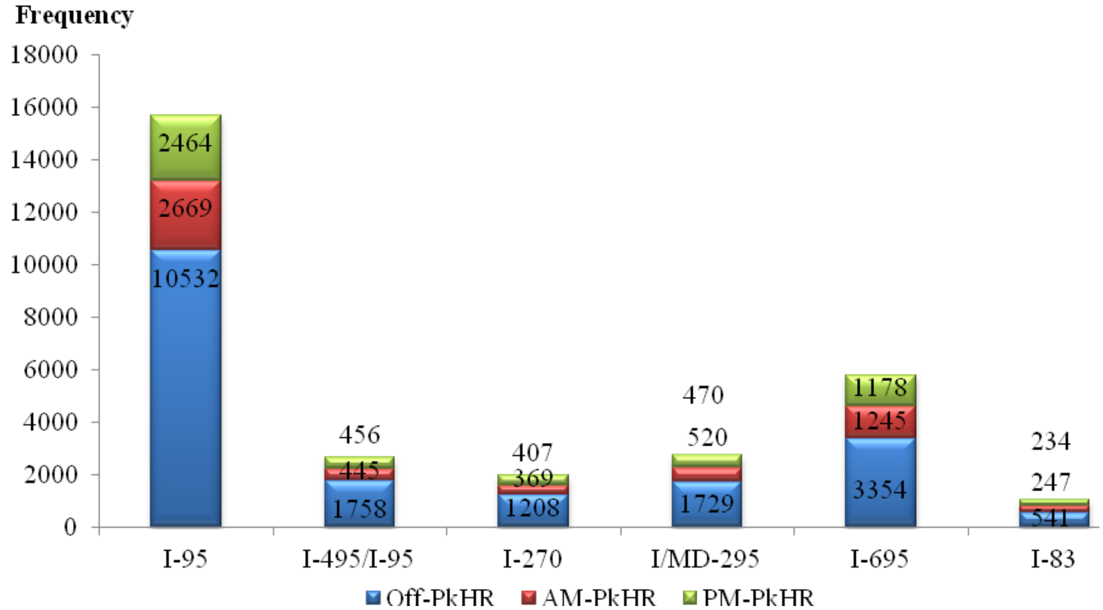


Figure 3.5 Distributions of Disabled Vehicles by Time of Day on Major Roads in 2012

I-95, I-270, and US-50 are connected to I-495/95 and are the main contributors of traffic congestion on I-495 during commuting periods. Due to its high traffic volumes, any incident on I-495 is likely to cause a spillback of vehicles onto I-95, I-270, and US-50, causing congestion on those three freeways as well. The interdependent nature of incidents between the primary commuting freeways should be considered when prioritizing and implementing incident management strategies. To better allocate patrol vehicles and response units to hazardous highway segments, the distribution of incidents/disabled vehicles between two consecutive exits was employed as an indicator in the analysis.

Figure 3.6 shows the distribution of incidents and disabled vehicles by location on I-695 in 2012, while Figure 3.7 compares these values with the 2011 values. The high-incident segments are from Exits 11 to 12 and Exits 17 to 18 (205 and 122, respectively). The two high frequencies of disabled vehicles (363 and 331 cases) were recorded on the segments between Exits 11 and 12 and Exits 22 and 23, which are close to the I-95 and I-83 interchanges, respectively.

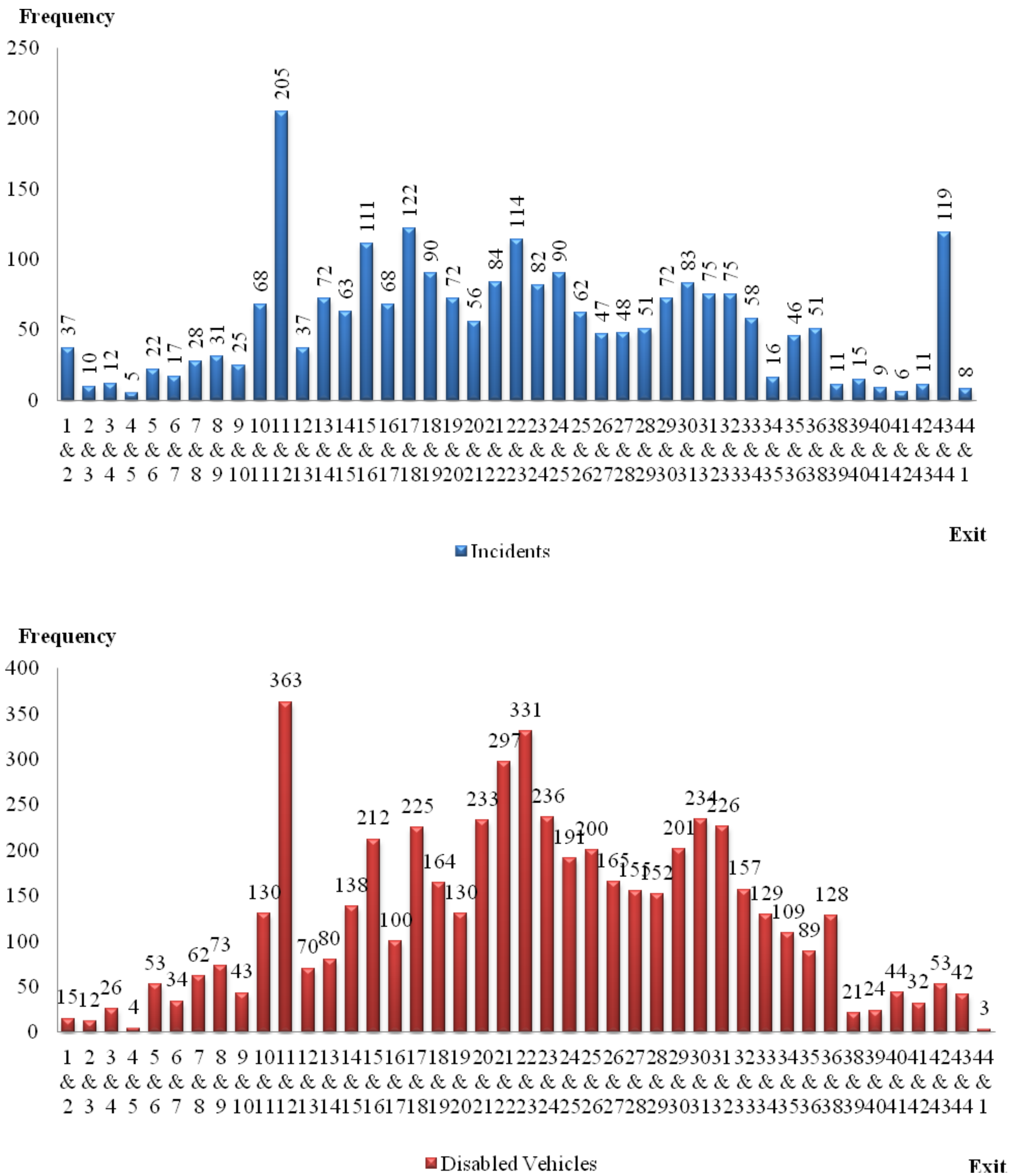
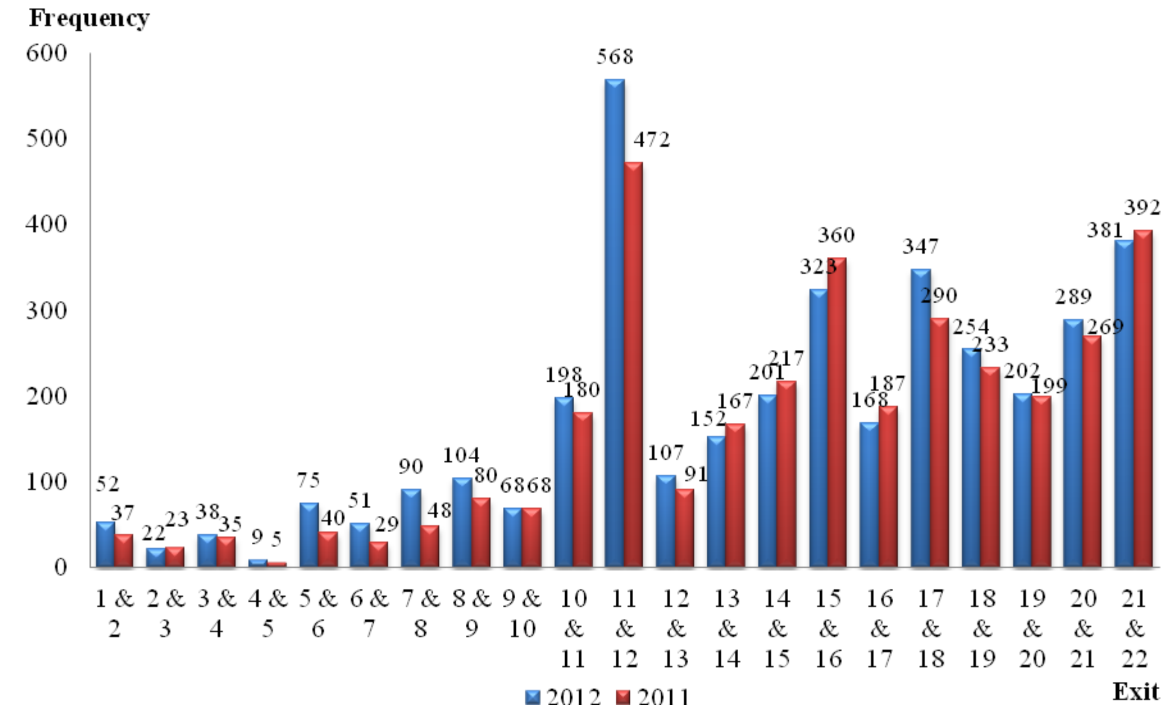


Figure 3.6 Distributions of Incidents/Disabled Vehicles by Location on I-695



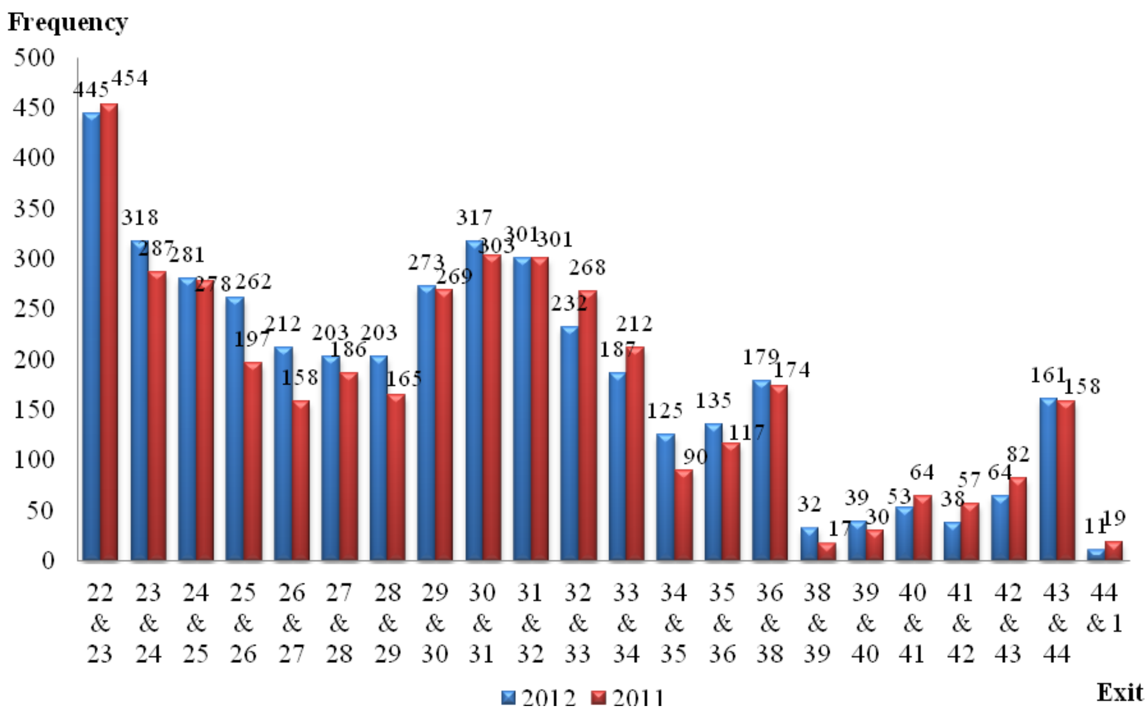


Figure 3.7 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-695

The subsequent figures present the comparison between 2012 and 2011 data, as well as the geographical distribution of incidents and disabled vehicles on I-495/95.

From Figure 3.8, it can be observed that the highest frequency of incidents (206 cases) occurred between Exits 31 and 33 of I-495. The location with the highest frequency of disabled vehicles (148 cases) occurred between Exits 17 and 19. A comparison with the previous year's data is illustrated in Figure 3.9.

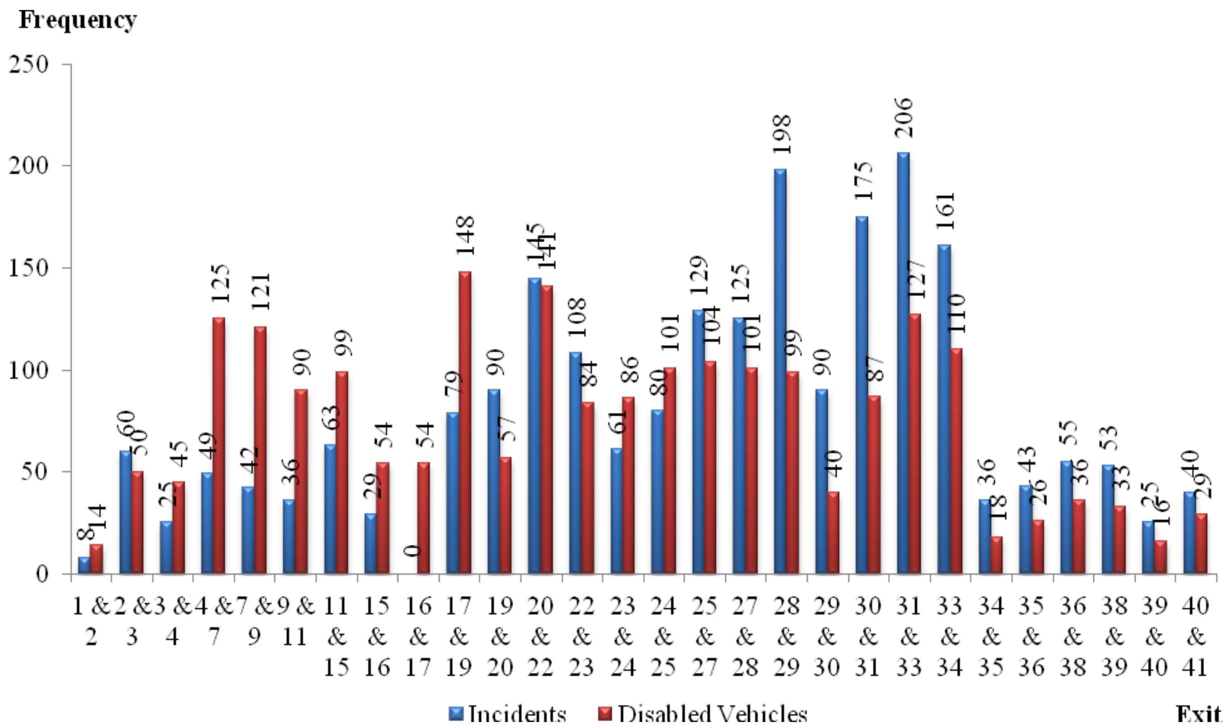


Figure 3.8 Distributions of Incidents/Disabled Vehicles by Location on I-495/I-95

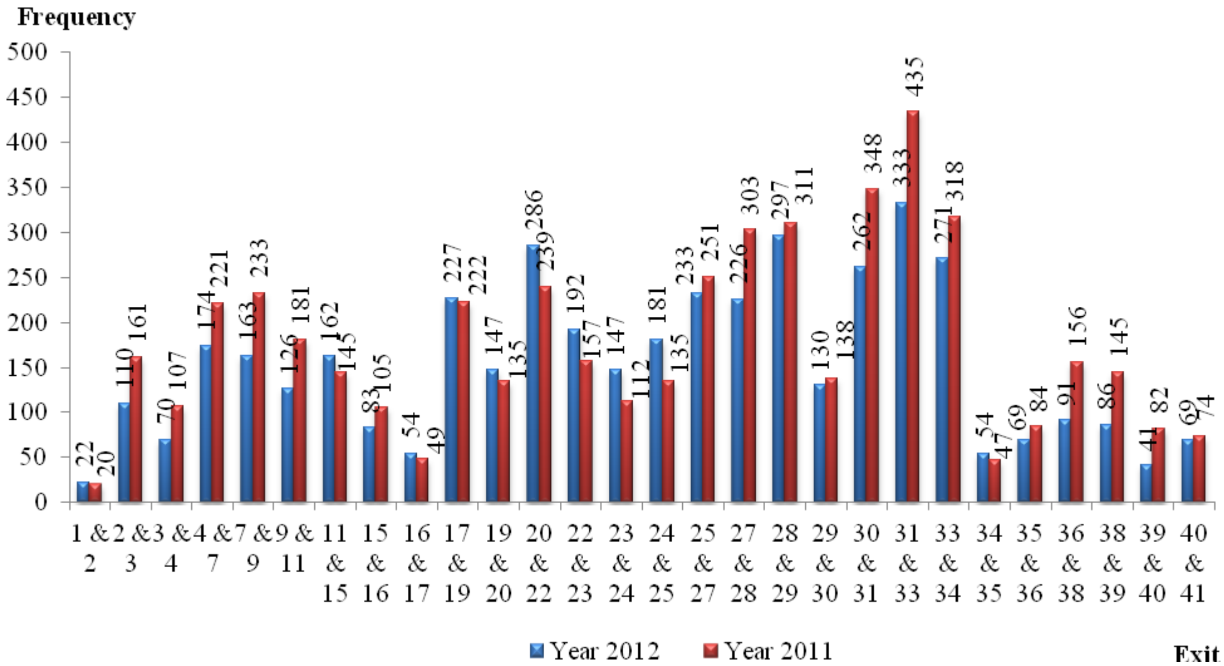


Figure 3.9 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-495/I-95

Figure 3.10 shows the distribution of incidents and disabled vehicles by location on I-95, and Figure 3.11 compares this distribution between data obtained in 2012 and 2011. As shown in Figure 3.10, the highest number of incidents occurred at the segment between Exits 55 and 56 (467 cases). The segments between Exits 67 and 74 experienced a high number of disabled vehicles (3,094 cases).

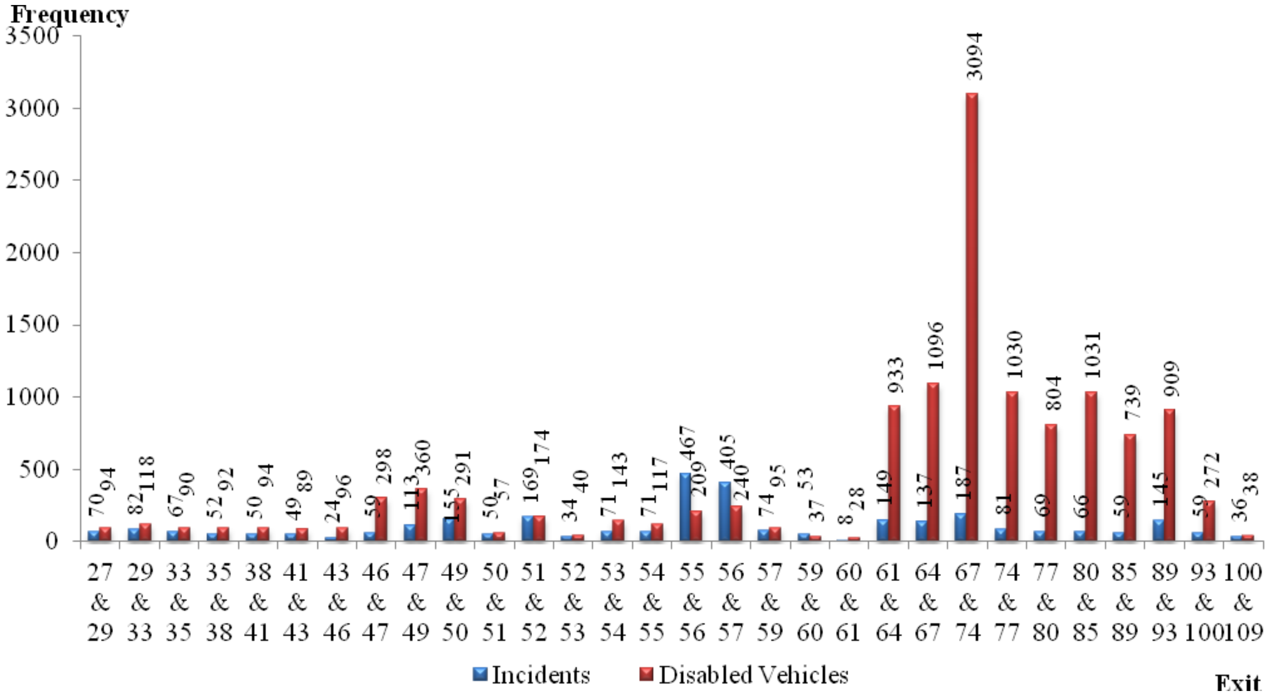


Figure 3.10 Distributions of Incidents/Disabled Vehicles by Location on I-95

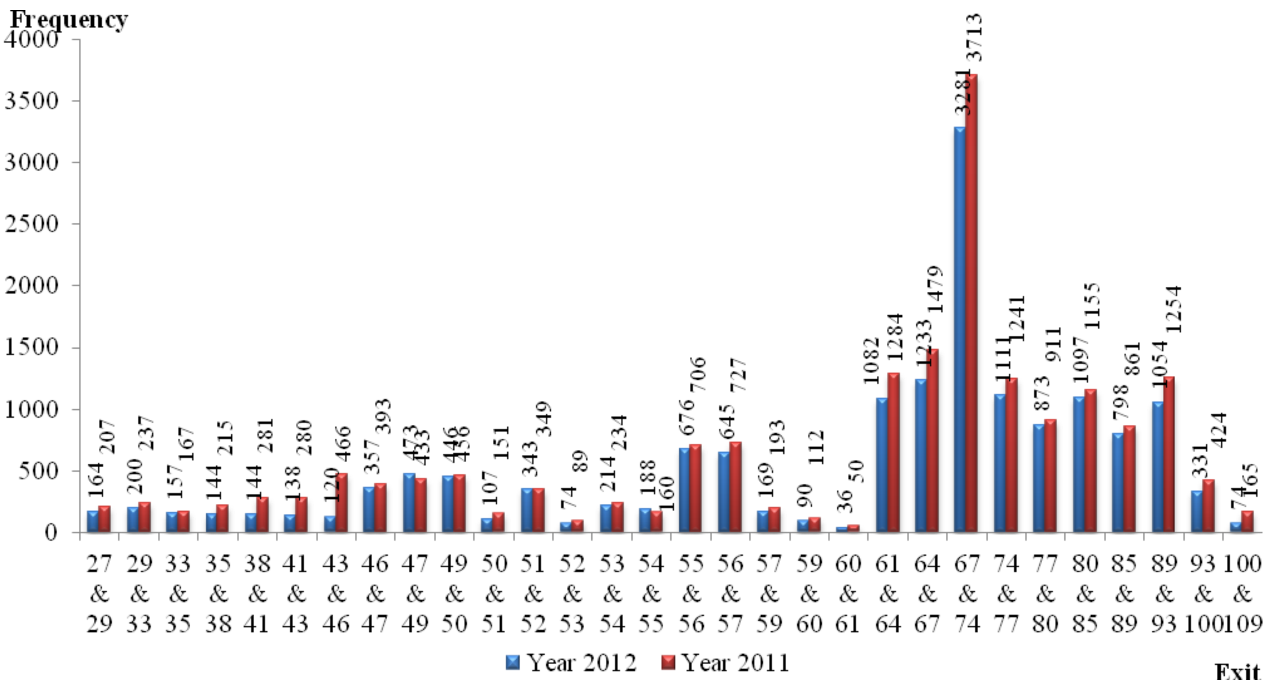


Figure 3.11 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-95

In 2012, the incidents and disabled vehicles recorded for the I-95 segment between Exits 67 and 74 received the maximum number of incident responses, with a total frequency of 3,281. The segment on I-95 between Exits 64 and 67 sustained the second largest number of incidents/disabled vehicles requests (1,233) in 2012. These trends are similar to those observed in 2011.

Figure 3.12 represents the spatial distribution of incidents/disabled vehicles data on I-270 for 2012. The segment between Exits 5 and 6 on I-270 in Figure 3.12 experienced the highest numbers of incidents (76) and the segment between Exits 11 and 13 experienced the highest number of disabled vehicles (118).

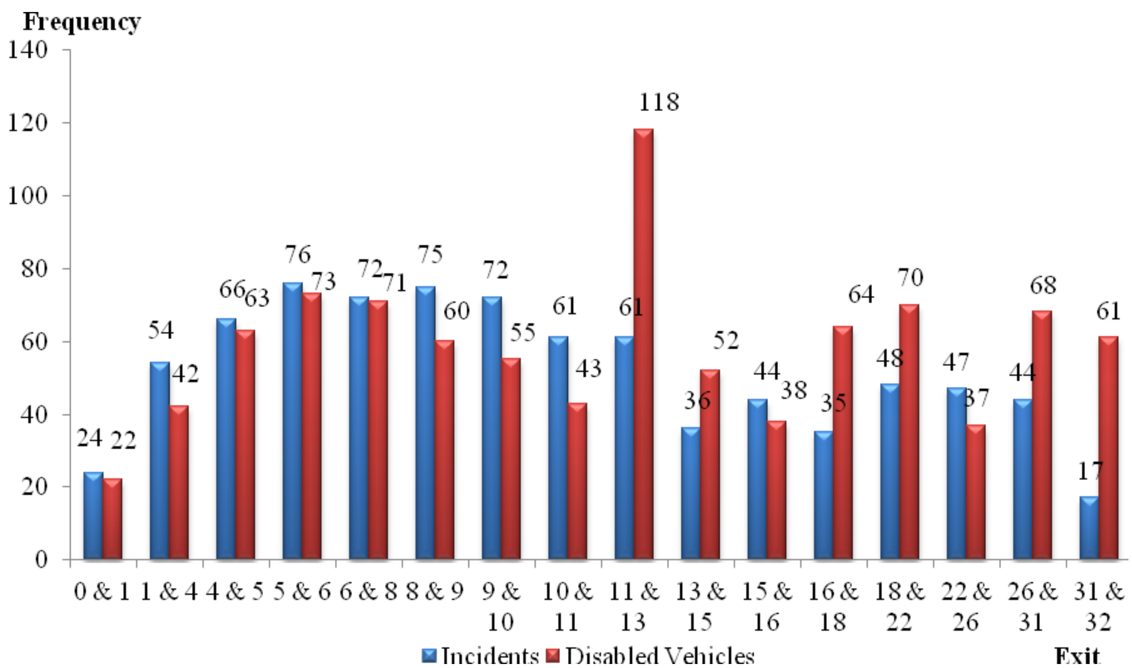


Figure 3.12 Distributions of Incidents/Disabled Vehicles by Location on I-270

Figure 3.13 shows a comparison between 2012 and 2011 data; the 2012 data recorded fewer incidents/disabled vehicles than in 2011 at almost all locations.

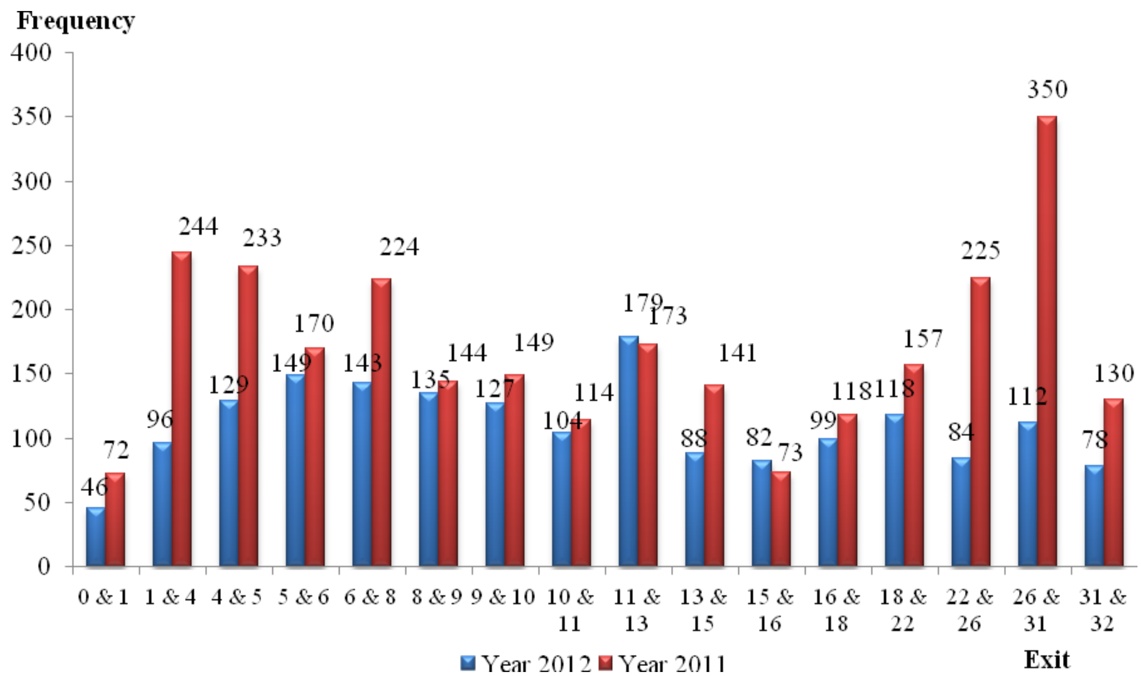
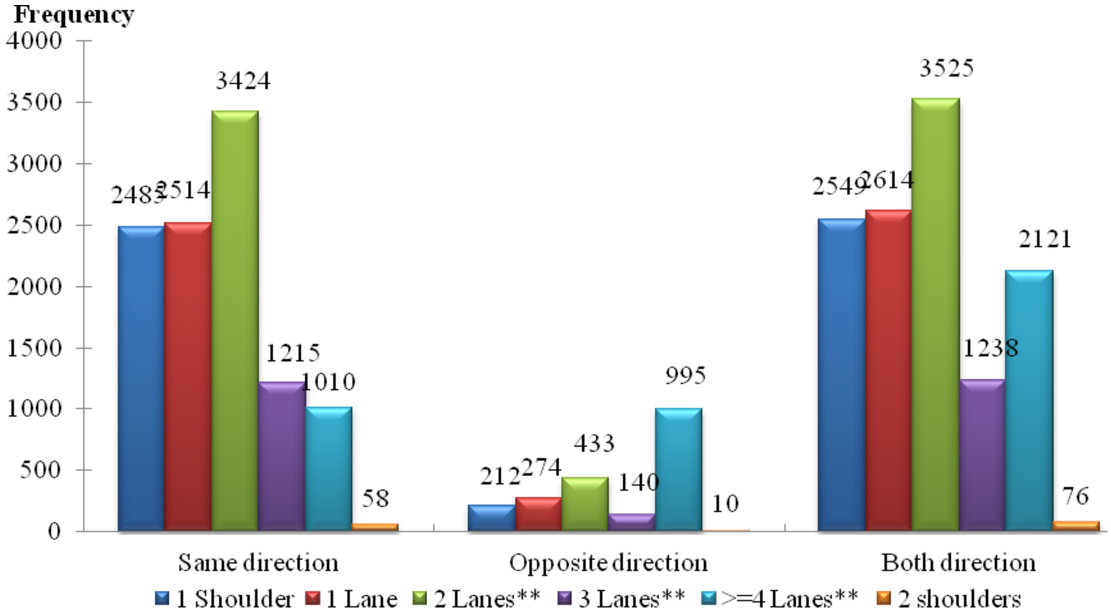


Figure 3.13 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-270

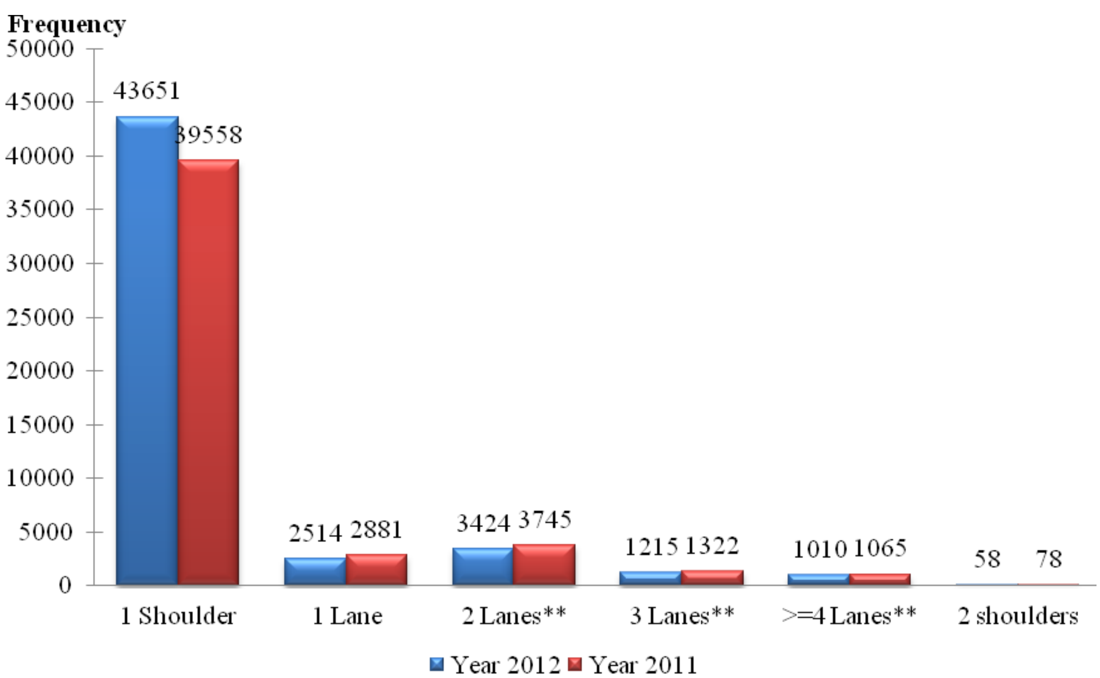
3.3 Distribution of Incidents and Disabled Vehicles by Lane Blockage Type

Figure 3.14 illustrates the distribution of incidents by lane blockage in 2012. A large portion of those incidents involved one-lane or two-lane blockages. The comparison of 2012 incidents/disabled vehicles distribution by lane blockage with 2011 data is illustrated in Figure 3.15. Note that all reported disabled vehicles are classified as shoulder lane blockages.



Note: * Not including "Disabled Vehicles"
** Also includes Shoulder Lane Blockages

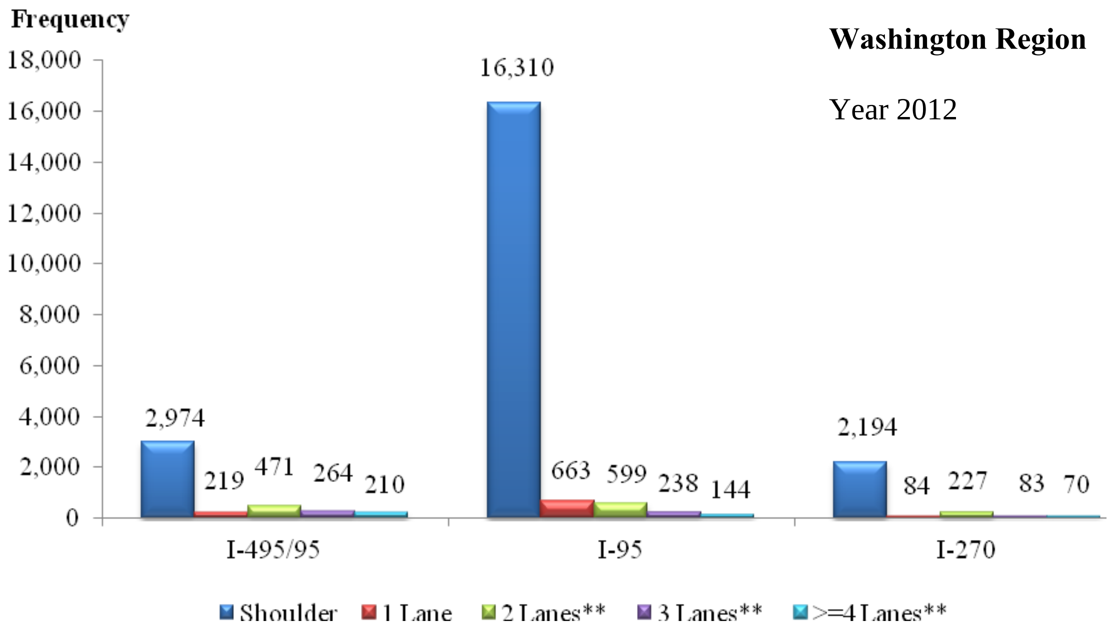
Figure 3.14 Distributions of Incidents by Lane Blockage

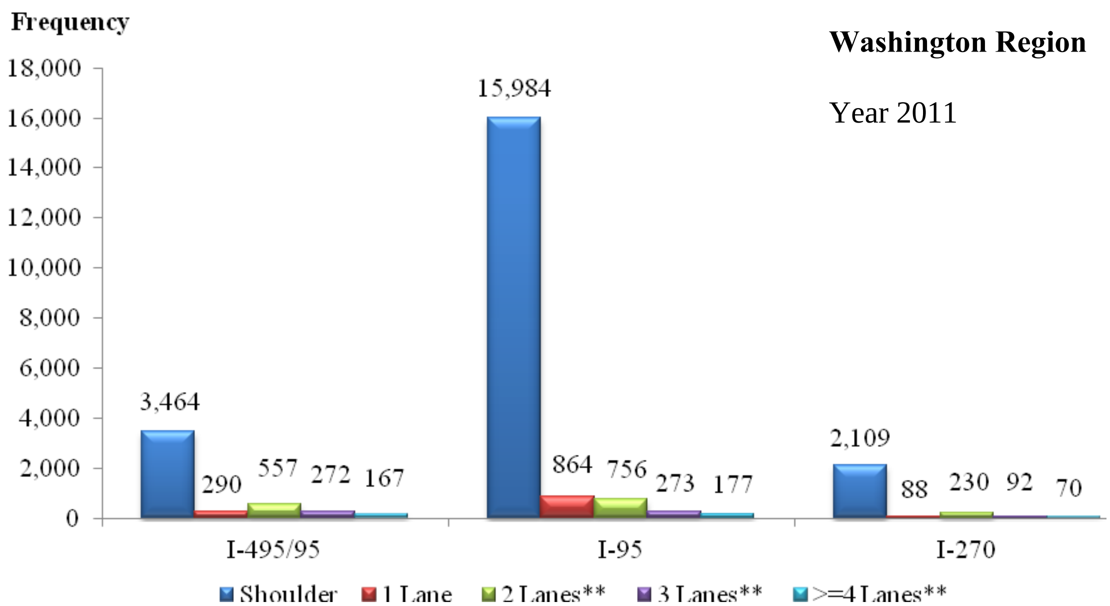


Note: * Disabled Vehicles are all classified as Shoulder Lane Blockages.
** Also includes Shoulder Lane Blockages

Figure 3.15 Comparisons of Incidents/Disabled Vehicles Distributions by Lane Blockage

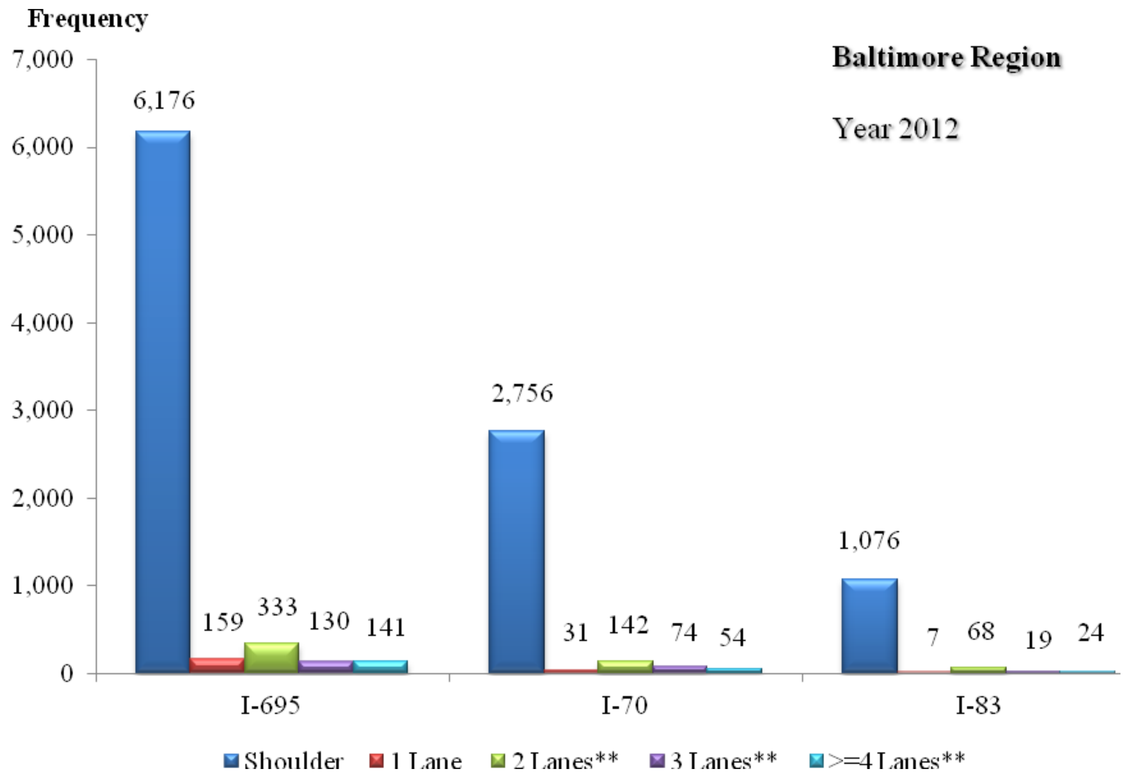
Figures 3.16 and 3.17 depict a comparison of lane blockage incidents between 2012 and 2011 for major roads in the Washington Metropolitan and Baltimore areas.

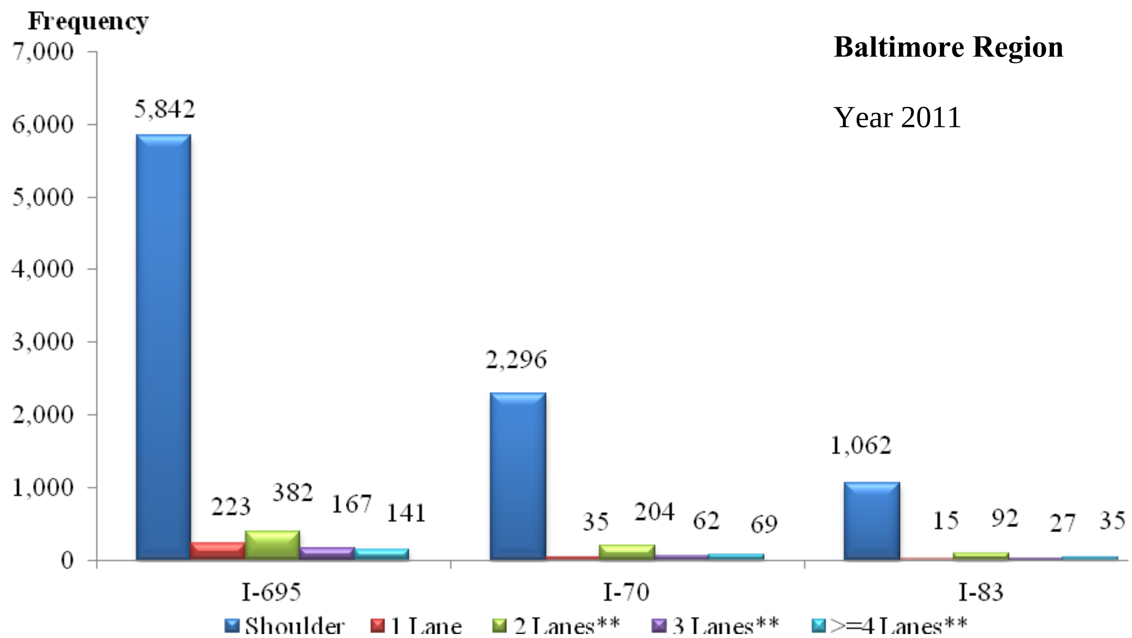




Note: ** Also includes Shoulder Lane Blockages.

Figure 3.16 Distributions of Lane Blockages Occurring on Major Freeways in the Washington Area





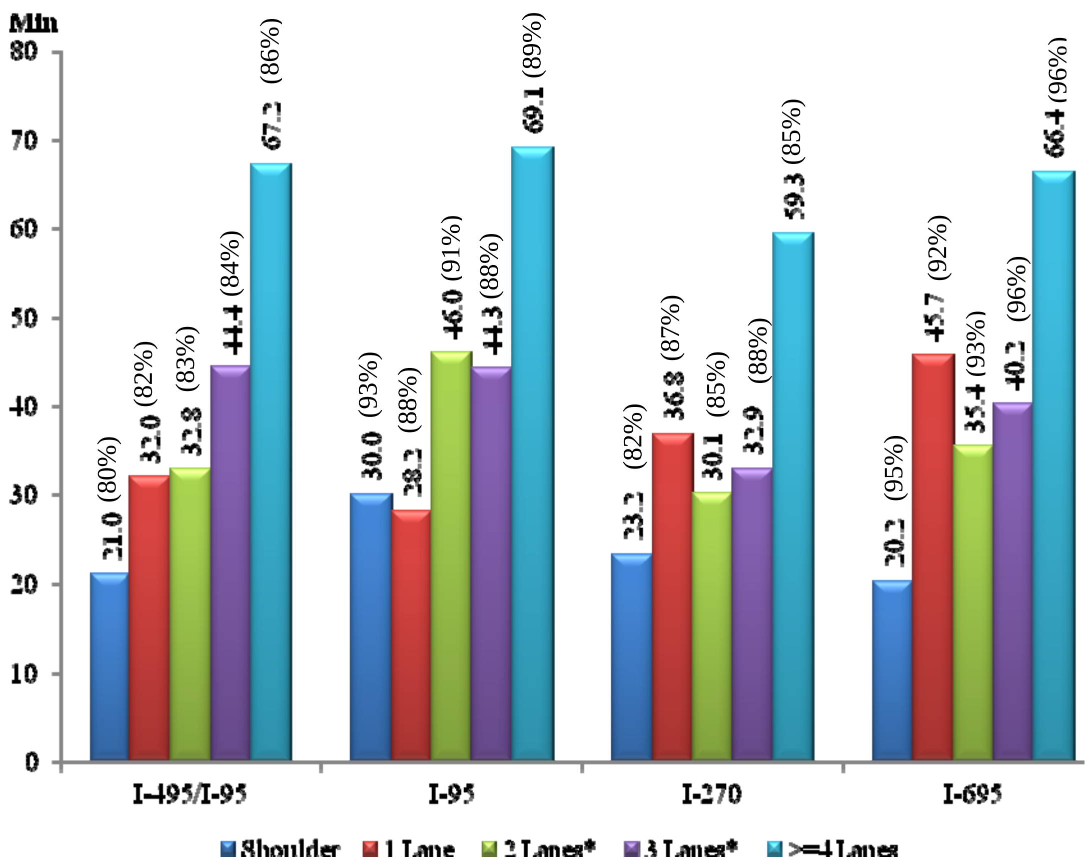
Note: ** Also includes Shoulder Lane Blockages.

Figure 3.17 Distributions of Lane Blockages Occurring on Major Highways in the Baltimore Region

Note that disabled vehicles caused most of the shoulder lane blockages. Most of the disabled vehicles were recorded as a result of driver assistance requests due to flat tires, minor mechanical problems, or gas shortages.

3.4 Distribution of Incidents and Disabled Vehicles by Blockage Duration

Lane blockage analysis naturally leads to the comparison of incident duration distribution. Figure 3.18 illustrates a relation between lane blockages and their average durations on each major freeway.



Note: *Also includes Shoulder Lane Blockages.
** Numbers in each parenthesis show the percentage of data available.

Figure 3.18 Distributions of Lane Blockages and Road

It is quite obvious that CHART's highway network has experienced high incident frequencies ranging from ten minutes to more than one hour in duration. These incidents are clearly primary contributors to traffic congestion in the entire region, especially on the major commuting highway corridors of I-495, I-695, I-270, and I-95, making it imperative, therefore, to continuously improve traffic management and incident response systems.

As shown below, most disabled vehicles did not block traffic for more than half an hour. About 80 percent of incidents and disabled vehicles had durations of less than 30 minutes.

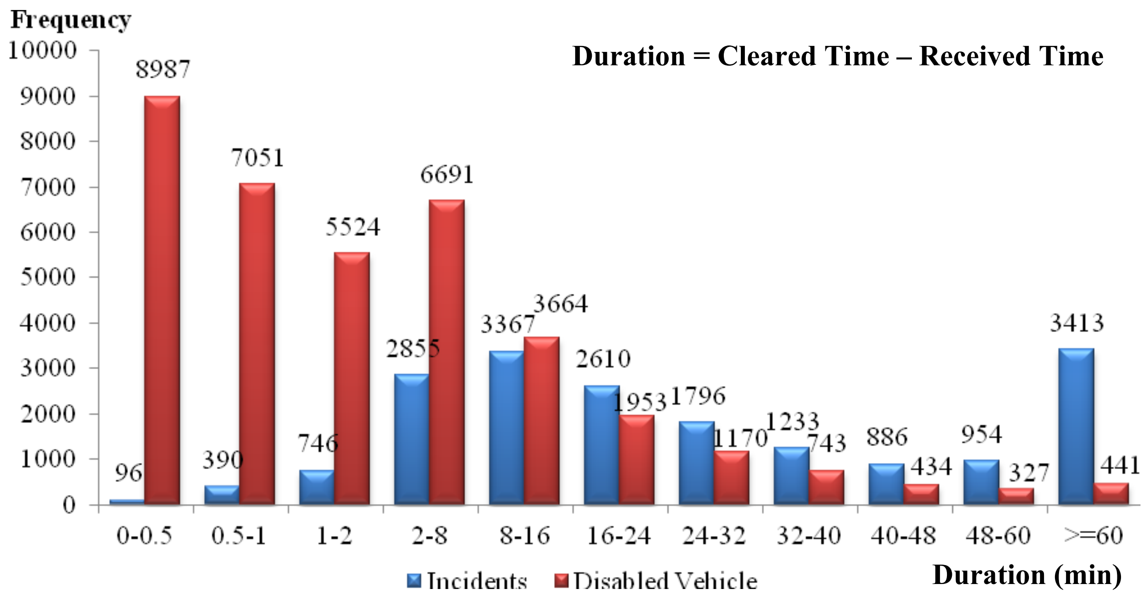
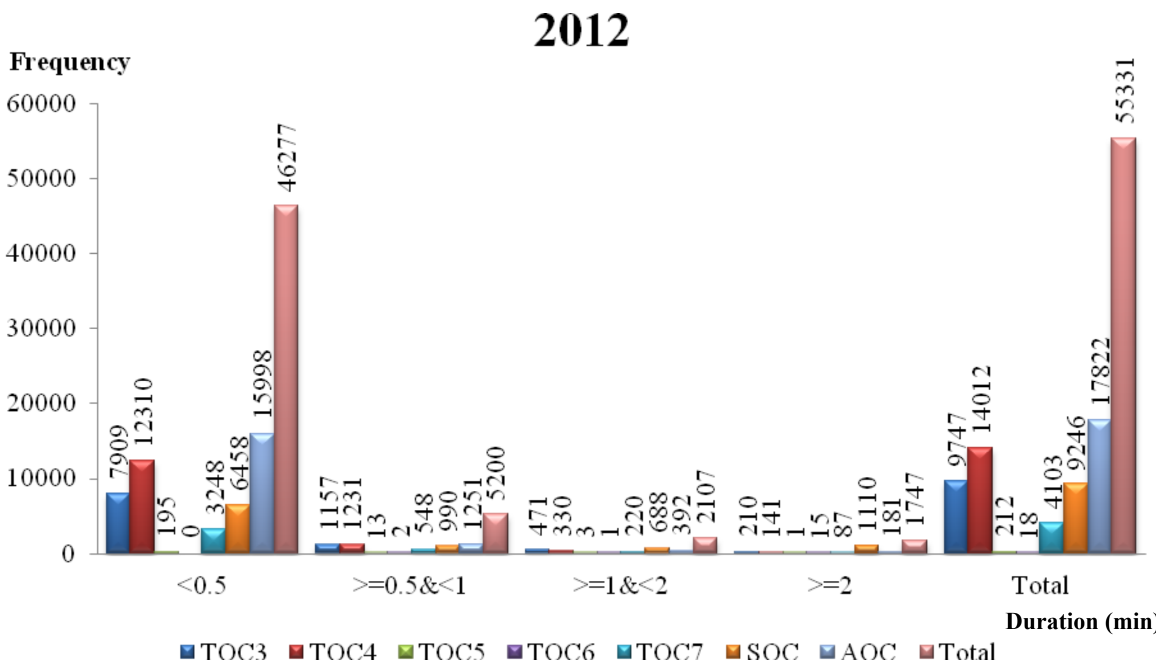


Figure 3.19 Distributions of Incidents/Disabled Vehicles by Duration in 2012

Although most incidents in 2012 were not severe, their impacts were significant during peak hours. Clearing the blockages did not require special equipment, and the incident duration was highly dependent on the travel time of the incident response units.

Figure 3.20 presents the distribution of records in 2012 and its comparison with 2011 data. About 19 percent, 12 percent, and 21 percent of reported incidents/disabled vehicles managed by TOC-3, TOC-4, and TOC-7, respectively, had blocked traffic lasting longer than 30 minutes. For SOC, about 30 percent of reported incidents lasted longer than 30 minutes. This implies that only 16 percent of reports to which CHART responded lasted more than 30 minutes in 2012.



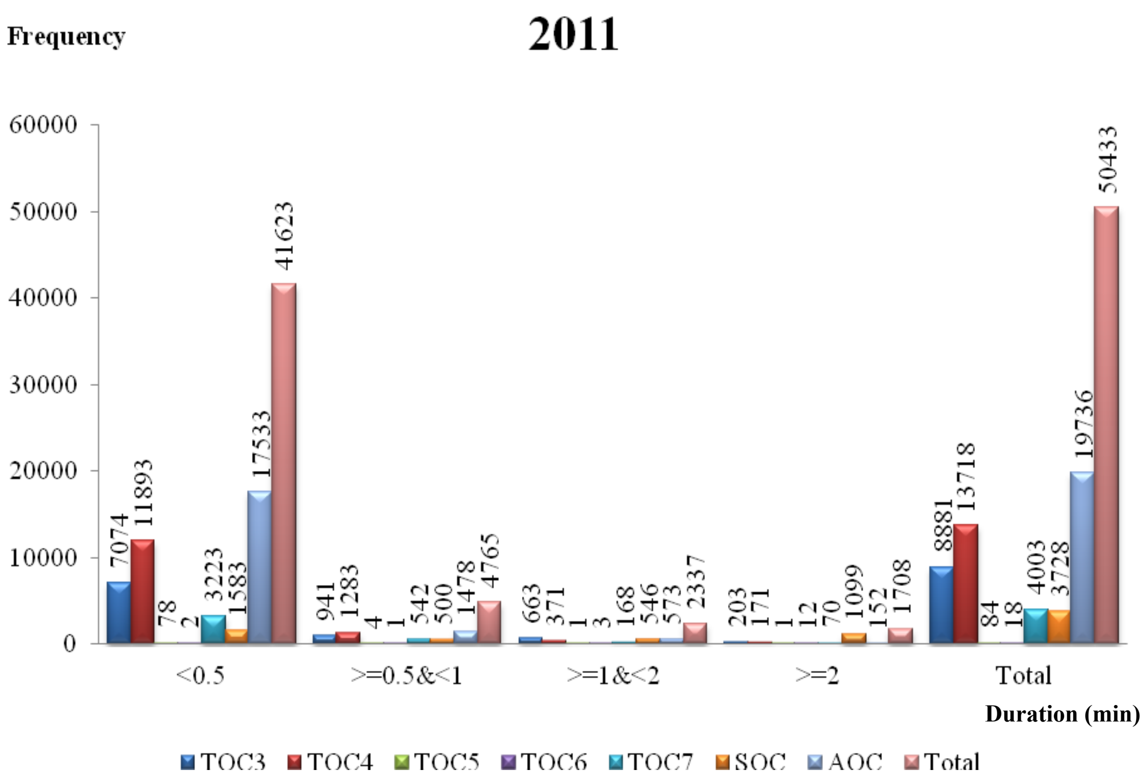


Figure 3.20 Comparisons of Incidents/Disabled Vehicles Distributions by Duration and Operation Center

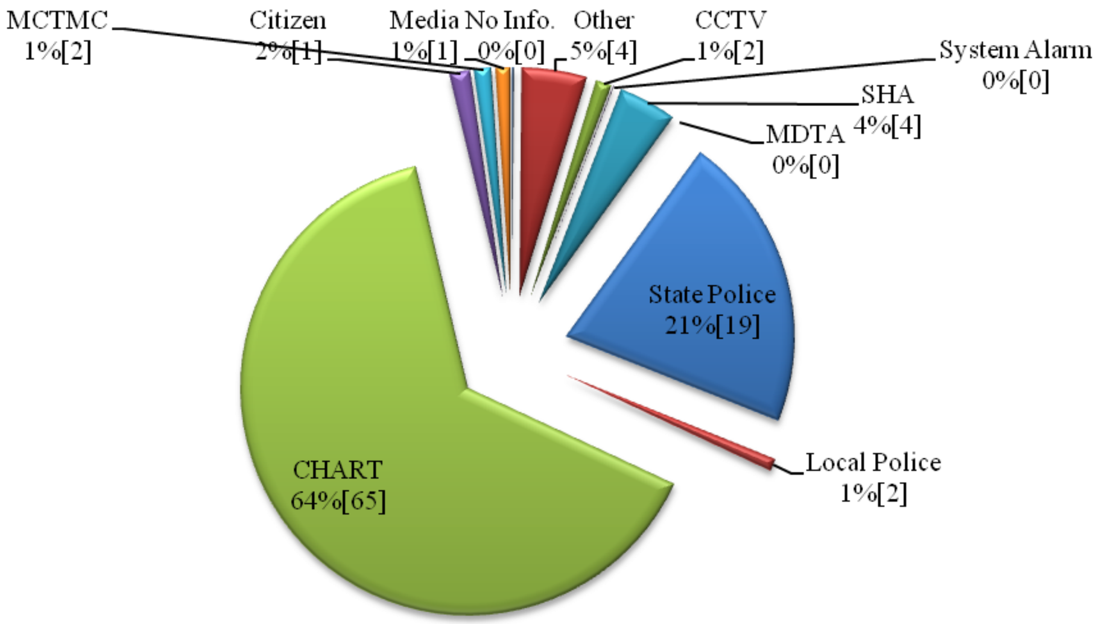
CHAPTER 4
EVALUATION OF EFFICIENCY AND EFFECTIVENESS

4.1 Evaluation of Detection Efficiency and Effectiveness

An automatic incident detection system has yet to be implemented by CHART. Therefore, CHART has no means of evaluating the detection and false-alarm rates. Also, at this point, CHART has no way to determine the time taken by the traffic control centers to detect an incident from various sources after its onset. Therefore, this evaluation of detection efficiency and effectiveness focuses only on the incident response rate and on the distribution of detection sources.

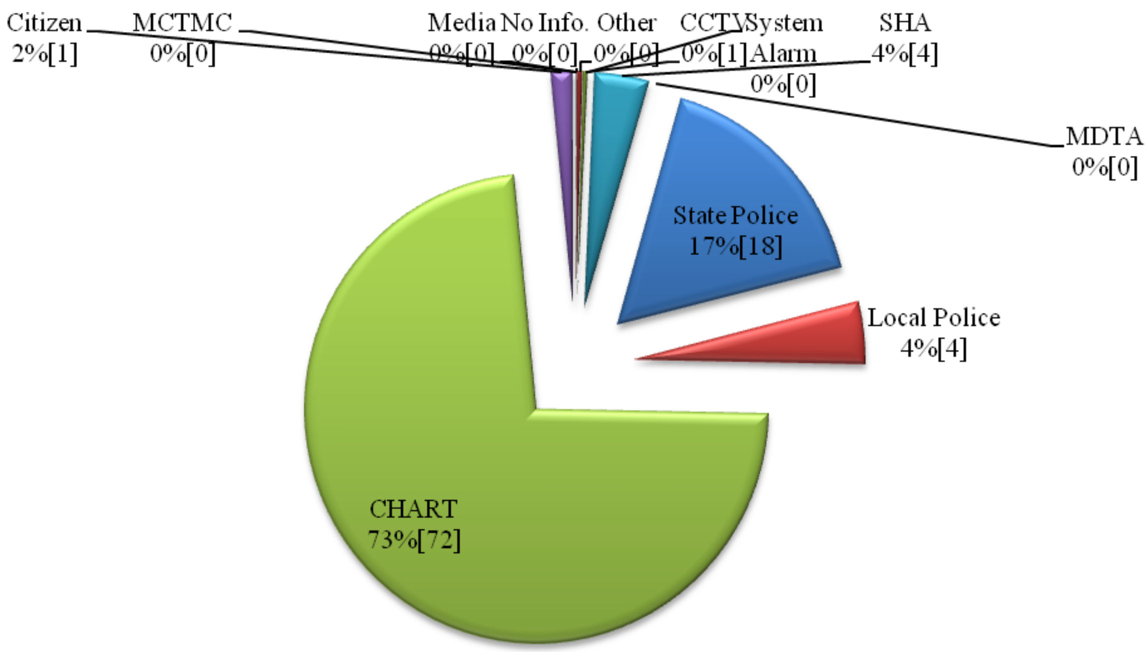
The response rate is defined as the ratio of the total number of traffic incidents reported to the CHART control center to those managed by the CHART/MSHA emergency response teams. Based on 2012 incident management records, the overall response rate was about 96 percent. As in the previous year, existing incident reports did not specify the reasons for ignoring some requests. It appears that most of the ignored incidents happened during very light traffic periods or were not severe enough to cause any significant traffic blockage or delay. Notwithstanding the lack of an automated incident detection system, CHART has maintained an effective coordination system with state and municipal agencies that deal with traffic incidents and congestion.

Figures 4.1, 4.2, 4.3 and 4.4 illustrate the distributions of Incidents/Disabled Vehicles by Detection Source for control centers TOC 3, TOC 4, TOC6 and TOC7, respectively.



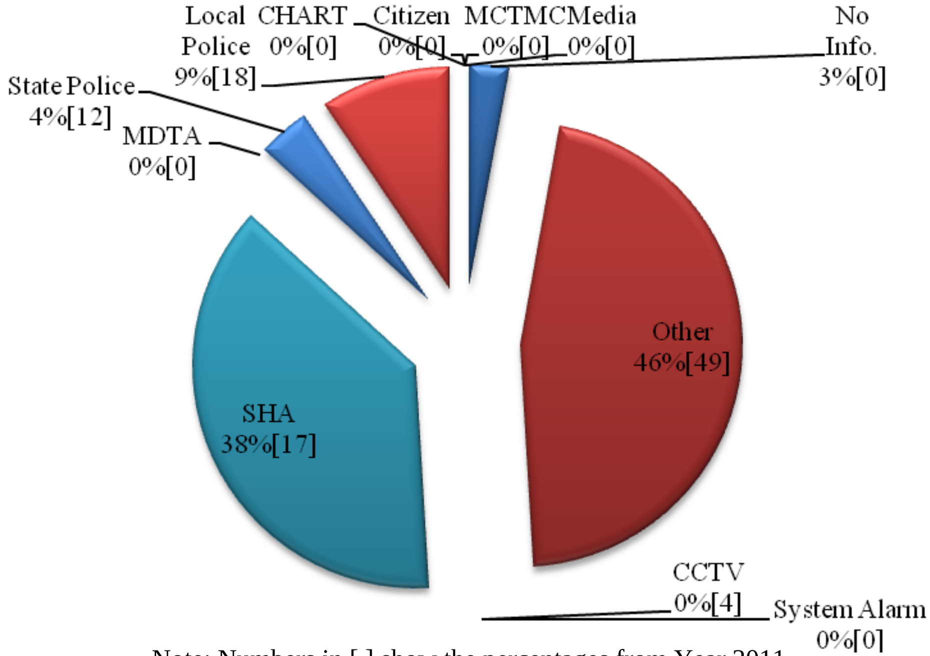
Note: Numbers in [ ] show the percentages from Year 2011

Figure 4.1 Distributions of Incidents/Disabled Vehicles by Detection Source for TOC 3



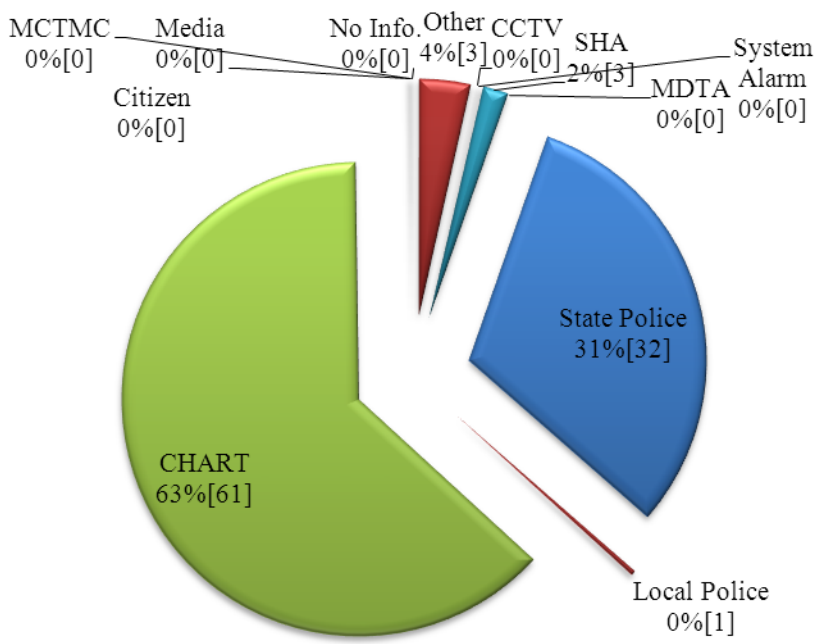
Note: Numbers in [ ] show the percentages from Year 2011

Figure 4.2 Distributions of Incidents/Disabled Vehicles by Detection Source for TOC 4



Note: Numbers in [ ] show the percentages from Year 2011

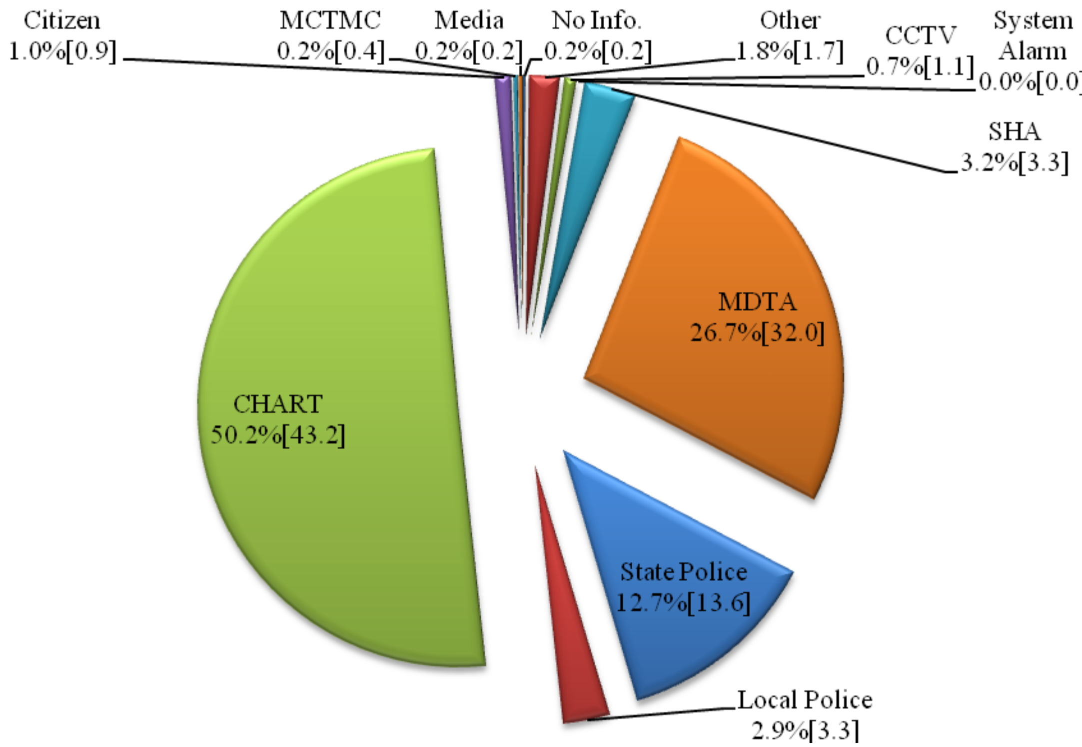
Figure 4.3 Distributions of Incidents/Disabled Vehicles by Detection Source for TOC 6



Note: Numbers in [ ] show the percentages from Year 2011

Figure 4.4 Distributions of Incidents/Disabled Vehicles by Detection Source for TOC 7

With respect to the distribution of all detection sources, the statistics in Figure 4.5 clearly show that about 50 percent of incidents in 2012 were detected by MSHA/CHART patrols, i.e., a higher percentage than in 2011. About 13 percent were reported by the MSP, similar to the 14 percent figure in 2011. Note that the numbers in parentheses indicate the 2011 statistics.



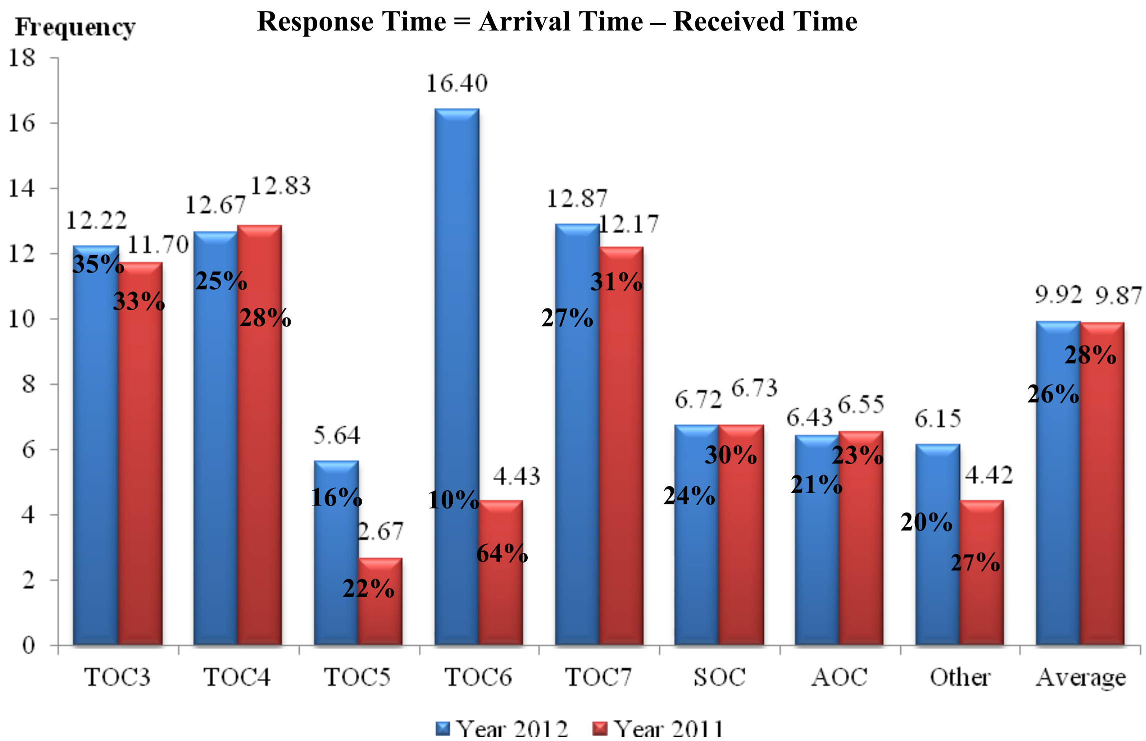
Note: Numbers in [ ] show the percentages from Year 2011

Figure 4.5 Distributions of Incidents/Disabled Vehicles by Detection Source

4.2 Analysis of Response Efficiency

The distributions of response times and incident durations were used to analyze the efficiency of incident responses. The response time is defined as the interval between the onset of an incident and the arrival of response units. Since the actual start time of an incident is unknown, the response time used in this analysis is based on the difference between the time the response center received a request and the time of arrival of the response unit at the incident site.

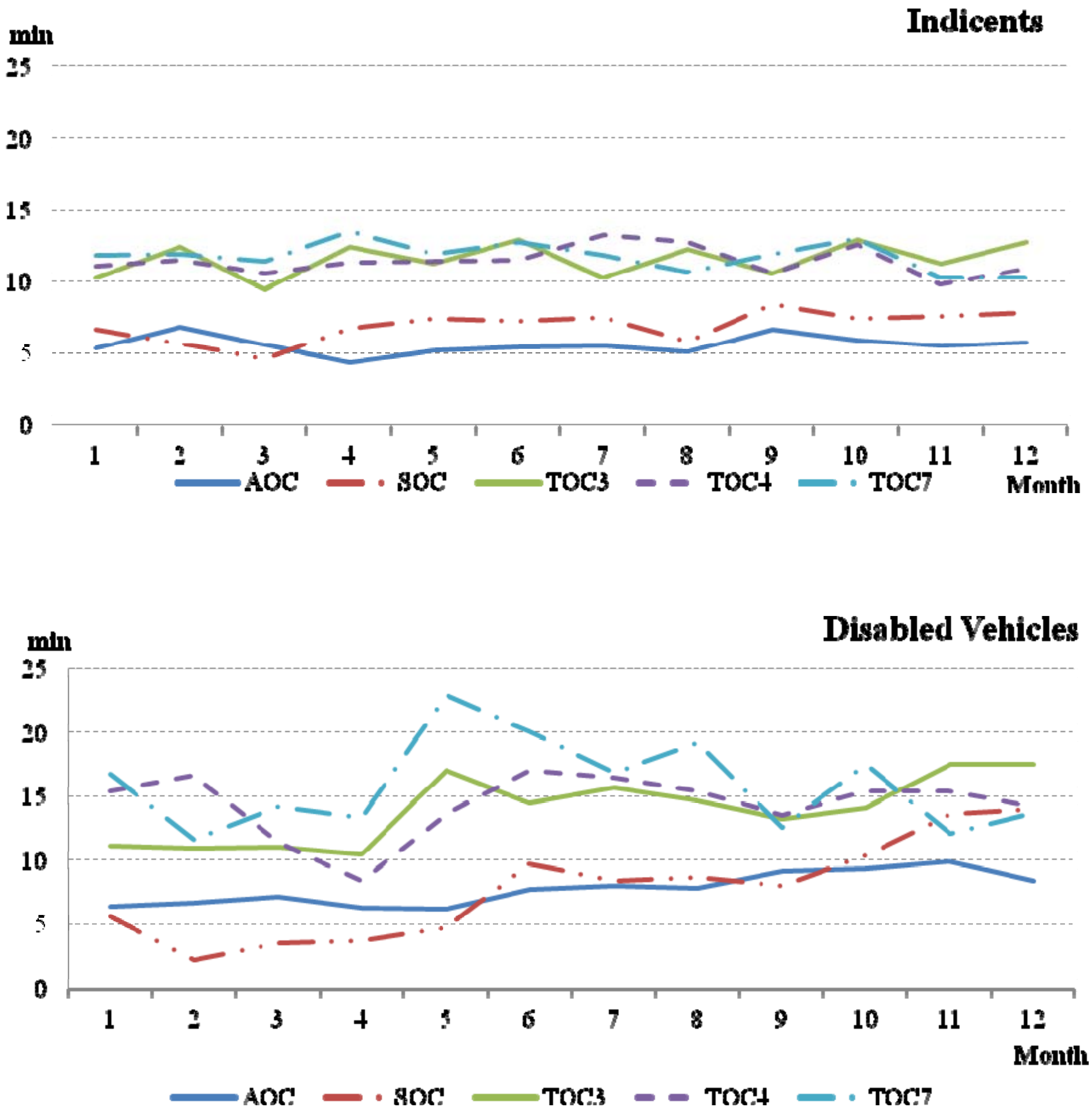
The average response time for incidents in 2012 is given in Figure 4.6. The average response time in 2012 was 9.92 minutes, slightly higher than that of 2011 (9.87 minutes).



Note: The percentage shows the amount of data available for computing the response time.

Figure 4.6 Average Response Time Distributions

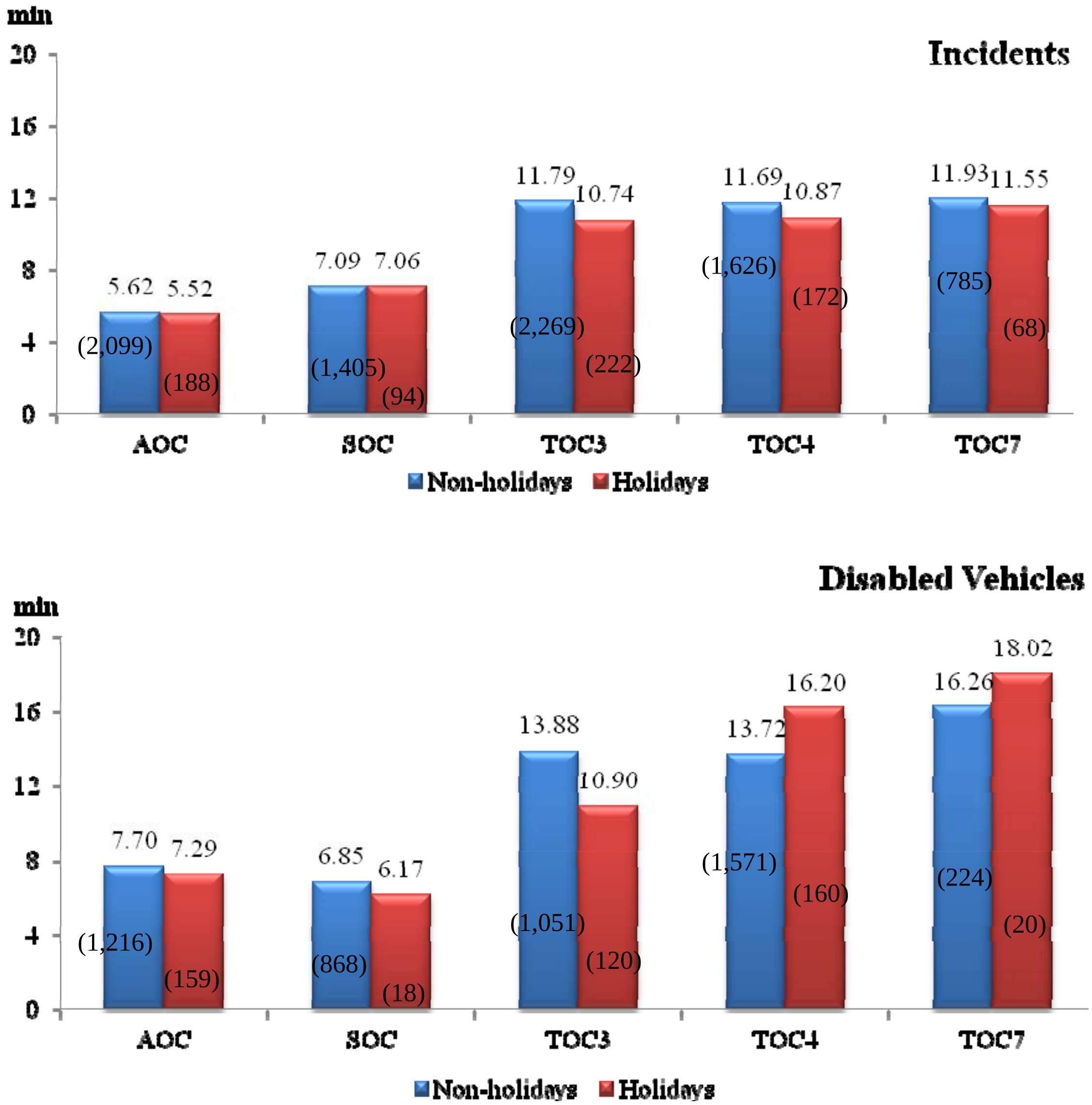
In Figure 4.7 the average response times of incidents by TOC 3, TOC 4, and TOC 7 are fairly consistent throughout the year and are between ten and fifteen minutes. AOC and SOC also show fairly consistent response times between five and ten minutes through year 2012. On the other hand, the response times for disabled vehicles show significant fluctuations for all operations centers except AOC. TOC 4 exhibits a big drop in the average response time for disabled vehicles in April, while TOC 7 shows a big increase in the average response time for disabled vehicles in May. Overall, the average response times for both AOC and SOC are shorter than for TOCs throughout the entire year.



Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. TOC 5 and TOC 6 were excluded in this analysis, since they operate on the seasonal base.

Figure 4.7 Average Response Time for Operation Centers by Month in 2012

Figure 4.8 illustrates the fact that most operation centers show slightly faster response times for incidents and disabled vehicles during holidays in 2012.



Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. Numbers in each parenthesis show the data availability.
3. Holidays include New Year's Day, Martin Luther King, Jr. Day, Washington's Birthday, Memorial Day, Independence Day, Labor Day, Columbus Day, Veterans Day, Thanksgiving Day, and Christmas Day

Figure 4.8 Average Response Time for Operation Centers by Holiday in 2012

Figures 4.9 to 4.13 present the average response times by time of day during weekdays for each operation center. The bar graph represents the average incident frequencies to which the operation center responded while the line graph illustrates its average response times by the time of day. Overall, AOC shows quite consistent response time during the daytime, and its response times after midnight become shorter likely due to the low incident frequency. On the other hand, the response times by SOC vary with the incident frequency responded to through the day.

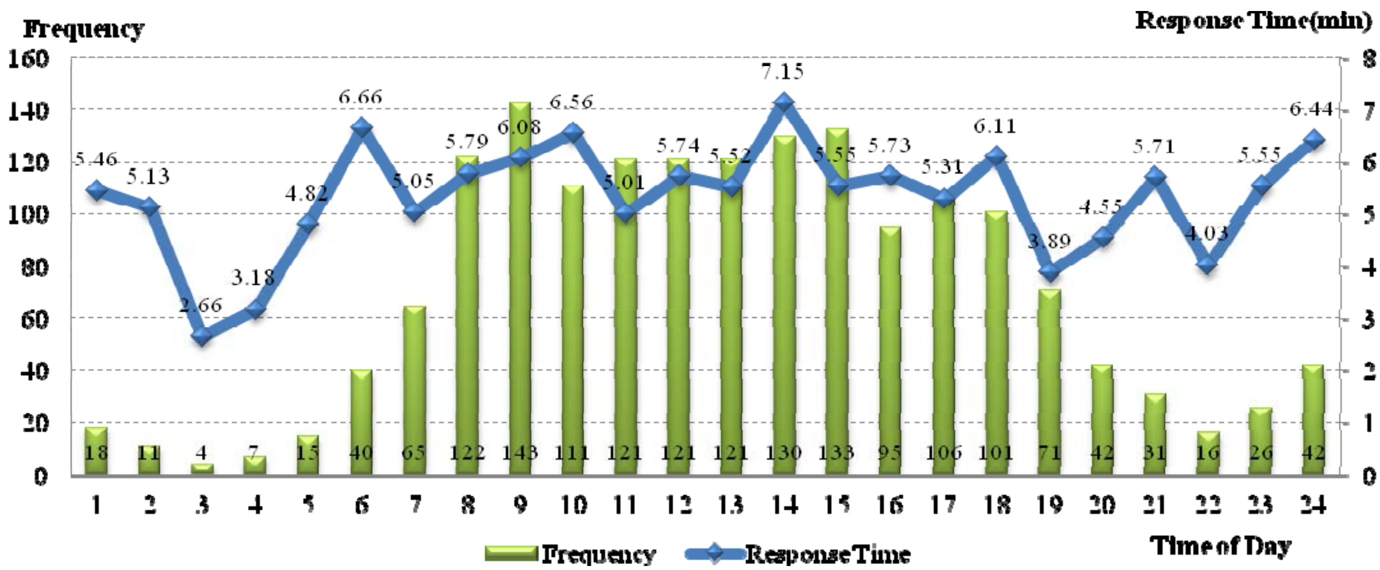


Figure 4.9 Average Response Time for AOC by Time of Day on Weekdays in 2012

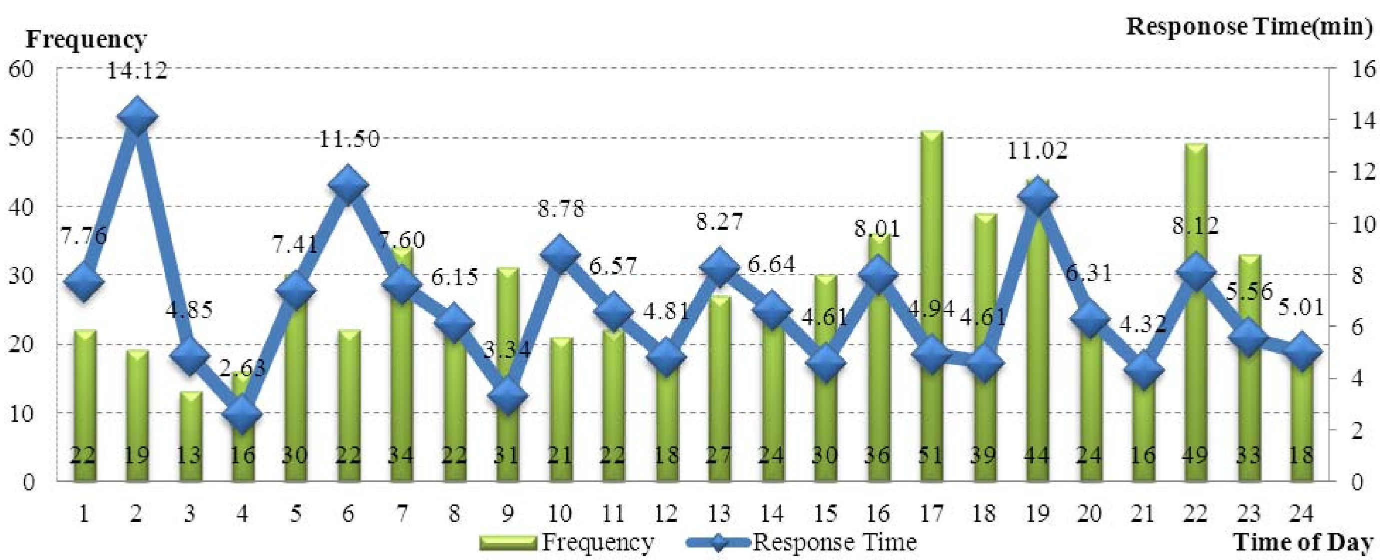


Figure 4.10 Average Response Time for SOC by Time of Day on Weekdays in 2012

The response times by TOC 3 and TOC 4 are very consistent during their operational periods (5 a.m. – 9 p.m.) between 9 and 13 minutes, and the responded incident frequencies also exhibit distinct patterns during peak periods. The average response times by TOC 3 during daytime operation hours are longer than those at night, whereas TOC 4 shows the reverse pattern.

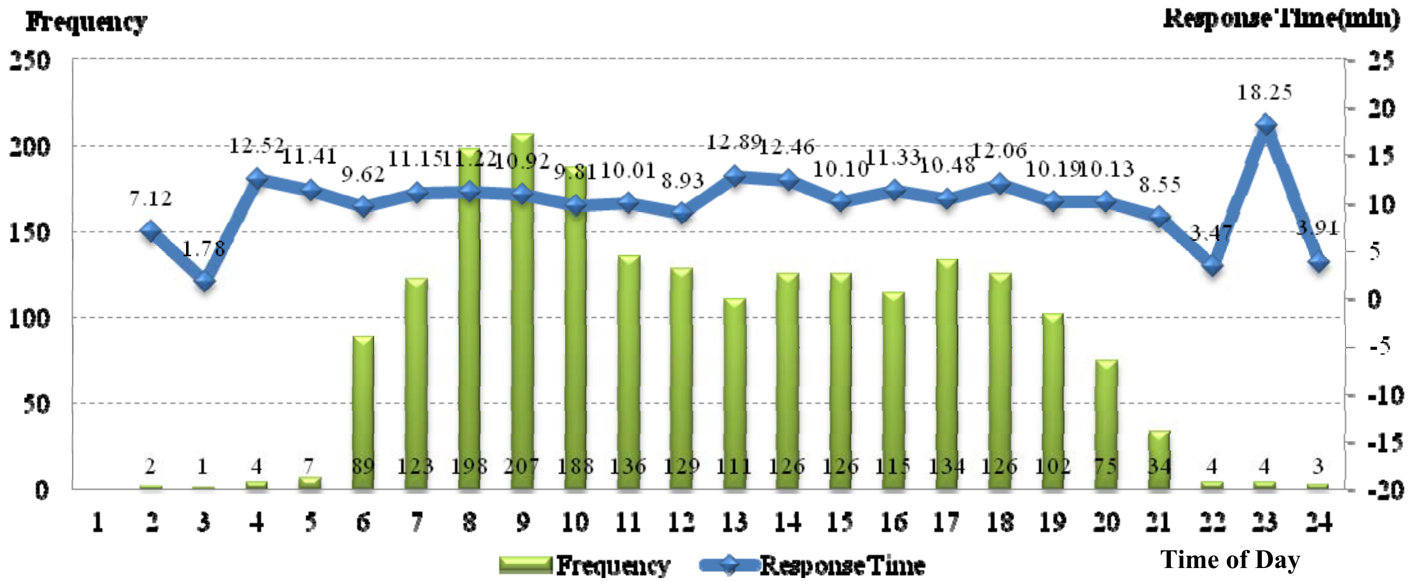


Figure 4.11 Average Response Time for TOC3 by Time of Day on Weekdays in 2012

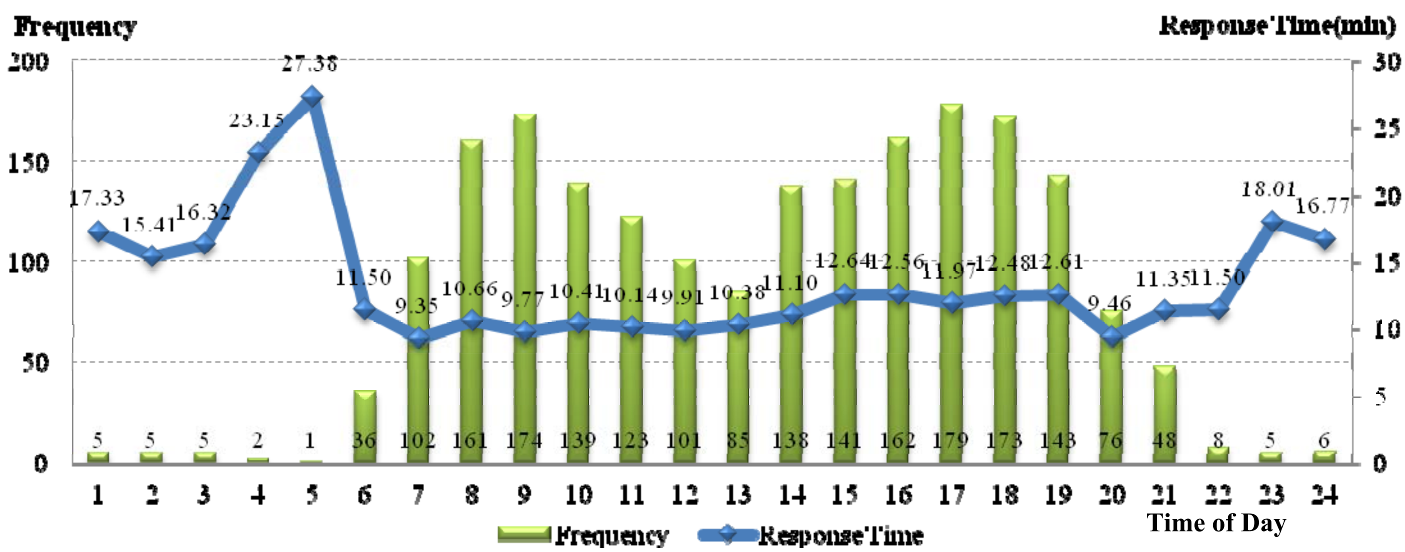


Figure 4.12 Average Response Time for TOC4 by Time of Day on Weekdays in 2012

TOC 7 shows a significantly different pattern where the average response time decreases as the time elapses throughout the day. As shown in the incident frequency chart, the p.m. peak period (4:30 p.m. – 6:30 p.m.) exhibited the highest incident frequency, but showed a relatively shorter average response time during its operation hours (5 a.m. – 9 p.m.).

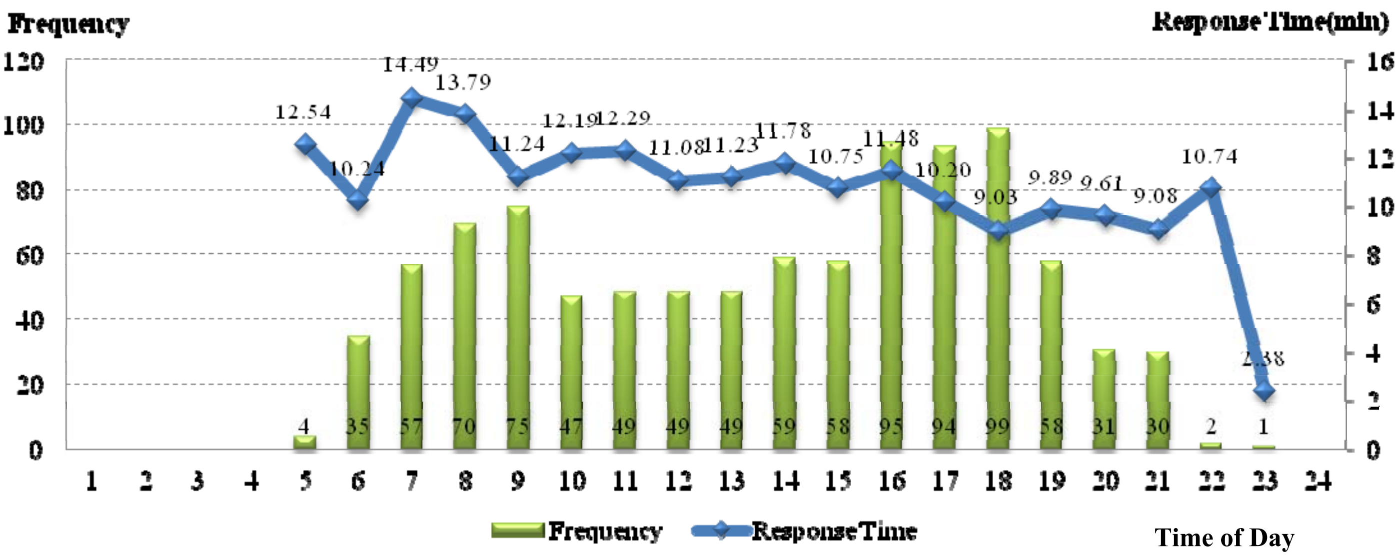
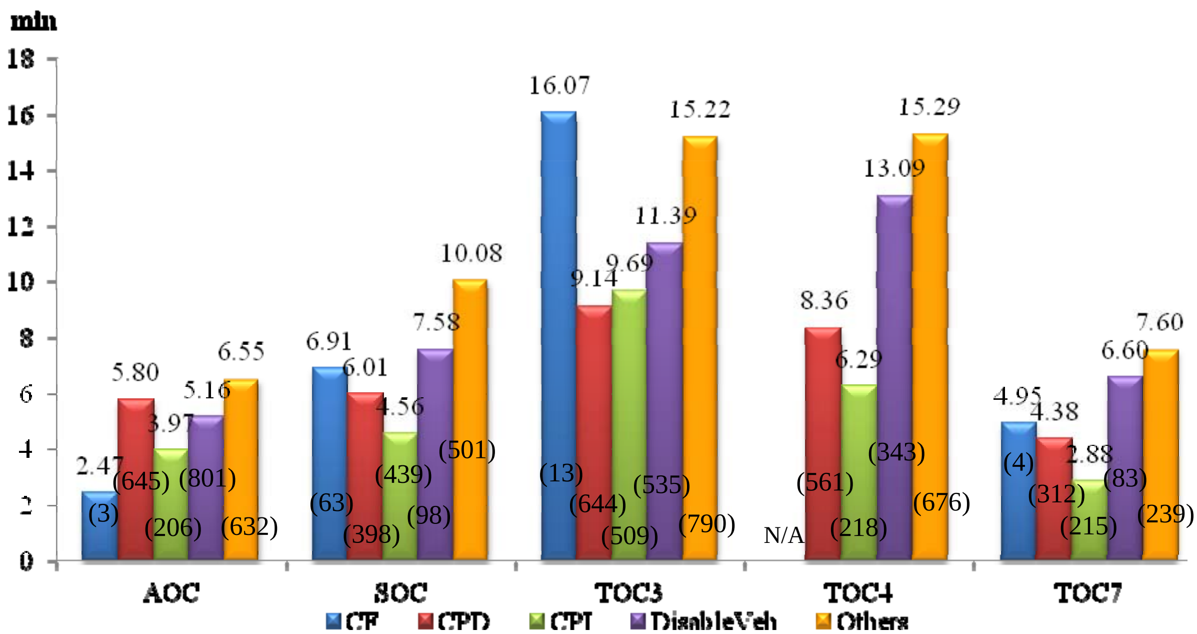


Figure 4.13 Average Response Time for TOC7 by Time of Day on Weekdays in 2012

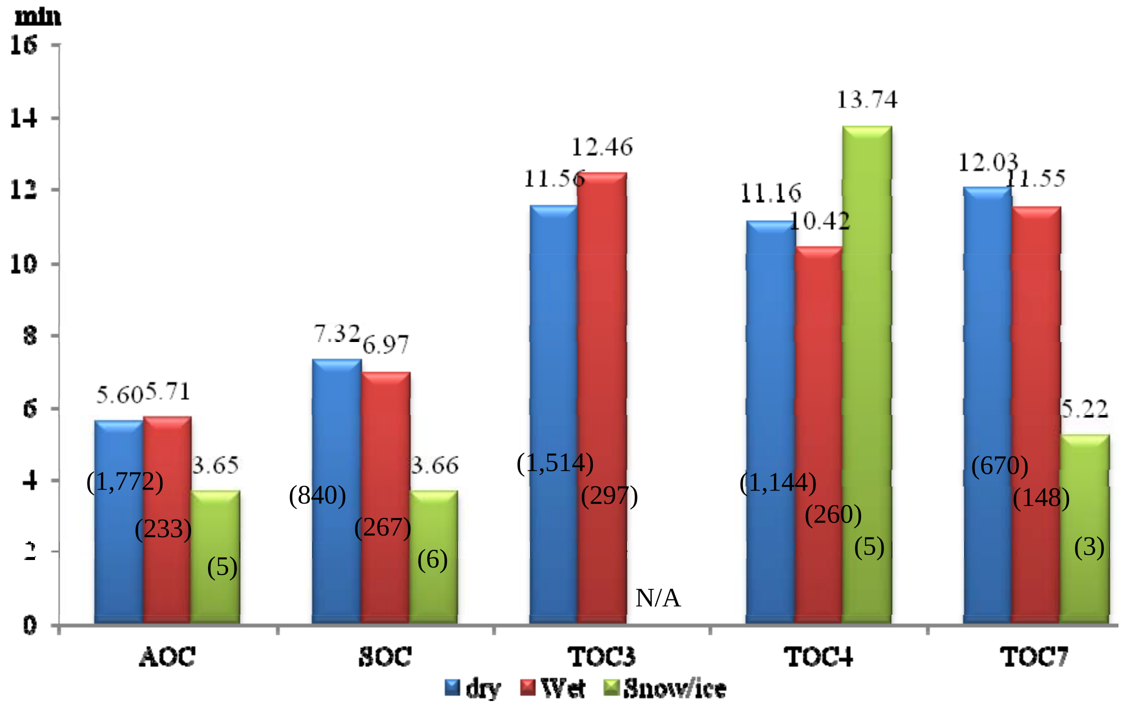
Figure 4.14 shows a further analysis of response efficiency, where all operation centers demonstrate faster responses for incidents involving vehicle collision and injuries (CPI). On the other hand, most operation centers took relatively longer response times for disabled vehicles and other types of incidents such as fire, debris, police activities, etc.



Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. Numbers in each parenthesis show frequencies.
3. *CF*, *CPD*, and *CPI* represents collision-fatality, collision-property damage, and collision-personal injury, respectively.
4. *Others* include police activities, off-road activities, emergency roadwork, debris in roadway, and vehicles on fire.

Figure 4.14 Average Response Times for Operation Centers by Incident Nature in 2012

With respect to the pavement conditions, most operation centers take longer response times under dry or wet conditions than snow/ice conditions. Overall, AOC shows a shorter average response than any other operation centers (See Figure 4.15).



Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. Numbers in the parenthesis show the data availability for this analysis.

Figure 4.15 Average Response Times for Operation Centers by Pavement Conditions in 2012

Figures 4.16 through 4.20 present the response times for operation centers by detection source. The bar graph represents the available data to compute the average response times, while the line graph represents the computed average response times. The major detection source for AOC is MDTA, while the CHART unit detects the most incidents to which SOC responded. For both operation centers, on average, the incidents detected by CHART units have a relatively fast response.

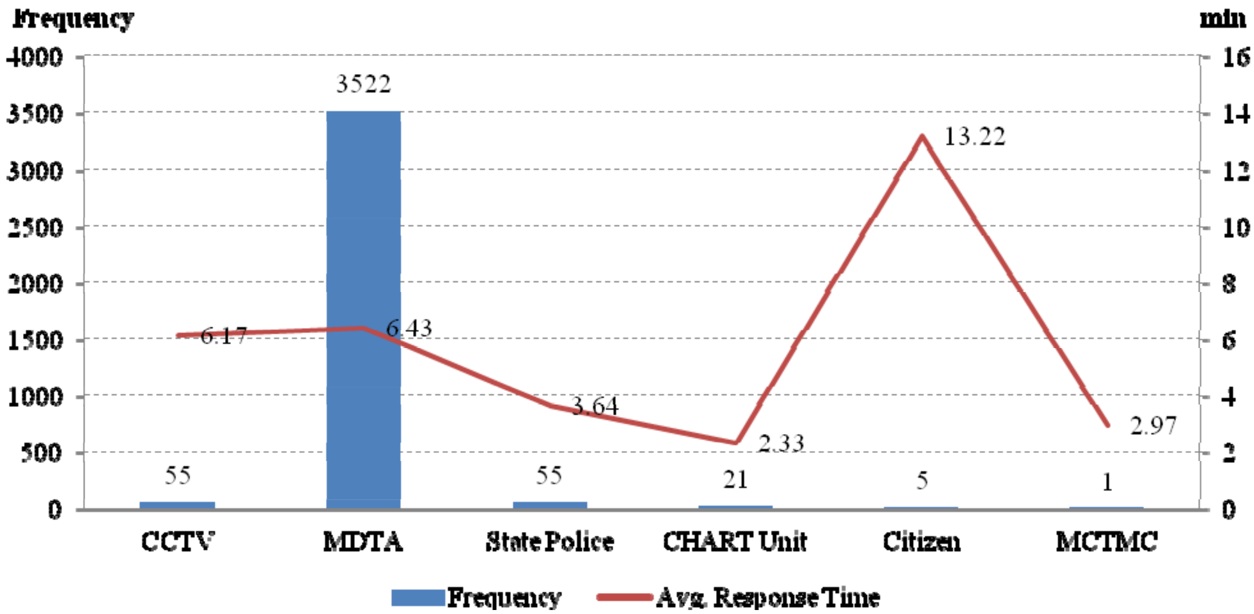


Figure 4.16 Average Response Times for AOC by Detection Source in 2012

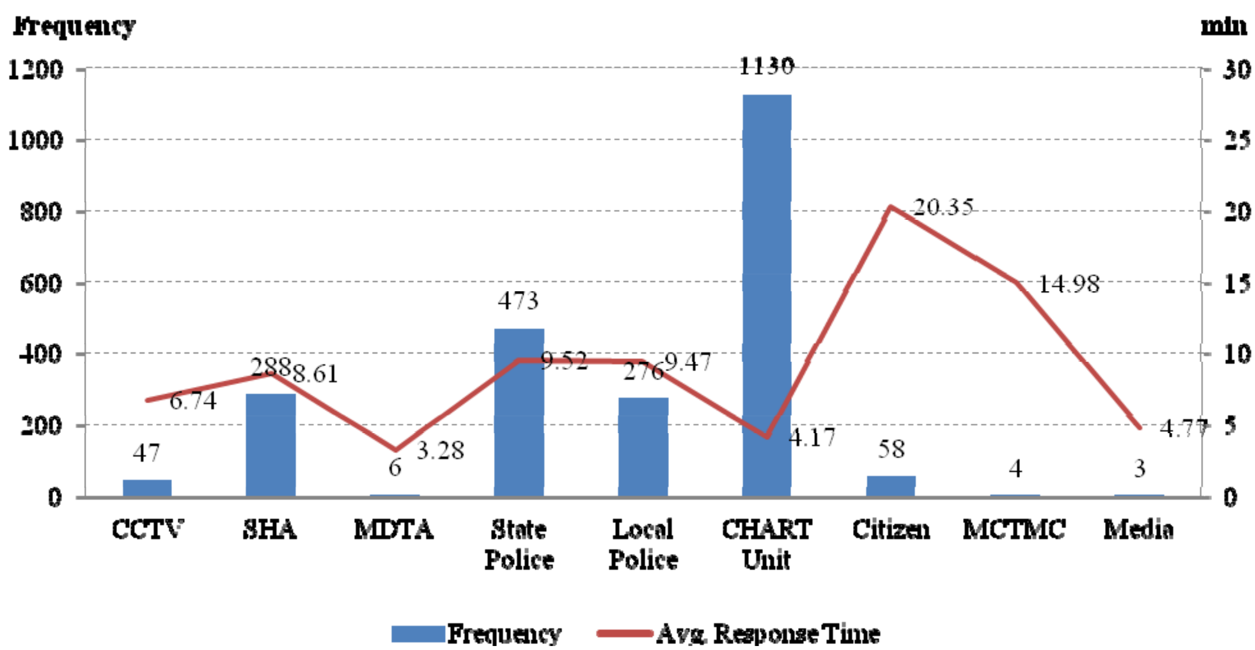


Figure 4.17 Average Response Times for SOC by Detection Source in 2012

For TOCs 3, 4, and 7, CHART and state police are the two major detection sources. However, the incidents detected by CHART units have a faster response than those detected via other sources in TOCs 3 and 4.

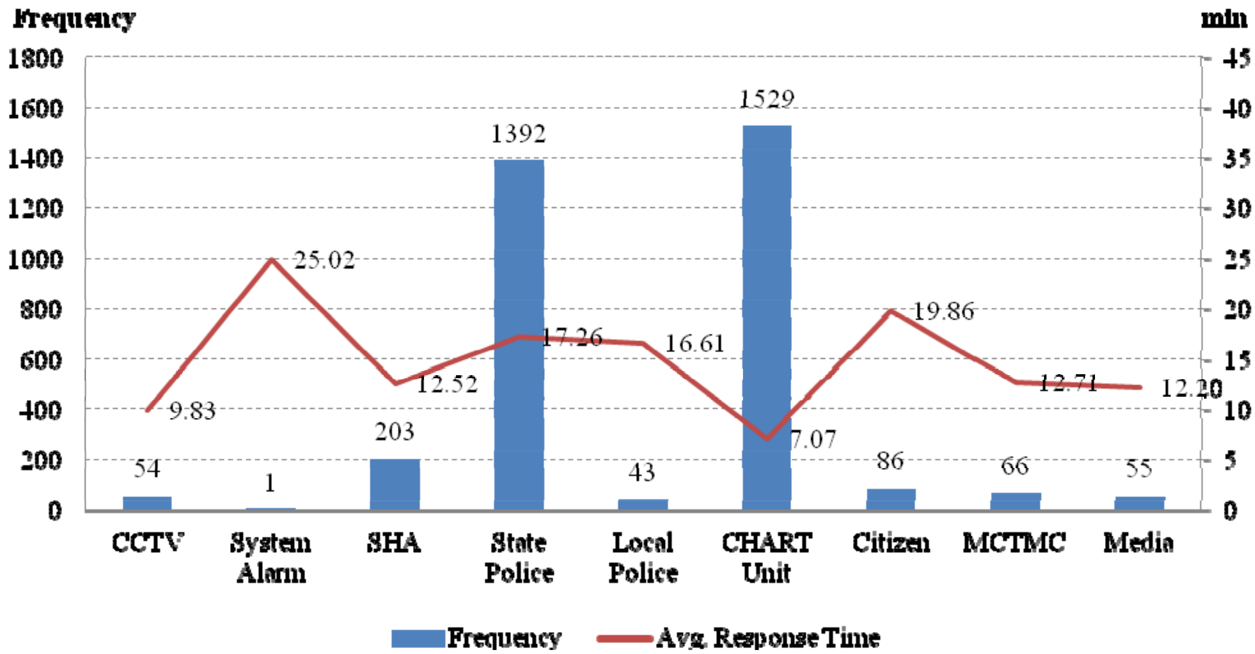


Figure 4.18 Average Response Times for TOC 3 by Detection Source in 2012

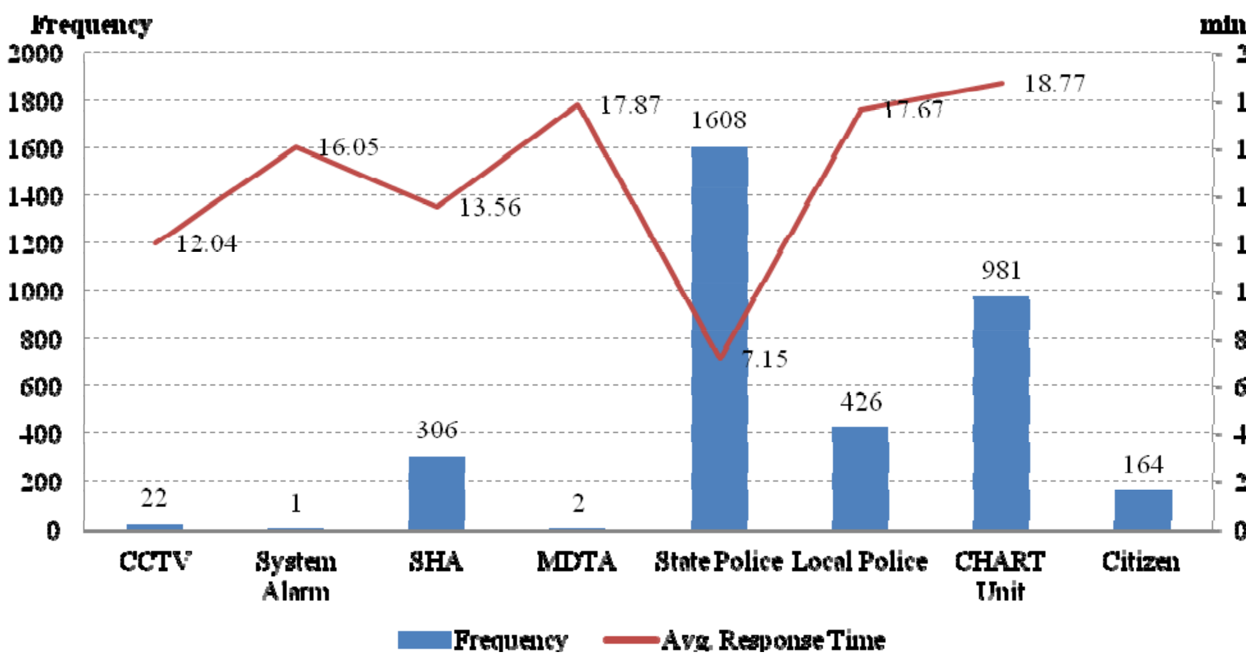


Figure 4.19 Average Response Times for TOC 4 by Detection Source in 2012

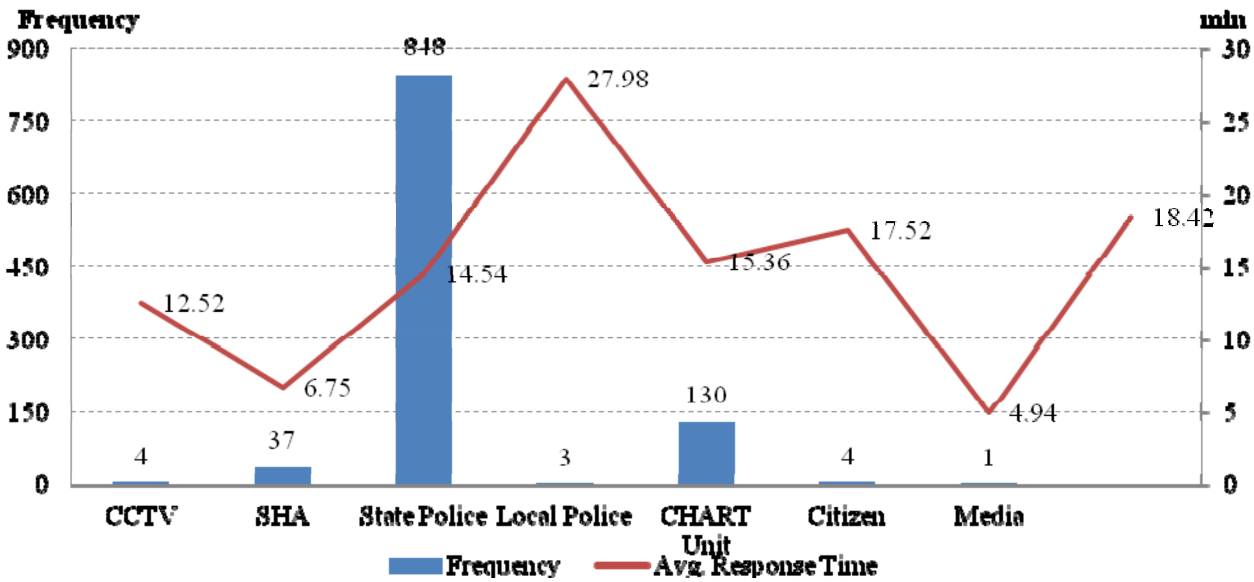
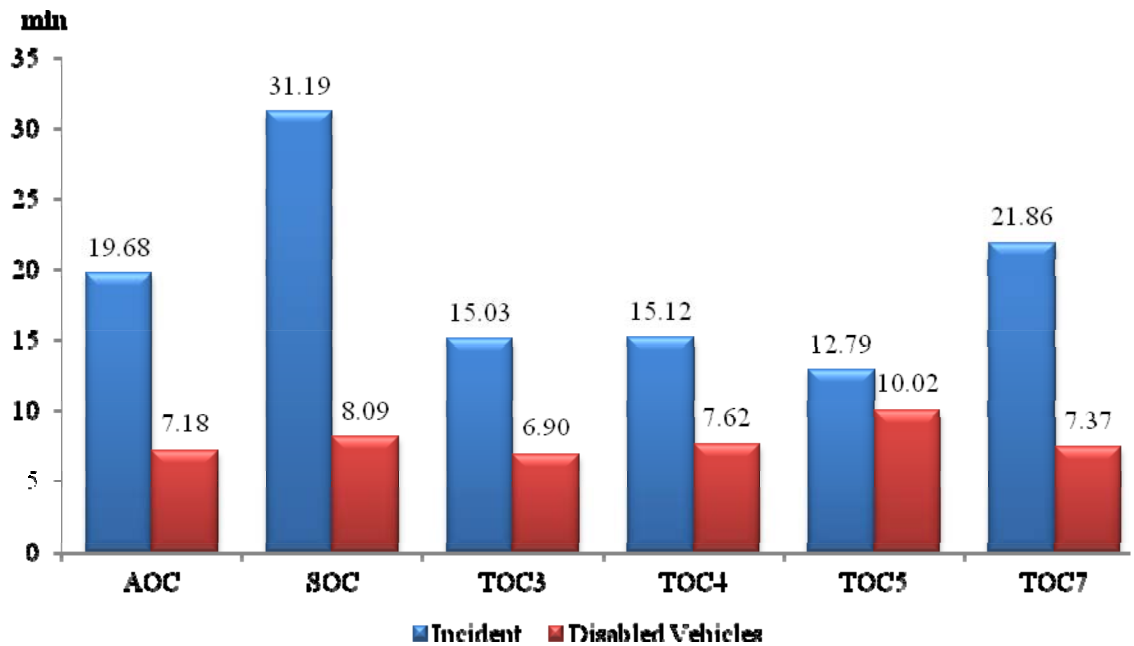


Figure 4.20 Average Response Times for TOC 7 by Detection Source in 2012

4.3 Analysis of Clearance Efficiency

As is well recognized, the efficiency of incident clearance could be varied by many factors. Figure 4.21 summarizes the performance of CHART incident clearance operations by operation center. The average clearance time by SOC is longer than any other for incidents, while TOC 5 has a longer average clearance time than any other for disabled vehicles. On the other hand, TOC 5 and TOC 3 show the smallest average clearance times for incidents and disabled vehicles, respectively. Further analysis of incident clearance times is presented in Chapter 6.



Note: Data only for incident duration between 1 minute and 120 minutes are used for this analysis.

Figure 4.21 Average Clearance Times by Operation Center in 2012

4.4 Reduction in Incident Duration

An essential performance indicator is the reduction in average incident duration due to the operations of CHART. Theoretically, a before-and-after analysis would be the most effective way to evaluate CHART's effects on incident duration. However, no incident-management-related data prior to CHART exists for any meaningful assessment. Hence, this study used the alternative of computing average incident clearance times in 2012 for non-responded incidents and those to which CHART responded. Since CHART's incident management team responded to most incidents in 2012, the data for non-CHART incidents are very limited.

As shown in Table 4.1, the average durations for clearing an incident with and without the assistance of CHART were, respectively, about 21.95 minutes and 28.95 minutes in 2012. Note that incidents with durations of less than one minute were excluded for the analysis. Also, incidents of Unknown Lane Blockage were redistributed into other blockage categories based on their resulting clearance times. Based on the results shown in Table 4.1, it seems clear that the assistance of CHART response units reduced the time it took to clear an incident. On average, CHART in 2012 contributed to a reduction in blockage duration of about 24.17 percent, which has certainly contributed significantly to savings in travel times, fuel consumption, and related socioeconomic costs. Note that the statistical results shown in Table 4.1 are likely to be biased, as only about 88 percent of incident reports contain all the required information (i.e., received time and cleared time) for incident duration computation.

Table 4.1 Comparisons of Incident Durations for Various Types of Lane Blockages in 2012 (Duration= Cleared Time-Received Time)

Blockage	With SHA Patrol		Without SHA Patrol	
	Duration (min)	Sample Frequency	Duration (min)	Sample Frequency
Shoulder	18.01	2,591	28.02	724
1 lane	19.92	6,764	26.45	960
2 lanes	33.17	1,206	39.92	173
3 lanes	43.06	340	46.10	42
>=4 lanes	45.82	137	52.40	19
Weighted Average	**21.95** (22.14)	**11,038** (12,872)	**28.95** (29.44)	**1,918** (601)
Unknown	17.67	4,480	25.41	558

Note: 1. Incidents with durations of less than 1 minute were excluded from the analysis.

2. Cases of “Unknown” blockage were redistributed into different blockage categories.

3. The numbers in parentheses show the results from year 2011

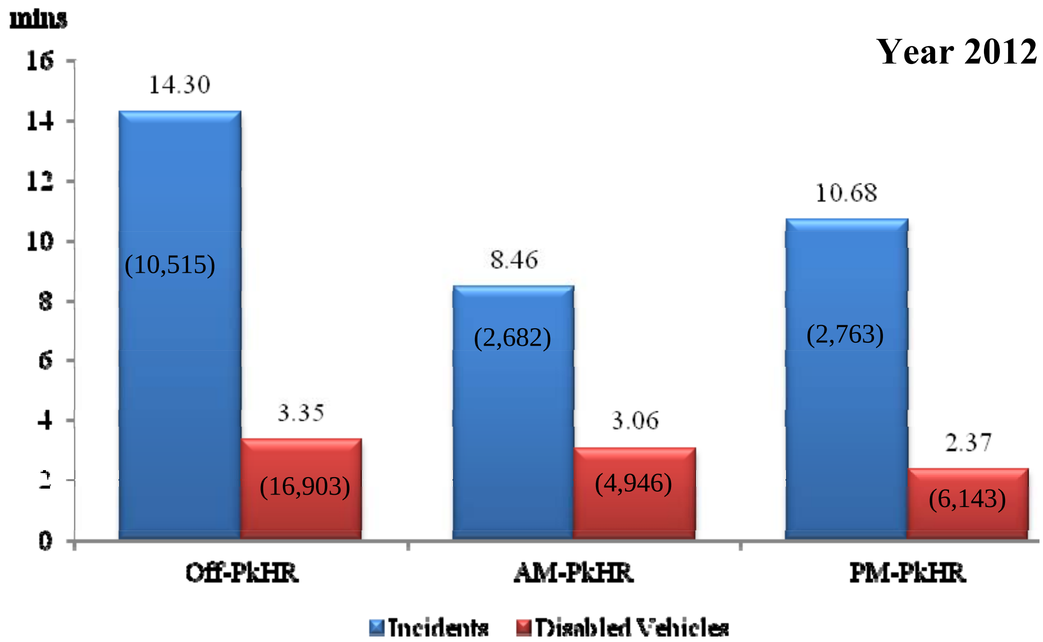
CHAPTER 5
ANALYSIS OF RESPONSE TIMES

A large body of traffic studies has pointed out the critical role of efficient response to the total delay incurred by incidents and concluded that an increase in incident response time may contribute to the likelihood of having secondary incidents (Bentham, 1986; Brodsky and Hakkert, 1983; Mueller et al., 1988). The study results by Sanchez-Mangas et al. (2009) show that a reduction of 10 minutes in emergency response time could result in 33 percent less probability of incurring vehicle collision and fatalities. Most studies conclude that dispatching emergency services units and clearing the incident scenes in a timely manner are the key tasks for minimizing incident impact (Kepaptsoglou et al., 2011: Huang and Fan, 2011).

For these reasons, this chapter presents the results from the statistical analysis of incident response times; this analysis provides a fundamental insight into the characteristics of incident response times under various conditions.

5.1 Distribution of Average Response Times by Time of Day

Figure 5.1 compares response times by time of day in 2012 and 2011. In the case of peak hours, in 2012, the response time during a.m. peak hours was slightly shorter than that during p.m. peak hours for incidents, whereas the reverse pattern appears for disabled vehicles. The response times to incidents during off-peak hours were longer than those during peak hours in 2012.



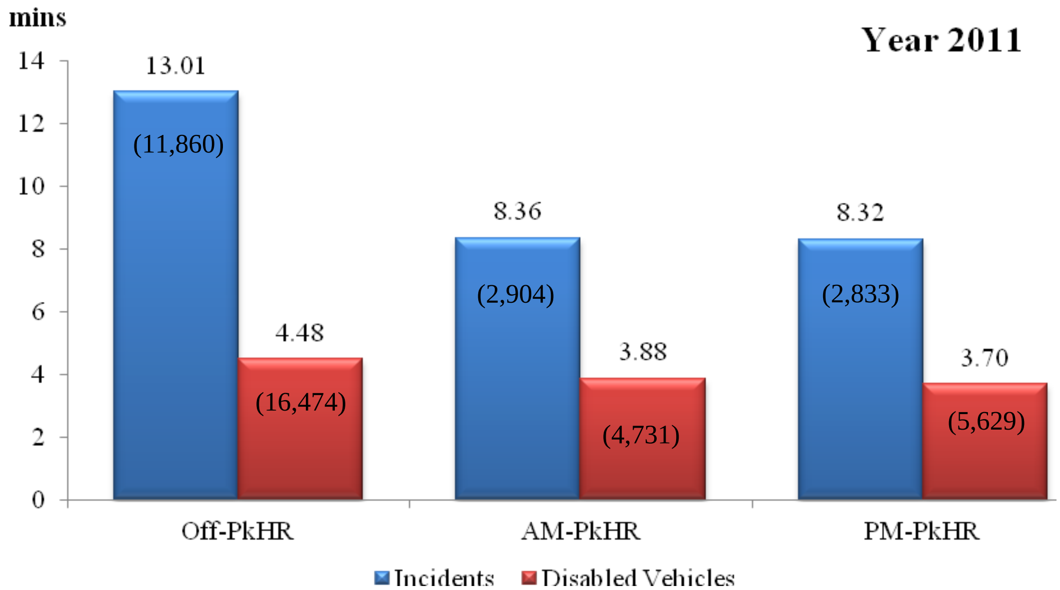
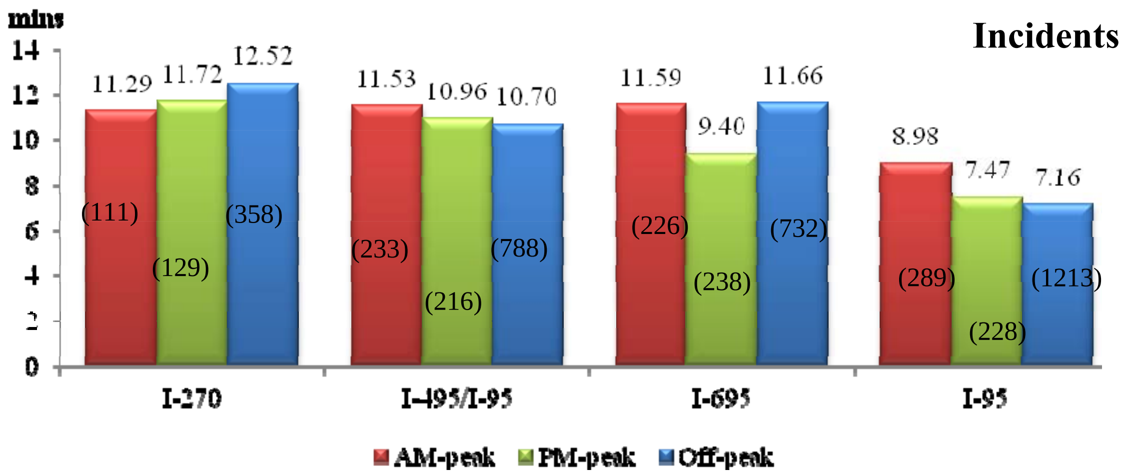
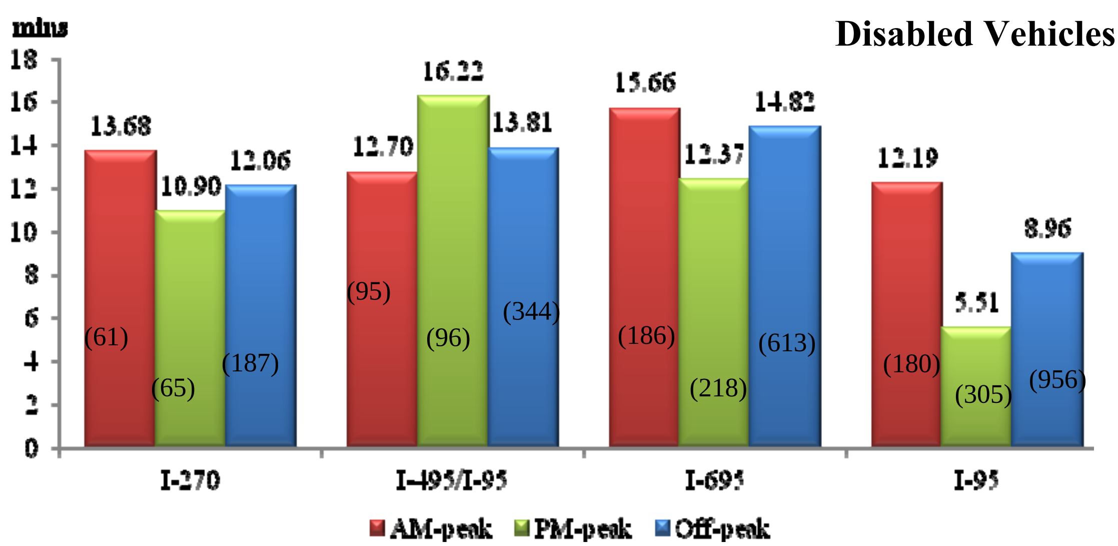


Figure 5.1 Average Response Time Distributions by Time of Day in 2012 and 2011

Figure 5.2 shows the average response times by different times of day through the major roads. The incidents on I-270 experienced the longer durations during the p.m. peak period, while the incidents on I-495/I-95, I-695, and I-95 suffered longer times during the a.m. peak period. For disabled vehicles, the response times during the a.m. peak hour were longer than those for any other periods on I-270, I-695, and I-95, whereas disabled vehicles on I-495/I-95 had a longer response during the p.m. peak hour.



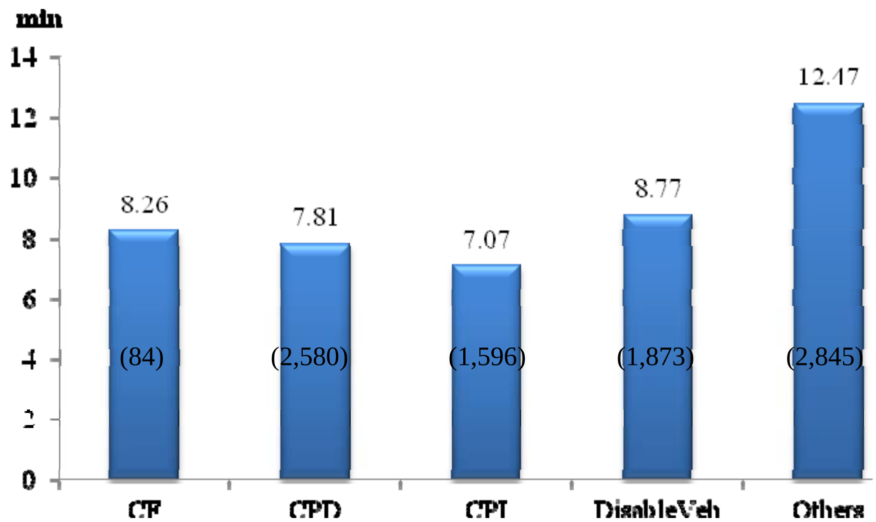


Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. Numbers in each parenthesis show frequencies.

Figure 5.2 Average Response Time Distributions for Roads by Time of Day in 2012

5.2 Distribution of Average Response Times by Incident Nature

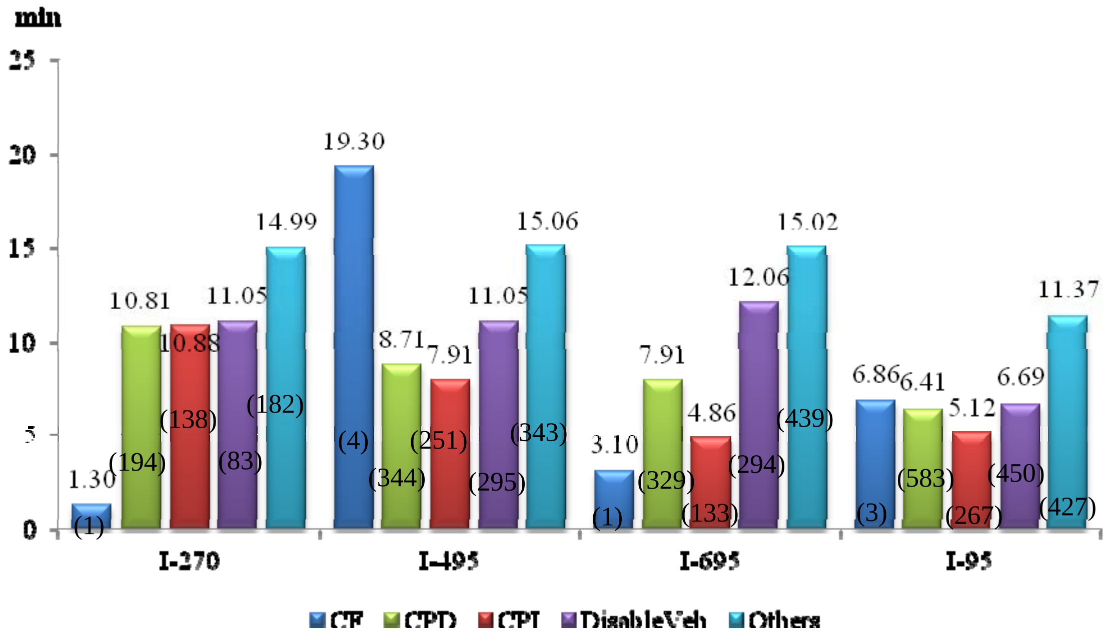
Figure 5.3 shows that the response times are likely to decrease as a detected incident becomes severe. For instance, the collision types of incidents, causing any fatality, injuries, or property damages (CF, CPI, and CPD), usually lead to quicker responses than any other types of incidents.



Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. Numbers in each parenthesis show frequencies.
3. *CF*, *CPD*, and *CPI* represents collision-fatality, collision-property damage, and collision-personal injury, respectively.
4. *Others* include police activities, off-road activities, emergency roadwork, debris in roadway, and vehicles on fire.

Figure 5.3 Average Response Time by Incident Nature in 2012

A similar pattern of decreased response times as the incident becomes severe appears on I-270, I-95 and I-695. However, as shown in Figure 5.4, the average response time for incidents involved with a fatality shows the longest on I-495.

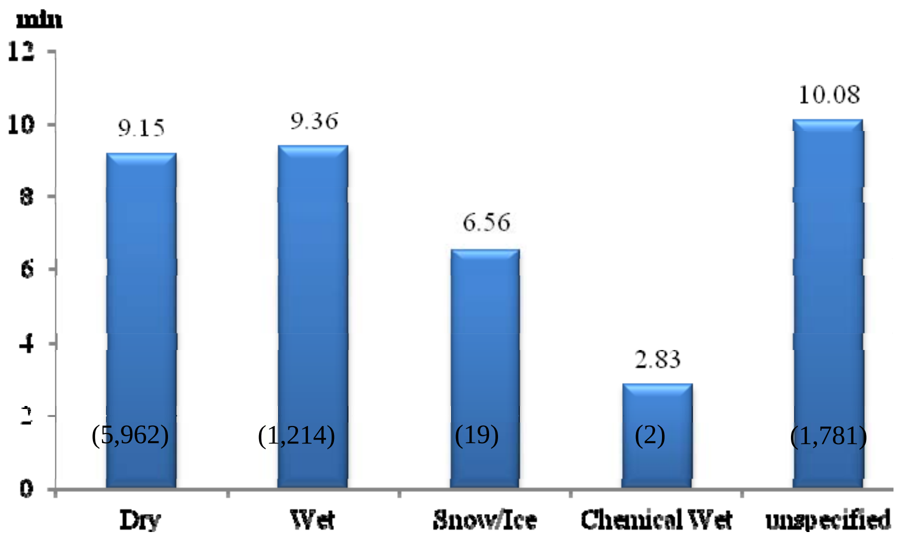


Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. Numbers in parenthesis show frequencies.

Figure 5.4 Average Response Time for Roads by Incident Nature in 2012

5.3 Distribution of Average Response Times by Various Factors

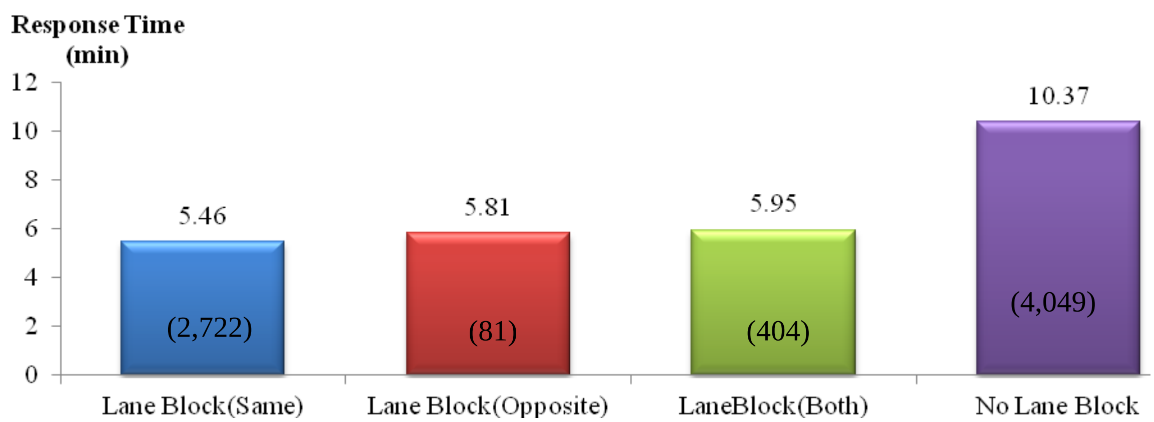
This section presents the results of analysis on how other factors would influence the response times. Figure 5.5 illustrates that the response times may vary with the pavement conditions. The responses are likely to be faster on snow/ice pavement, whereas they tend to be slower on wet or dry conditions. This factor reflects the weather conditions that are usually unavailable in most incident databases. When the pavement is chemically wet, the response time is likely to be faster than under any other conditions.



Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. Numbers in parentheses show frequencies.

Figure 5.5 Average Response Time by Pavement Condition in 2012

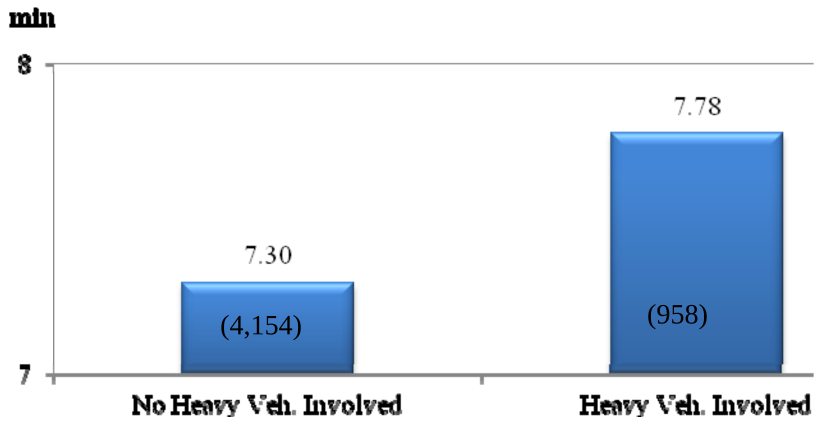
As summarized in Figure 5.6, incidents causing lane closure are likely to have a faster response than those not involved with a lane closure. Figures 5.4 and 5.6 illustrate that the response times are likely to be shorter for more severe incidents such as those causing a fatality, an injury, or a lane closure.



Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. Numbers in parentheses show frequencies.

Figure 5.6 Average Response Time by Lane Blockage in 2012

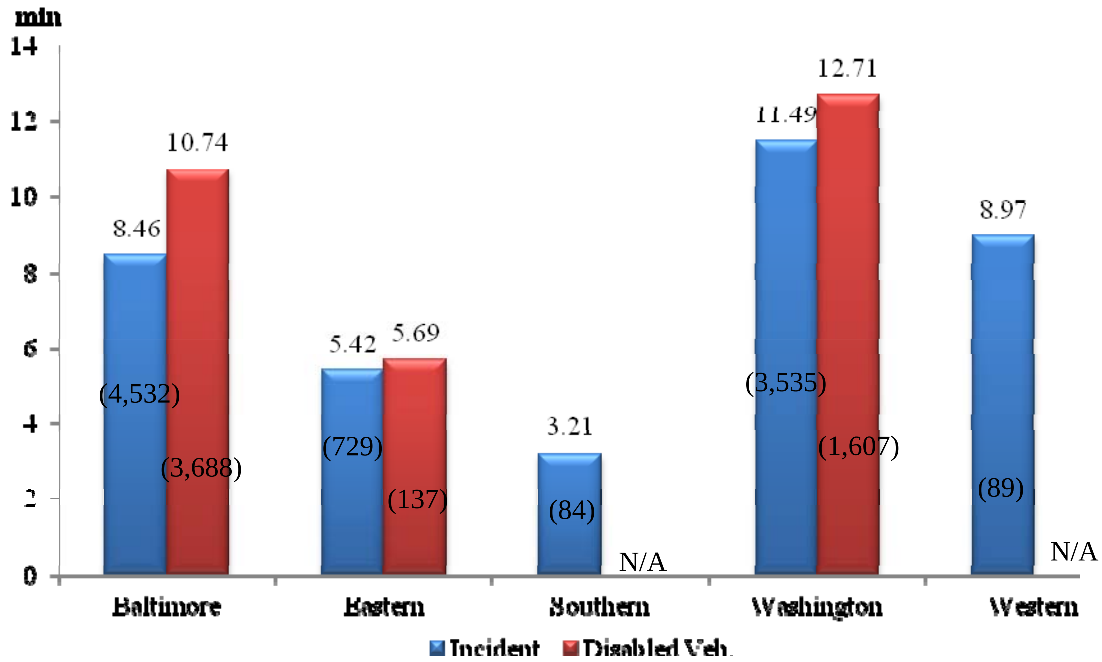
When a detected incident is involved with any heavy vehicles such as vans, SUVs, pick-up trucks, single-unit trucks, and tractor-trailers, the response is slightly longer, as shown in Figure 5.7.



Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. Numbers in parentheses show frequencies.

Figure 5.7 Average Response Time by Heavy Vehicle Involvement in 2012

The response time may differ among regions, since the available resources and working environments differed for each operation center, including coverage area, incident rates, traffic volumes, etc. Figure 5.8 demonstrates that the response times were faster in suburban areas, including Eastern, Southern, and Western Maryland, than for the metropolitan areas such as the Baltimore and Washington regions. Urban areas are more likely to have higher incident rates and heavier traffic volumes, which could impede the efficiency of response units. One can also notice that the responses for incidents (blue bins in Figure 5.8) would be quicker than those for disabled vehicles (red bins in Figure 5.8) in most regions.



Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. Numbers in parentheses show frequencies.

Figure 5.8 Average Response Time by Region in 2012

CHAPTER 6

ANALYSIS OF INCIDENT DURATIONS

For effective and efficient traffic management after incidents, responsible agencies can convey information to travelers by updating variable message signs, estimating the resulting queue length, assessing the need to implement detour operations, and performing any other control strategies to mitigate congestion. To maximize the effectiveness of these operational measures, reliably predicted/estimated incident durations will certainly play an essential role.

This chapter presents the results from the statistical analysis of incident duration data; this analysis provides a fundamental insight into the characteristics of incident duration under various conditions. In this analysis, the distributions of average incident duration are identified by the following categories: Nature, County, County and Nature, Weekdays and Weekends, Peak and Off-Peak Hours, CHART Involvement, and Roads.

6.1 Distribution of Average Incident Durations by Nature

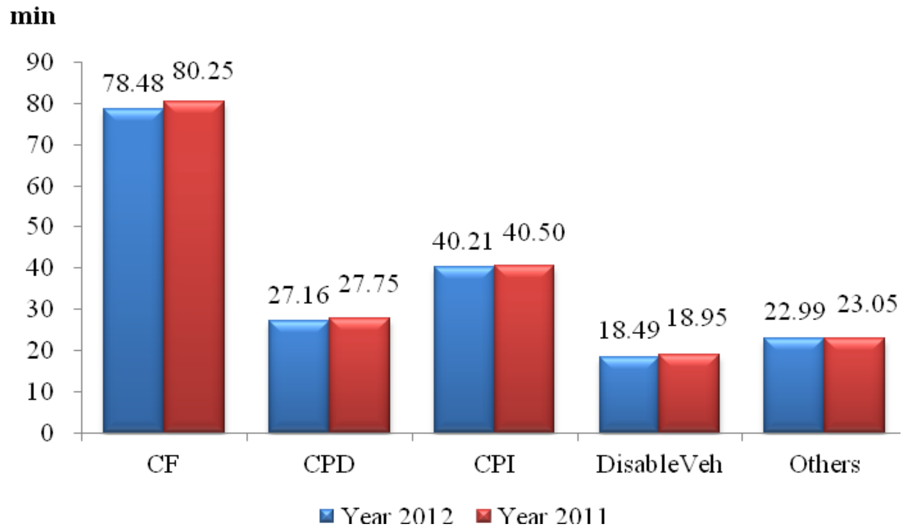
In general, incidents are classified into two large groups, based on whether or not they involve collisions. The first group, incidents with collisions, consists of three types: collisions with fatalities (CFs), collisions with personal injuries (CPIs), and collisions with property damage (CPDs). The second group, incidents without collisions, includes incidents of various natures, such as disabled vehicles, debris in the roadway, vehicles on fire, police activities, etc. Table 6.1 summarizes the categories of incidents by their nature as used in the remaining analysis.

Table 6.1 Categories of Incident Natures

<table>
<tr><td rowspan="9">Incidents</td><td rowspan="3">With Collisions</td><td colspan="2">Collisions-Fatalities(CF)</td></tr>
<tr><td colspan="2">Collisions-Property Damage (CPD)</td></tr>
<tr><td colspan="2">Collisions-Personal Injuries (CPI)</td></tr>
<tr><td rowspan="6">Without Collisions</td><td colspan="2">Disabled Vehicles</td></tr>
<tr><td rowspan="5">Others</td><td>Police Activities</td></tr>
<tr><td>Off-Road Activities</td></tr>
<tr><td>Emergency Roadwork</td></tr>
<tr><td>Debris in Roadway</td></tr>
<tr><td>Vehicles on Fire</td></tr>
</table>

Note that *Disabled Vehicles*, one type of incident, are defined as those disabled vehicles that interrupt the normal traffic flow on the main lanes. In the category of incidents without collisions, most are *Disabled Vehicles*. In 2012, about 40 percent of incidents without collisions were caused by Disabled Vehicles. A similar pattern was also observed in 2011, when about 44 percent of non-collision incidents occurred due to Disabled Vehicles. In contrast, the other types of non-collision incidents occurred in relatively low frequencies; therefore, the study classifies all such incident types as one category, i.e., *Others*, as shown in Table 6.1.

Figure 6.1 summarizes the average incident duration of each type for year 2012. The statistical results indicate that the average incident duration for *CFs* is significantly higher than for the other incident natures. Statistically, an incident that has resulted in a fatality can last more than an hour on average. In contrast, incidents caused by *Disabled Vehicles*, on average, were much shorter in duration.

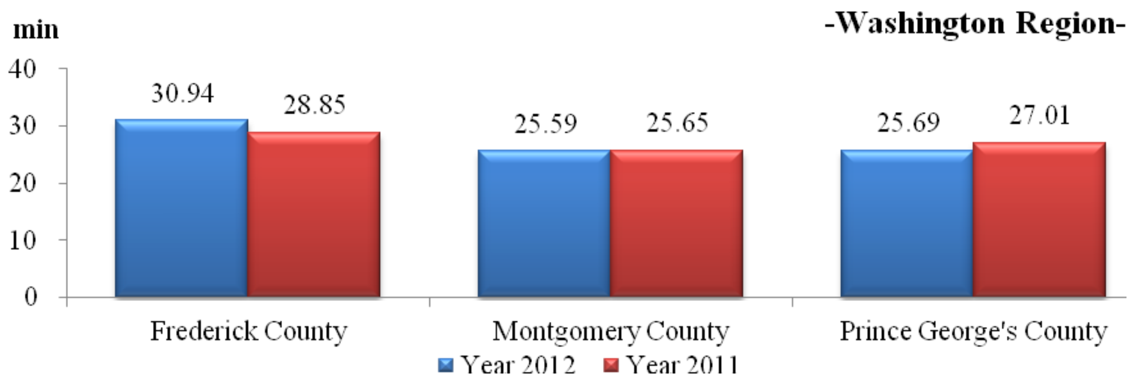


Note: 1. Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis
2. *CF*, *CPD*, and *CPI* represents collision-fatality, collision-property damage, and collision-personal injury, respectively.

Figure 6.1 Distribution of Average Incident Duration by Nature in 2012 and 2011

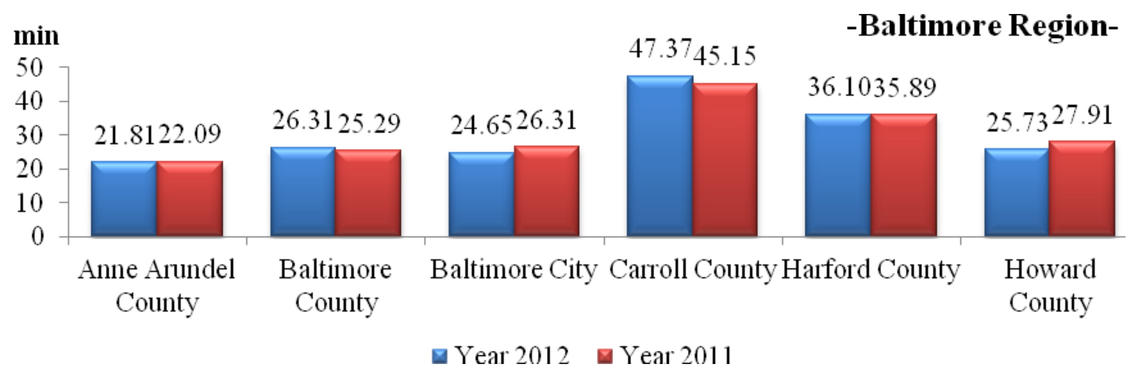
6.2 Distribution of Average Incident Durations by County and Region

The distribution of incident durations also varies between counties and regions. In the Washington region, the area around Washington D.C. (Montgomery and P.G. Counties) has much shorter incident duration, as shown in Figures 6.2. Figures 6.3 to 6.5 illustrate that incident durations in the Baltimore region were likely to be shorter than those in other regions. However, Figure 6.3 shows that the incidents especially around Carroll and Harford Counties had longer durations than incidents occurring in any other counties in the Baltimore region.



Note: Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis

Figure 6.2 Distribution of Average Incident Duration by County in Washington Region in 2012 and 2011

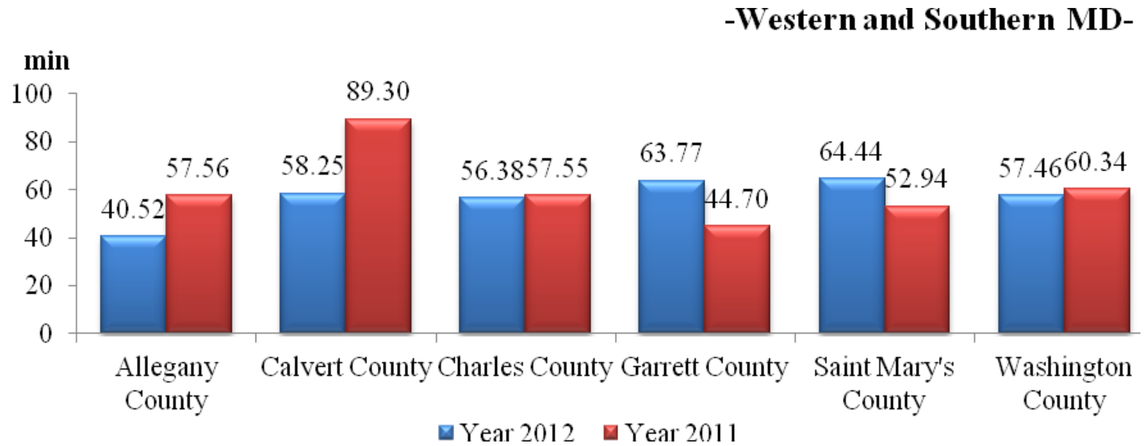


Note: Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis

Figure 6.3 Distribution of Average Incident Duration by County in Baltimore Region in 2012 and 2011

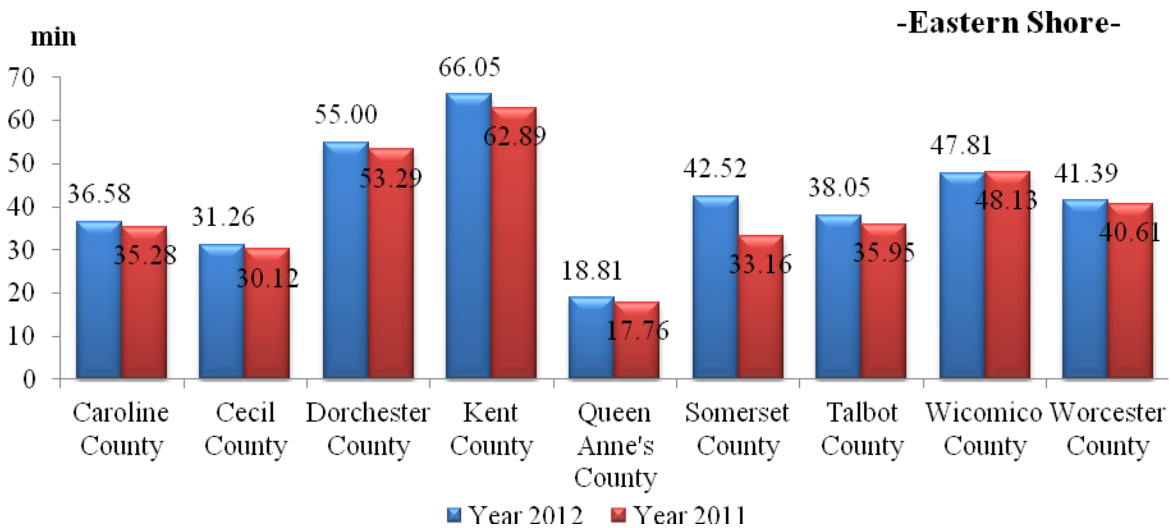
Incidents that occurred in counties of western and southern Maryland mostly resulted in relatively longer durations. Figure 6.4 shows that the average incident duration in these areas is usually about one hour. Allegany County had the shortest average incident duration in western and southern Maryland in the year 2012.

Similarly, the incidents occurring in Dorchester and Kent Counties on the Eastern Shore (Figure 6.5) are highly likely to result in longer durations than those in any other area of Eastern Shore. On the other hand, incidents occurring in Queen Anne’s County on the Eastern Shore take about 19 minutes on average to be cleared.



Note: Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis

Figure 6.4 Distribution of Average Incident Duration by County in Western and Southern Regions in 2012 and 2011



Note: Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis

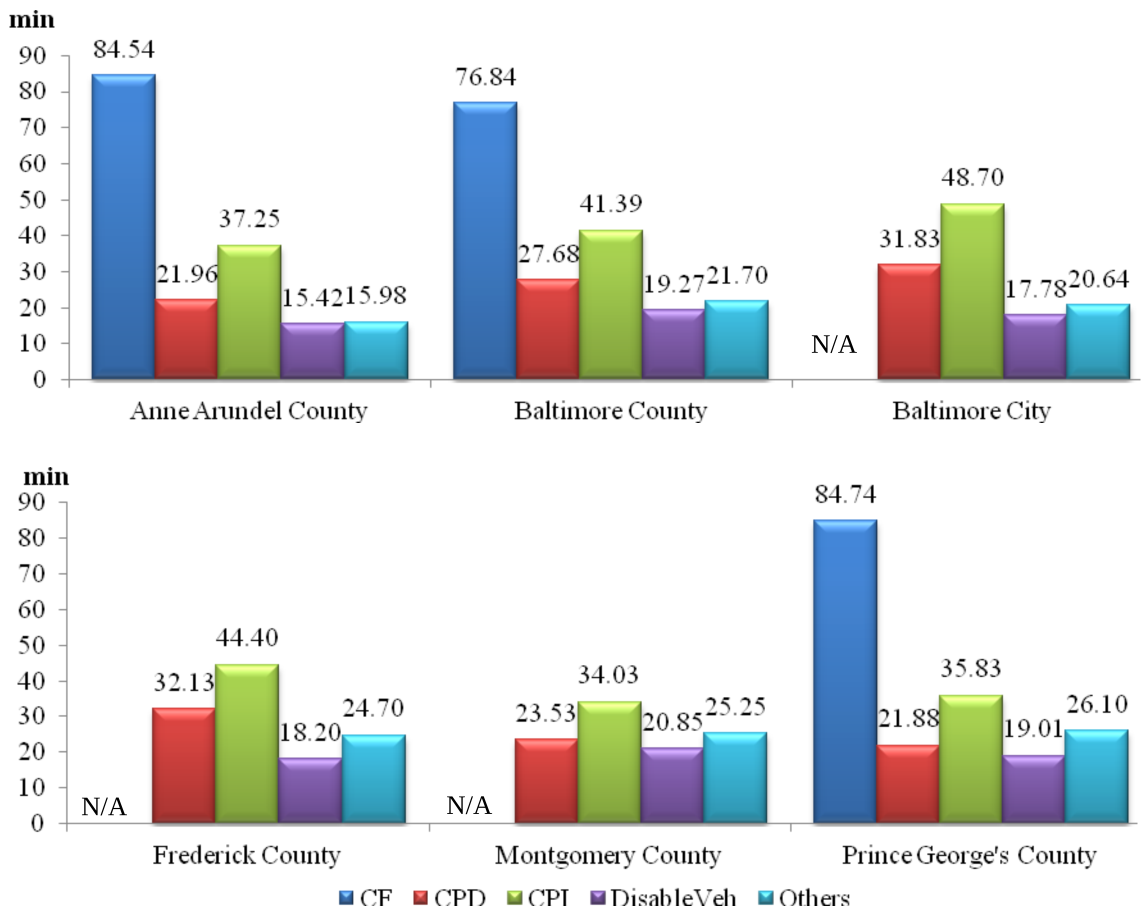
Figure 6.5 Distribution of Average Incident Duration by County on Eastern Shore in 2012 and 2011

Table 6.2 summarizes the average response times, clearance times and incident durations by region. One can easily notice that the average response time in the southern area was relatively short, although it took longer to clear the detected incident than in any other region. On the other hand, the Washington region takes longer to respond to an incident, even though the average clearance time was shorter than for any other areas in Maryland in 2012.

Table 6.2 Summary of Incident Duration Components by Region

Region	Sample Frequency*	Avg. Response Time (mins)	Avg. Clearance Time (mins)	Avg. Incident Duration (mins)
Baltimore	6,640	6.01	19.43	25.43
Washington	4,744	9.35	17.60	26.95
Western	103	7.77	43.82	51.60
Southern	87	4.20	54.02	58.22
Eastern	878	4.02	21.69	25.71

* Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis.



*Note: 1. Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis.
2. CF, CPD, and CPI stand for collision-fatality incident, collision-property damage incident, and collision-personal injury incident, respectively.

Figure 6.6 Distribution of Average Incident Duration by County and Nature

Figure 6.6 compares incident durations by nature only for several major counties in Maryland. As shown in the figure, the average incident duration for *CF* in Baltimore County was shorter than in any other area. On the other hand, CF-related incidents in Anne

Arundel and Prince George's Counties mostly resulted in relatively long durations. In most areas, the incident durations are highly likely to increase as the incident becomes more severe. For instance, the incidents with any fatality showed the longest durations, followed by incidents with personal injury, incidents with property damage, and so on.

6.3 Distribution of Average Incident Durations by Weekdays/Ends and Peak/Off-Peak Hours

According to Table 6.3, although the average response times for weekdays and weekends in 2012 have only about two minutes' difference, the average clearance time for weekends was approximately 1.3 times longer than that for weekdays. As a result, weekend incidents were highly likely to last longer than those occurring on weekdays. This would be mostly because fewer response teams are available during weekends than during weekdays; thus, it would take more time to clear the incident scene.

Table 6.3 Distribution of Average Incident Duration by Weekday and Weekend

		Sample* Frequency	Avg. Response Time	Avg. Clearance Time	Avg. Incident Duration
Weekdays	**2012**	10,907	7.39	18.69	26.08
	2011	11,522	7.26	18.85	26.11
Weekends	**2012**	1,555	5.43	24.00	29.43
	2011	1,642	6.00	24.11	30.11

Note (*): 1. Incident records with the completed data items for duration computation
2. Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis.

Table 6.4 Distribution of Average Incident Duration by Off-Peak and Peak Hours

		Sample* Frequency	Avg. Response Time	Avg. Clearance Time	Avg. Incident Duration
Off-Peak	**2012**	8,079	7.21	20.41	27.62
	2011	8,677	7.15	20.45	27.60
Peak*	**2012**	4,383	7.02	17.40	24.42
	2011	4,487	7.01	17.68	24.69

Note (*): 1. Incident records with the completed data items for duration computation
2. Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis.
3. 7:00 AM to 9:30 AM and 4:00 PM to 6:30 PM

Table 6.4 shows that the average clearance time during off-peak hours was longer than during peak hours. Consequently, the average duration for incidents occurring during off-peak hours was longer than for those during peak hours.

6.4 Distribution of Average Incident Durations by CHART Involvement, Pavement Condition, Heavy Vehicle Involvement, and Road

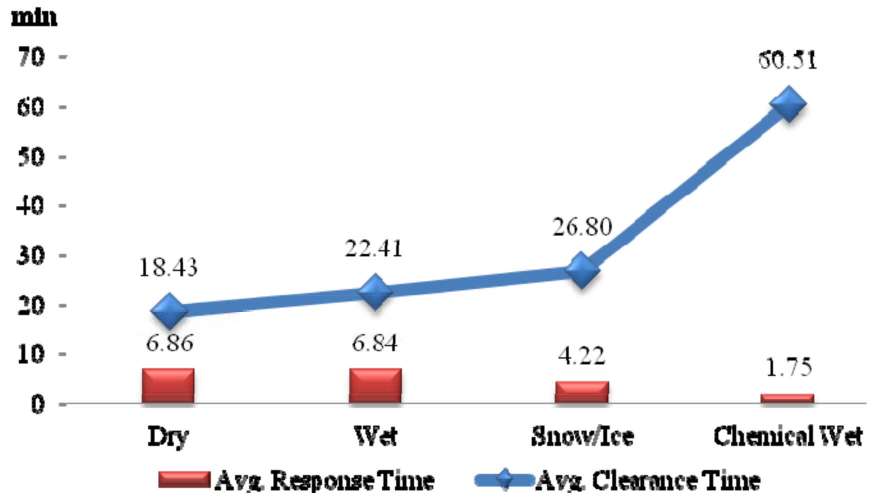
Whether or not CHART responded to an incident is another significant factor affecting the distribution of incident durations. When CHART was involved in the incident recovery task, the incident duration was likely to be reduced. This observation indicates that CHART played an efficient role in shortening incident durations, reducing the delay caused by non-recurrent congestion.

Table 6.5 Distribution of Average Incident Duration without and with CHART

		Sample* Frequency	Avg. Response Time	Avg. Clearance Time	Avg. Incident Duration
w/ CHART	**2012**	10,490	7.62	18.29	25.91
	2011	10,569	7.69	18.32	25.99
w/o CHART	**2012**	1,972	4.61	25.00	29.61
	2011	2,595	4.74	24.36	29.10

* Incident records with the completed data items for duration computation

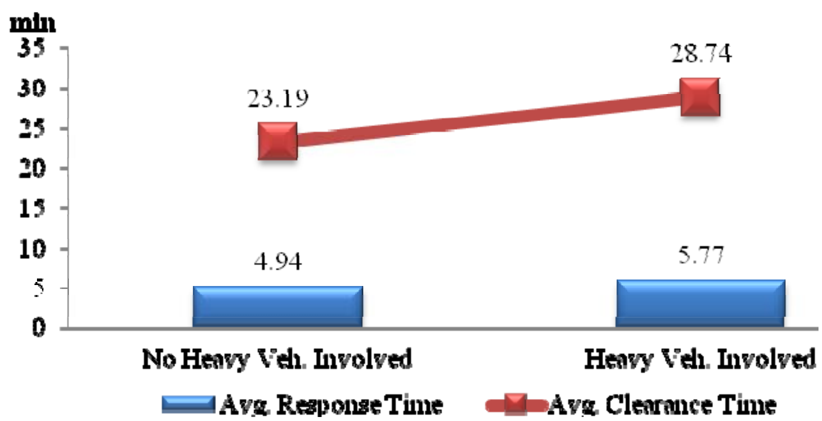
The response time and clearance time of incidents could vary, based on the pavement conditions. Figure 6.7 shows that the condition of chemically wet pavement such as an oil spill would lead to a faster response, but a longer clearance time, than any other conditions. Wet and snow/ice pavement conditions cause a shorter response but longer clearance performance than those on dry pavement.



Note: Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis.

Figure 6.7 Distribution of Average Incident Duration by Pavement Condition

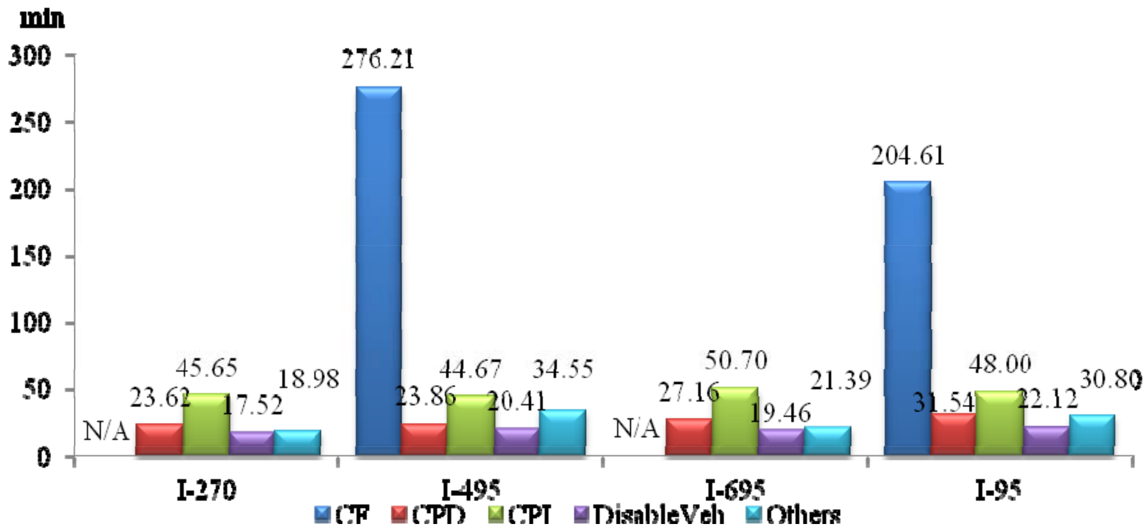
Figure 6.8 illustrates how a heavy vehicle influences the incident durations. In 2012, the response and clearance times for incidents involved with a heavy vehicle were likely to be longer than those without a heavy vehicle due to their incident severity.



Note: Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis.

Figure 6.8 Distribution of Average Incident Duration by Heavy Vehicle Involvement

Figure 6.9 shows the distribution of average incident duration by road and nature. Notably, the average incident duration of *CFs* was much longer than for other incident types. Also, note that *CF* incidents occurring on I-495 seemed to exhibit the longest average duration (i.e., 276.21 minutes).



Note:
CF: Collision-fatality incident
CPD: Collision-property damage incident
CPI: Collision-personal injury incident

Figure 6.9 Distribution of Average Incident Duration by Road and Nature

CHAPTER 7

BENEFITS FROM CHART'S INCIDENT MANAGEMENT

Due to the data availability, the benefit assessment for CHART has always been limited to those directly measurable or quantifiable based on incident reports. These direct benefits, both to roadway users and to the entire community, are classified as the following categories:

- assistance to drivers;
- reduction in secondary incidents;
- reduction in driver delay time;
- reduction in vehicle operating hours;
- reduction in fuel consumption; and
- reduction in emissions.

Some other intangible impacts, such as revitalizing the local economy and increasing network mobility, are not included in this benefit analysis.

7.1 Assistance to Drivers

The public has expressed great appreciation for the timely assistance given to drivers by the CHART incident management units. Prompt responses by CHART have directly contributed to minimizing the potential effects of rubbernecking on the traffic flow, particularly during peak hours, where incidents can cause excessive delays. Thus, providing assistance to drivers is undoubtedly a major direct benefit generated by the CHART program.

The distributions of assistance to drivers (labeled Disabled Vehicles in the CHART II Database) by request type in Year 2012 and Year 2011 are depicted in Figure 7.1. Those assists offered by TOC 3, TOC 4 and TOC 7 are illustrated in Figure 7.2, Figure 7.3 and Figure 7.4, respectively.

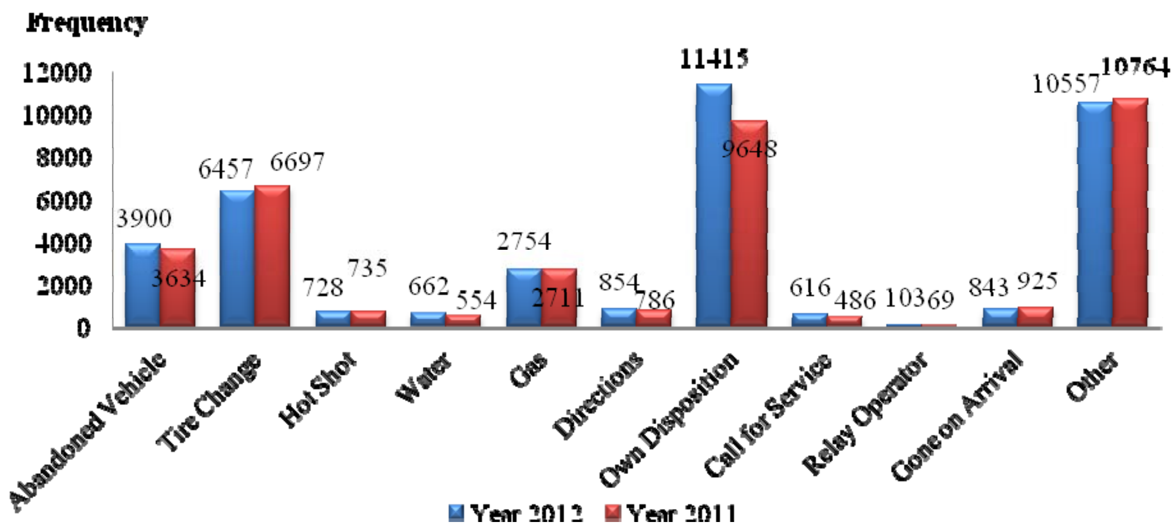


Figure 7.1 Natures of Driver Assistance Requests in 2012 and 2011

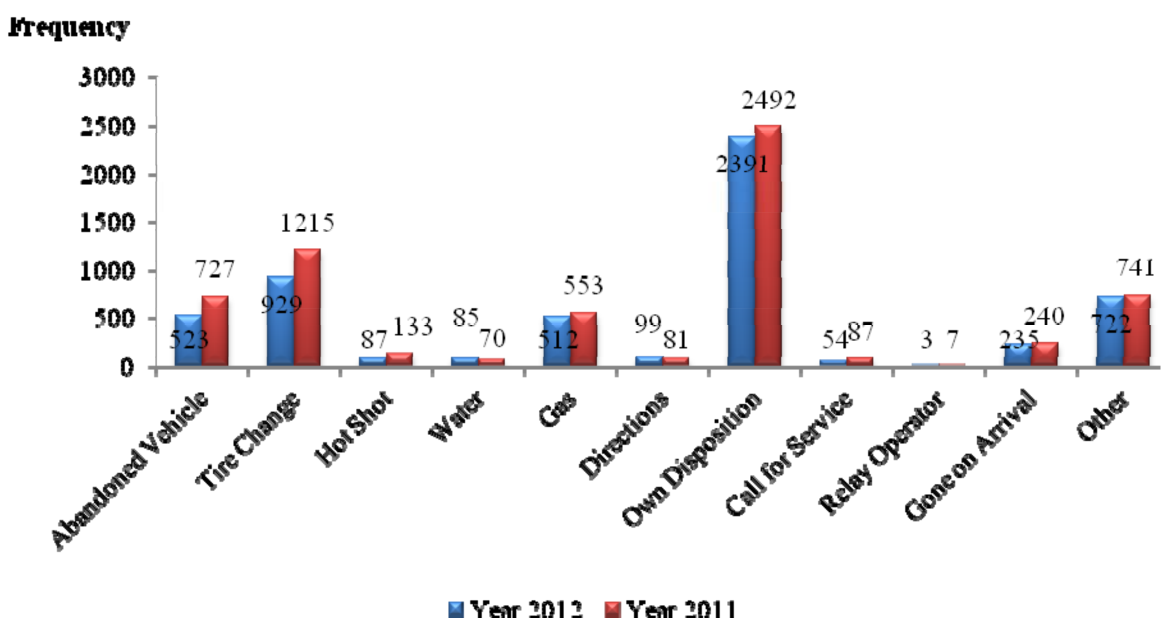


Figure 7.2 Natures of Driver Assistance Requests for TOC 3

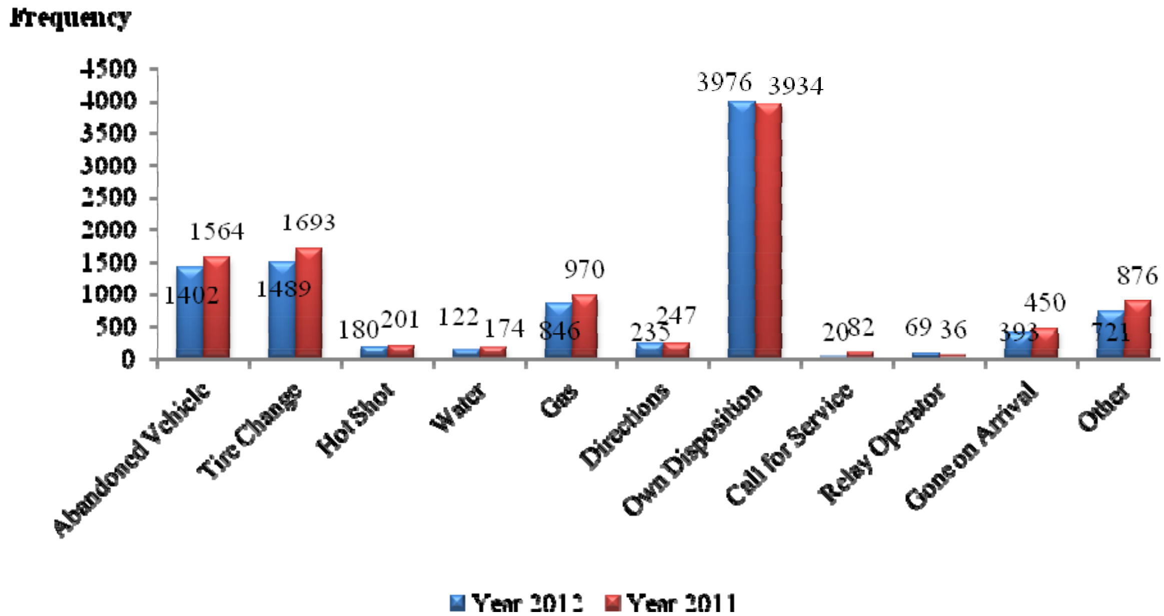


Figure 7.3 Natures of Driver Assistance Requests for TOC 4

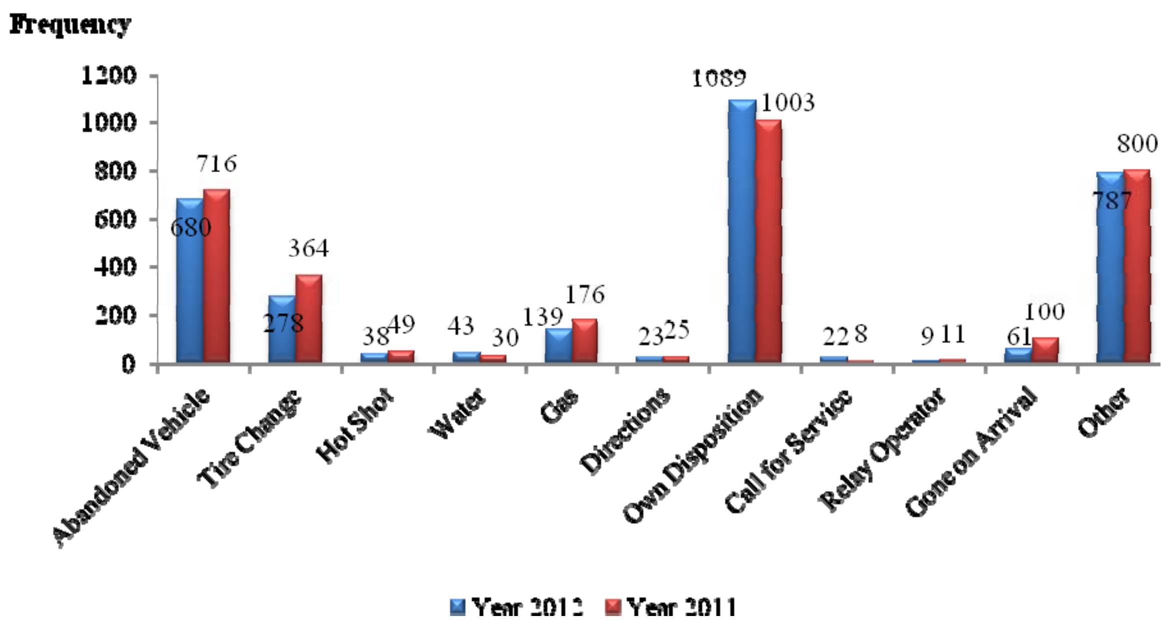


Figure 7.4 Natures of Driver Assistance Requests for TOC 7

The types of driver assistance accounted for in 2012 include flat tires, shortages of gas, or mechanical problems. Out of the 38,889 assistance requests, a total of 9,211 assists were related to "out of gas" or "tire changes," i.e., less than the number in 2011 (9,408 cases).

7.2 Potential Reduction in Secondary Incidents

Major accidents are known to induce a number of relatively minor secondary incidents. These may occur as a result of dramatic changes in traffic conditions, such as rapidly spreading queue lengths or substantial drops in traffic speed. Some incidents are caused by rubbernecking effects. Hence, the efficient removal of incident blockage is also beneficial in reducing potential secondary incidents.

Based on the experience gained from previous studies, this study has adopted the following definition for secondary incidents:

- Incidents that occur within two hours from the onset of a primary incident and also within two miles downstream of the location of the primary incident.
- Incidents that happen half a mile either downstream or upstream of the primary incident location in the opposite direction, occurring within half an hour from the onset of the primary incident.

Figure 7.5 shows the distribution of incidents classified as secondary incidents by our definition, using the accident database of the MSP for the year 2012. Notably, 684 secondary incidents occurred in 2012. A linear correlation is assumed between the number of secondary incidents and incident duration; the reduction in secondary incidents due to CHART's operations is estimated as follows:

- Number of reported secondary incidents: 684
- Estimated number of secondary incidents without CHART, which reduced incident duration by 24.18 percent, calculated as: 684/(1-0.2418) = 902 incidents
- The number of incidents potentially reduced due to CHART/MSHA operations: 902-684 = 218 secondary incidents

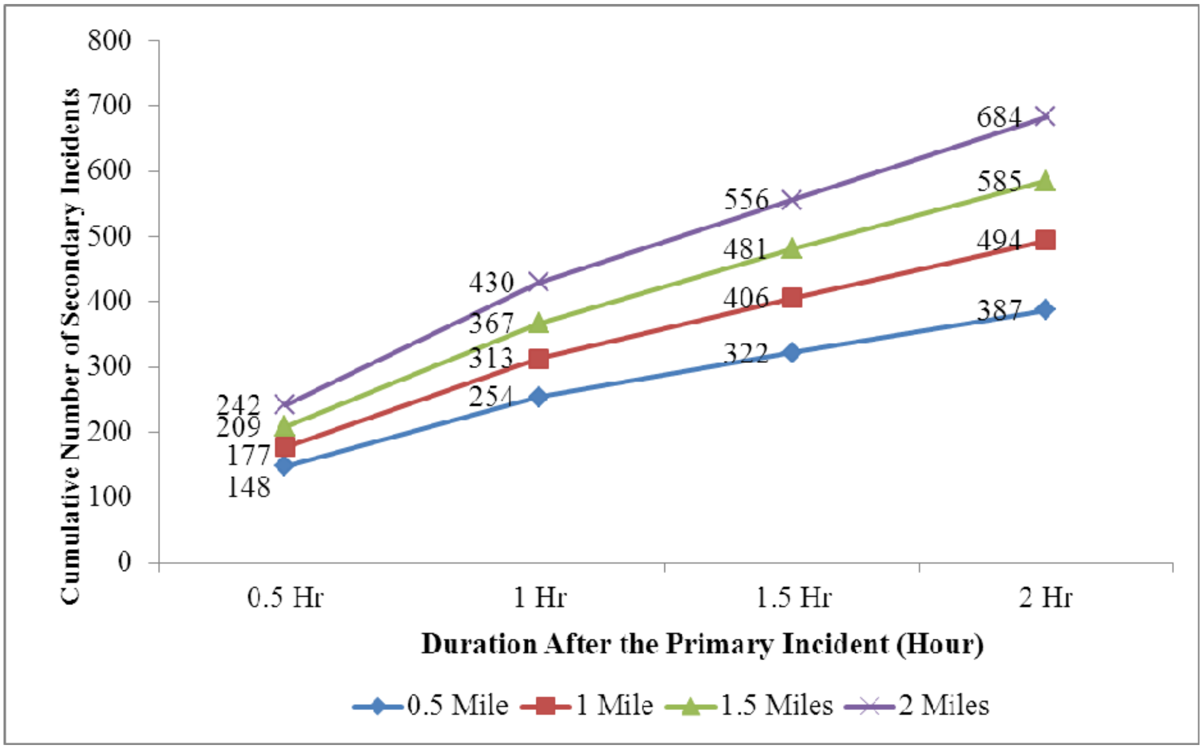


Figure 7.5 Distributions of Reported Secondary Incidents

Note that the 218 secondary incidents might have further prolonged the primary incident duration, increasing congestion, fuel consumption, and travel times. These associated benefits are not computed in this report due to data limitations but will be investigated in future studies.

7.3 Estimated Benefits due to Efficient Removal of Stationary Vehicles

Drivers are forced to perform undesirable lane-changing maneuvers because of lane blockages around incident sites. Considering that improper lane changing is a prime contributor to traffic accidents, prolonged obstruction removal certainly increases the risk of accidents. Thus, CHART/MSHA's prompt removal of stationary vehicles in travel lanes may directly alleviate potential lane-changing-related accidents around incident sites.

The estimated results from potential incident reduction for selected freeways are reported in Table 7.1. Note that this estimation was made using peak period data. Off-peak data were omitted because they are known not to have any correlation with lane-changing maneuvers and accidents. A detailed description of the estimation methodology can be found in the previous CHART performance evaluation reports (chartinput.umd.edu).

Table 7.1 Reduction of Potential Incidents due to CHART Operations

Road Name		I-495/95	I-95	I-270	I-695	I-70	I-83	I/MD-295	US-50	Total
Mileage		41	63	32	44	13	34	30	42	
No. Potential Incident Reduction	2012	90	140	27	54	39	13	8	58	429
	2011	86	174	33	68	38	22	7	54	482
	2010	99	225	41	84	27	18	10	60	564
	2009	127	211	40	76	43	21	13	40	571
	2008	129	181	27	98	33	25	14	43	550

* The analysis has excluded the outlier data (i.e., mean ± 2 standard deviation)

7.4 Direct Benefits to Highway Users

The benefits obtained as a result of reduced delays and fuel consumption are summarized in the following tables. Table 7.2 shows the benefits from delays calculated using the unit rates obtained from the U.S Census Bureau (2012) and the Energy Information Administration (2012). To convert delays to monetary value for commercial vehicles, we multiply delays by the value of time factors ($20.21/hr for driver and $45.40/hr for cargo). Figure 7.6 also shows the benefits' difference in 2011 and 2012.

The evaluation for 2012 has adopted delay reduction for cars and trucks in conversion of delays to fuel consumption. Please refer to ***Note 4*** under Table 7.2 for details.

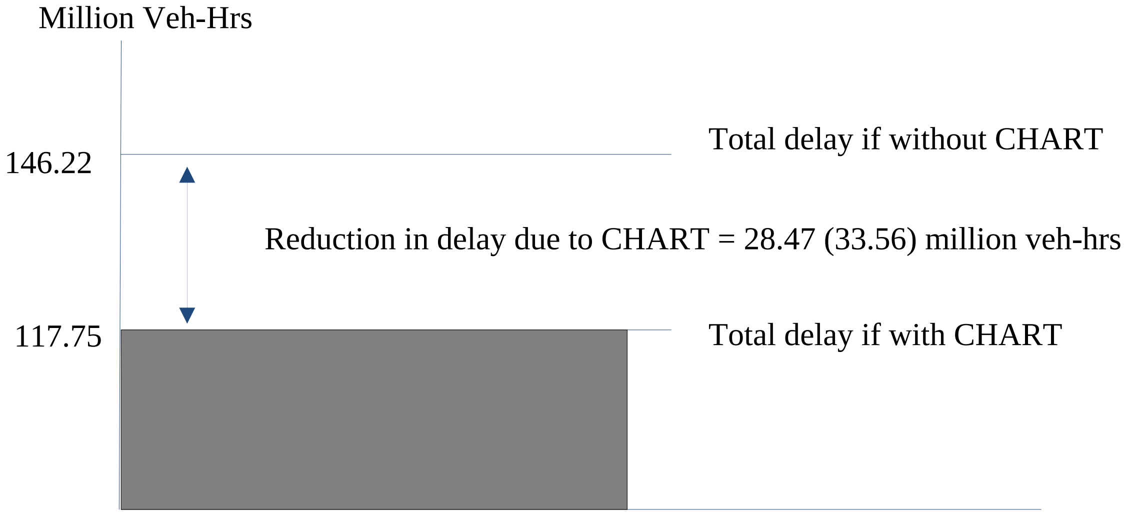
The estimated reductions in vehicle emissions for HC, CO, and NO were based on parameters provided by MDOT and the total delay reduction. Since CO_2 is recognized as a primary factor of global warming, we also included the estimated reduction of this emission based on the factor from the Energy Information Administration. Using the cost parameters shown in Table 7.2 (DeCorla-Souza, 1998), the above reduction in emissions resulted in a total savings of 32.56 million dollars. Thus, CHART/MSHA's activities in Year 2012 generated a total savings of 961.69 million dollars.

Table 7.2 Total Direct Benefits to Highway Users in 2012

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr) [6]	**Truck**	1.66 (1.80)	Driver *$20.21/hour (20.86)* [3]	33.44 (37.56)
			Cargo $45.40/hour [3]	75.15 (81.76)
	Car	26.82 (31.76)	*$29.82/hour (28.82)* [3]	799.54 (915.30)
Fuel Consumption (M gallon)		5.59 [4] (6.49)	Gasoline *$3.69/gal (3.58)* [3]	21.01 (26.63)
			Diesel *$3.97/gal (3.85)* [3]	
Emission	**HC**	372.20	$6,700/ton	32.56 (38.36)
	CO	4,180.40	$6,360/ton	
	NO	178.26	$12,875/ton	
	CO2 [5]	51,411.95	$23/metric ton [5]	
Total		$961.69 (1,096.61)		

Note: 1. The number in each parenthesis is the data in year 2011

2. Italic unit rates indicate changes in 2012, and the number in the parenthesis is the unit rate for the 2011 analysis
3. The car driver's cost and fuel price are updated based on the information from the U.S Census Bureau in Year 2012 and the Energy Information Administration in Year 2012, respectively.
4. The fuel consumption was computed based on the rate of 0.156 gallons of gas per hour for passenger cars from the Ohio Air Quality Development Authority and the rate of 0.85 gallon per hour for trucks from the literature "Heavy-Duty Truck Idling Characteristics-Results from a Nationwide Truck Survey" by Lutsey et al. and the Environmental Protection Agency (EPA).
5. This value is computed based on the unit rates of 19.56 lbs CO_2/gallon of gasoline and 22.38 lbs CO_2/gallon of diesel from the Energy Information Administration and $23/metric ton of CO_2 from CBO (Congressional Budget Office)'s cost estimate for S. 2191, America's Climate Security Act of 2007.
   e.g. 4.21(million gallon) * 19.56 (lbs CO_2/gallon) / 2204 (lbs/metric ton) * 23($/metric ton)
6. The total delay reduction consists of the car delay reduction occurring over all roads covered by CHART and the truck delay reduction occurring only along major roads. The extended analysis of the total benefit with respect to truck volume using both major highways and all roadways covered by CHART is presented in Appendix-B



* The number in the parenthesis shows the data from year 2011

Figure 7.6 Reduction in Delay due to CHART in Year 2012

The total benefits decreased from 1,096.61 million dollars in 2011 to 961.69 million dollars in 2012. The possible contributing factors are listed as follow:

- The AADT change is shown in Table 7.3. The AADT decreased on several major roads, including I-495, I-270, I-695, I-83 and I-70.
- As shown in Table 7.4, the difference in incident duration with and without CHART decreased to about 4.11% from 2011 to 2012.
- Table 7.5 shows that the truck percentage decreased on most major roads.
- The total number of eligible incidents for the benefit estimate decreased by 3.5% from 2011 to 2012 as shown in Table 7.6.

The impact of each key factor on the resulting benefit change is further analyzed in Appendix-B.

Table 7.3 Changes of AADTs for Major Roads from 2011 to 2012

	Year	**I-495**	**I-95**	**I-270**	**I-695**	**MD 295**	**US 50**	**US 1**	**I-83**	**I-70**	**Total**
$\sum_{segments} AADT(vplph)*PHF$	**2012**	12,409	8,595	7,170	9,679	4,342	2,671	4,529	2,686	3,976	**56,057**
	2011	12,609	8,513	7,455	10,906	4,129	2,602	4,529	2,956	4,030	**57,729**
Δ('11 ~ '12) (%)		**-1.59**	0.96	**-3.82**	**-11.25**	5.16	2.65	0.00	**-9.13**	**-1.34**	**-2.90**

Table 7.4 Comparison of Incident Duration Reduction in 2011 and 2012

	With CHART (mins)	Without CHART (mins)	Difference (mins)	Ratio in Difference
2012	21.95	28.95	7.00	24.18%
2011	22.14	29.44	7.30	24.80%

Table 7.5 Changes of Truck Percentage for Major Roads from 2011 to 2012

	Year	I-495	I-95	I-270	I-695	MD 295	US 50	US 1	I-83	I-70	Average
Truck Percentage (%)	**2012**	8.25	14.95	7.47	9.02	3.41	8.43	5.90	8.26	14.37	**8.90**
	2011	9.12	14.61	7.36	8.93	3.99	8.79	5.94	9.03	18.30	**9.56**
Δ('11 ~ '12)		**-0.87**	0.34	0.11	0.09	**-0.58**	**-0.36**	**-0.04**	**-0.77**	**-3.93**	**-0.66**

Table 7.6 Total Number of Incidents Eligible for the Benefit Estimate

	2011	2012	Δ('11 ~ '12) (%)
No. of Incidents	20,547	19,920	-3.5

Note: They only include the incidents causing main lanes blockage. To estimate benefit, the incidents causing only shoulder lanes blockage are excluded.

In addition to the above benefit analyses, a reduction in emissions due to reduced running time in the Baltimore and Washington regions has been computed. The results are summarized in Tables 7.7.

As shown in Tables 7.7 (a) and 7.7 (b), the daily delay reductions for the Washington region in 2012 were 2,182 hours/day and 38,752 hours/day for trucks and cars, respectively, compared with the 1,873 hours/day for trucks and 40,555 hours/day for cars recorded in 2011. The delay reduction for trucks in the Baltimore region decreased from 5,054 hours/day in 2011 to 4,184 hours/day in 2012, and decreased from 81,612 hours/day in 2011 to 64,385 hours/day in 2012 for passenger cars. The overall reductions in emissions (i.e., by cars and trucks) for the entire region were $125,225/day and $147,531/day for the years 2012 and 2011, respectively.

Table 7.7(a) Delay and Emissions Reductions for Trucks Due to CHART/MSHA Operations for Washington and Baltimore Regions

Truck		Total by CHART		Washington Region		Baltimore Region	
		Year 2012	Year 2011	Year 2012	Year 2011	Year 2012	Year 2011
Annual Delay Reduction	hour	1,655,257	1,800,775	567,356	486,852	1,087,900	1,313,924
Daily Delay Reduction	hour	6,366	6,926	2,182	1,873	4,184	5,054
Emission Reduction							
HC reduction	ton/day	0.083	0.091	0.036	0.037	0.047	0.054
	$/day	557.62	606.65	240.20	244.57	317.42	362.07
CO reduction	ton/day	0.935	1.017	0.403	0.410	0.532	0.607
	$/day	5,945.21	6,467.87	2,560.96	2,607.57	3,384.25	3,860.30
NO reduction	ton/day	0.040	0.043	0.017	0.017	0.023	0.026
	$/day	513.20	558.31	221.06	225.09	292.13	333.22
CO_2 reduction	metric ton/day	54.95	59.78	23.67	23.97	31.28	35.22
	$/day	1,263.83	1374.93	544.46	551.35	719.37	823.58
Total	$/day	8,279.85	9,007.76	3,566.68	3,628.58	4,713.17	5,379.18

Table 7.7(b) Delay and Emissions Reductions for Cars due to CHART/MSHA Operations for Washington and Baltimore Regions

Car		Total by CHART		Washington Region		Baltimore Region	
		Year 2012	Year 2011	Year 2012	Year 2011	Year 2012	Year 2011
Annual Delay Reduction	hour	26,815,579	31,763.354	10,075,440	10,544,180	16,740,138	21,219,173
Daily Delay Reduction	hour	103,137	122,167	38,752	40,555	64,385	81,612
Emission Reduction							
HC reduction	ton/day	1.348	1.597	0.581	0.644	0.768	0.953
	$/day	9,033.66	10,700.48	3,891.34	4,313.97	5,142.32	6,386.50
CO reduction	ton/day	15.144	17.938	6.523	7.232	8.620	10,706
	$/day	96,313.84	114,084.82	41,488.13	45,994.09	54,825.71	68,090.73
NO reduction	ton/day	0.646	0.765	0.278	0.308	0.368	0.457
	$/day	8,313.90	9,847.91	3,581.29	3,970.25	4,732.61	5,877.65
CO_2 reduction	metric ton/day	142.79	169.14	61.51	67.82	81.28	101.31
	$/day	3,284.15	3,890.12	1,414.81	1,559.94	1,869.34	2,330.18
Total	$/day	116,945.56	138,523.32	50,375.57	55,838.26	66,569.99	82,685.07

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Building on the previous research experience, this study has conducted a rigorous evaluation of CHART's performance in 2012 and its resulting benefits under the constraints of data availability and quality. Overall, CHART has made significant progress in recording more reliable incident reports, especially after implementation of the CHART-II Database.

However, much remains for CHART to do in terms of collecting more data and extending its operations to major local arterials if resources are available to do so. For example, data associated with the potential impacts of major incidents on local streets have not been collected by CHART. Without such information, one may substantially underestimate the benefits of CHART operations, as most incidents causing lane blockage on major commuting freeways are likely to spill their congestion back to neighboring local arterials if the speed of traffic queue formation is faster than the pace of progress on incident clearance. Similarly, a failure to respond to major accidents on local arterials, such as MD-355, may also significantly degrade traffic conditions on I-270. Effectively coordinating with county agencies on both incident management and operational data collection is one of the major tasks to be done by CHART.

With respect to its performance, CHART has maintained nearly the same level of efficiency in responding to incidents and driver assistance requests in recent years. The average response time in 2012 was 9.92 minutes. In view of the worsening congestion and the increasing number of incidents in the Washington-Baltimore region, it is commendable that CHART can maintain its performance efficiency with diminishing resources.

In brief, CHART operations by MSHA in Year 2012 have yielded significant benefits by assisting drivers, and by reducing delay times and fuel consumption, as well as emissions. Other, indirect benefits could be estimated if appropriate data regarding traffic conditions before and after incidents were collected during each operation. Such benefits include impacts related to secondary incidents, potential impacts on neighboring roadways, and reductions in driver stress on major commuting corridors. In addition, an in-depth analysis of the nature of incidents and their spatial distribution may offer insight into developing safety improvement measures for the highway networks covered by CHART.

8.2 Recommendations and Further Development

The main recommendations, based on the performance of CHART in 2012, are listed below:

- More resources should be allocated to CHART for incident response and traffic management to improve the performance of the response teams so they can effectively contend with the ever-increasing congestion and accompanying incidents.
- CHART's quality evaluation report should be made available to the operators to facilitate their continuous improvement of response operations.
- CHART should coordinate with county traffic agencies to extend its operations to major local routes and to include the data collection, as well the performance benefit, in the annual CHART review.
- Training sessions should be implemented to instruct operators on how to effectively record critical data associated with incident response performance.
- The data structure used in the CHART-II system for recording incident location should be improved to eliminate the current laborious, complex procedures.
- The average response time should be reduced by increasing freeway service patrols and by assigning patrol locations based on both the spatial distribution of incidents along freeway segments and the probability of an incident occurring.
- Police accident data should be efficiently integrated into the CHART incident response database in order to have a complete representation of statewide incident records.
- The benefits of reduced potential secondary incidents on delay and fuel consumption should be incorporated into the CHART benefit evaluation.

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APPENDIX A

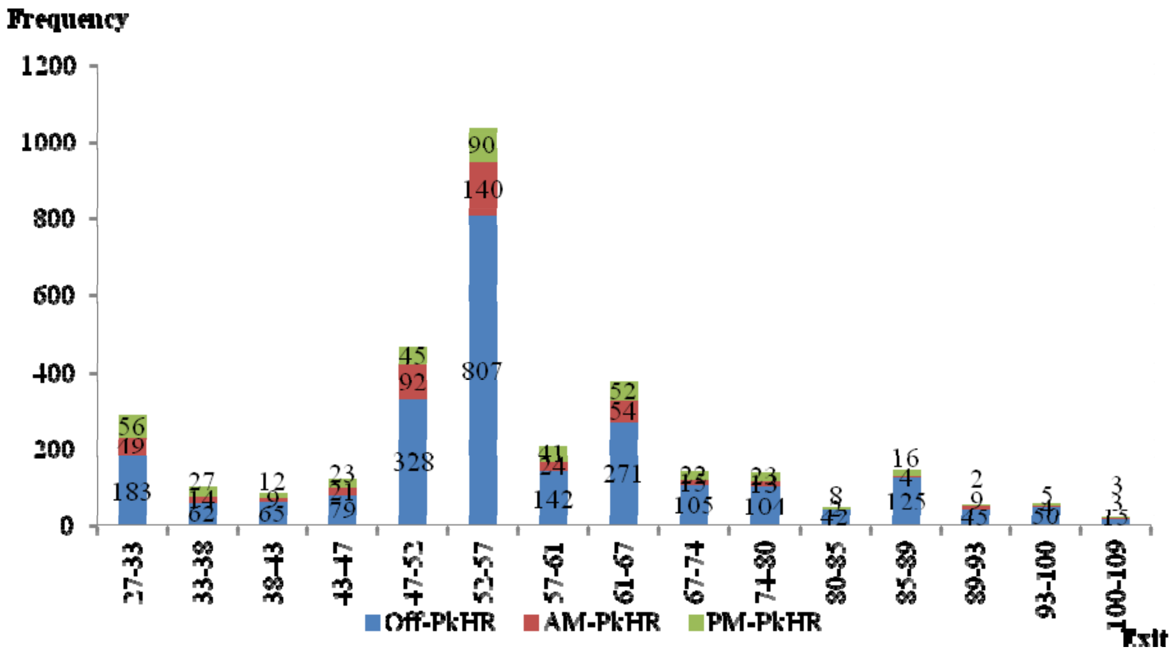

Figure A.1 Distributions of Incidents by Time of Day on I-95 in Year 2012

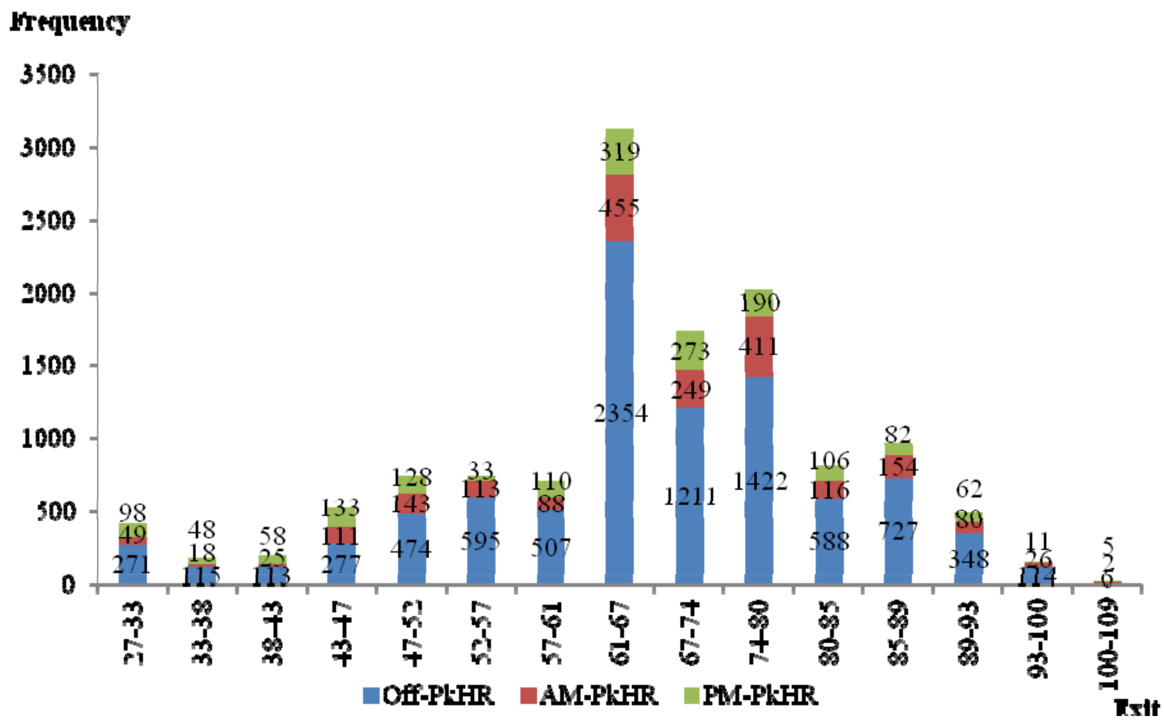

Figure A.2 Distributions of Disabled Vehicles by Time of Day on I-95 in Year 2012

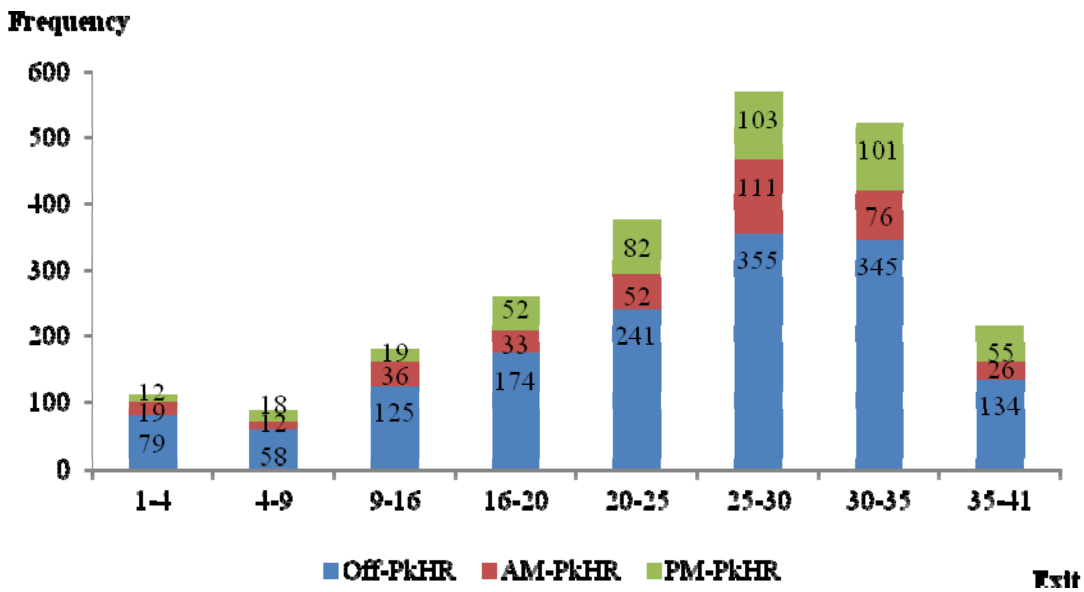

Figure A.3 Distributions of Incidents by Time of Day on I-495 in Year 2012

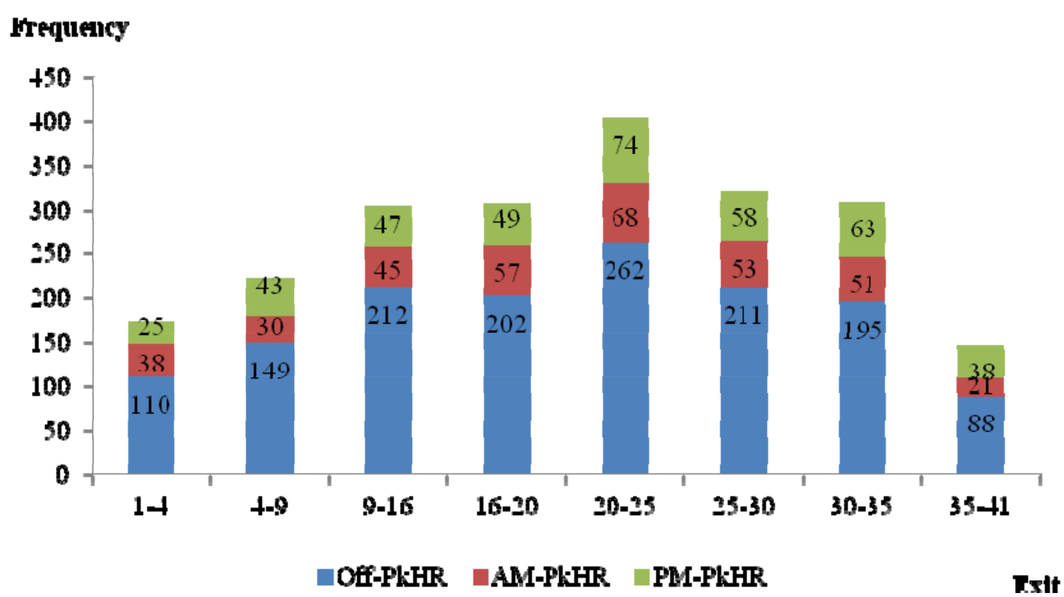

Figure A.4 Distributions of Disabled Vehicles by Time of Day on I-495 in Year 2012

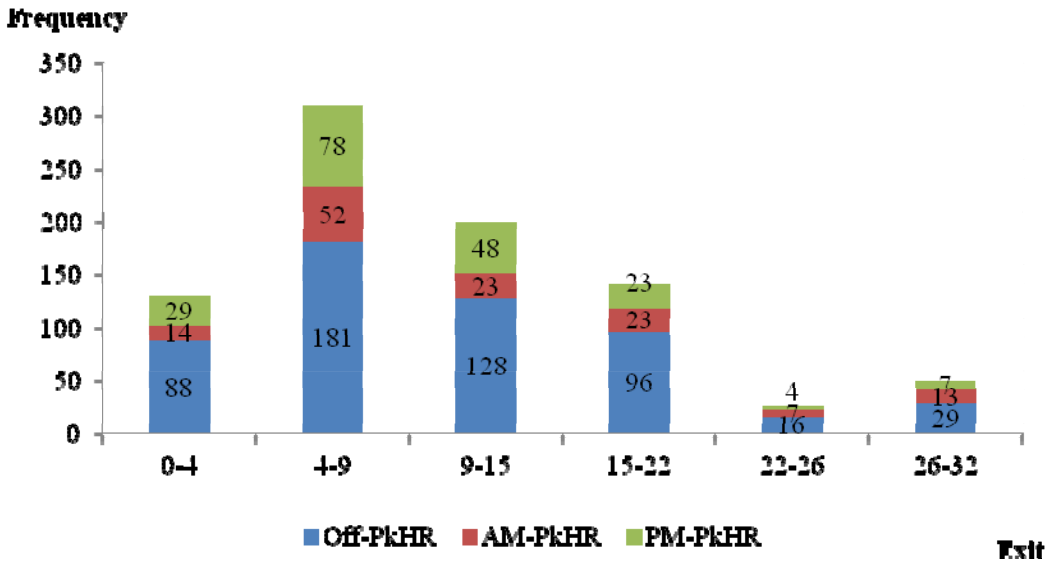

Figure A.5 Distributions of Incidents by Time of Day on I-270 in Year 2012

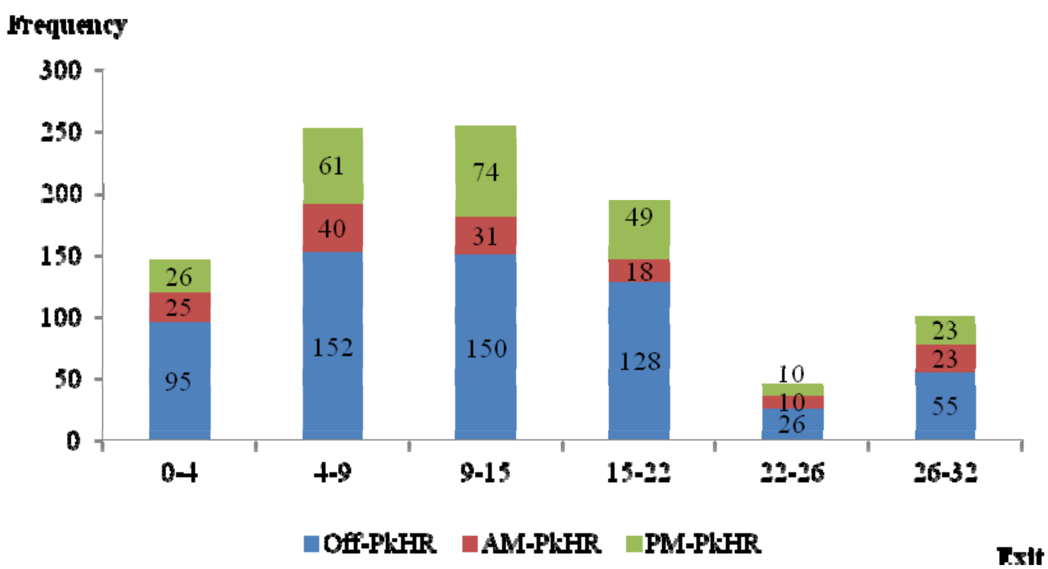

Figure A.6 Distributions of Disabled Vehicles by Time of Day on I-270 in Year 2012

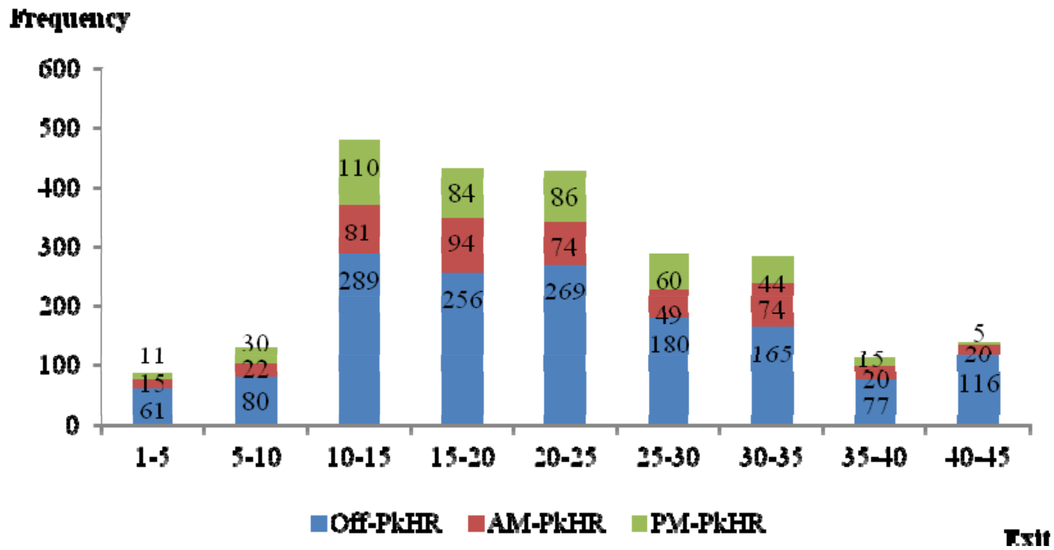

Figure A.7 Distributions of Incidents by Time of Day on I-695 in Year 2012

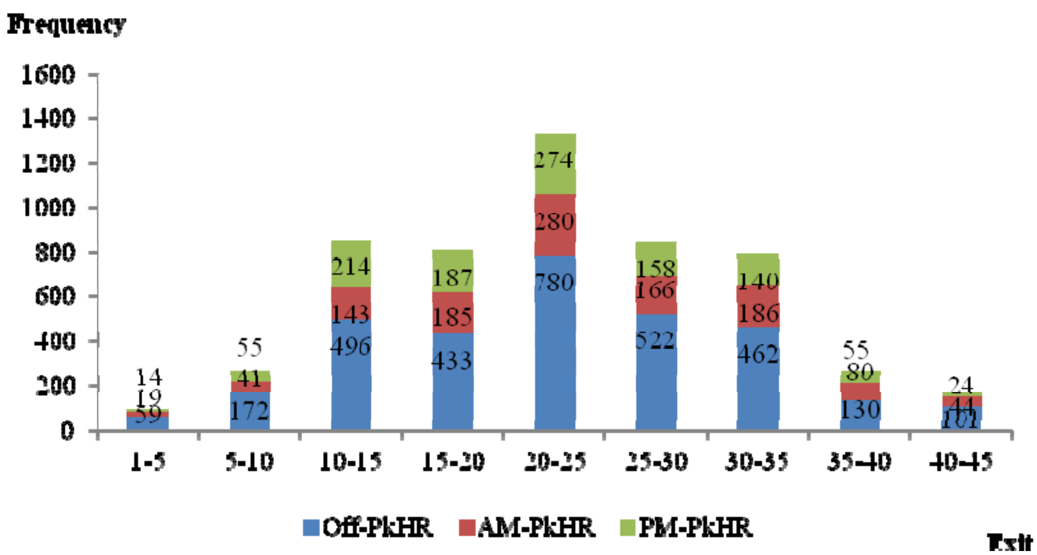

Figure A.8 Distributions of Disabled Vehicles by Time of Day on I-695 in Year 2012

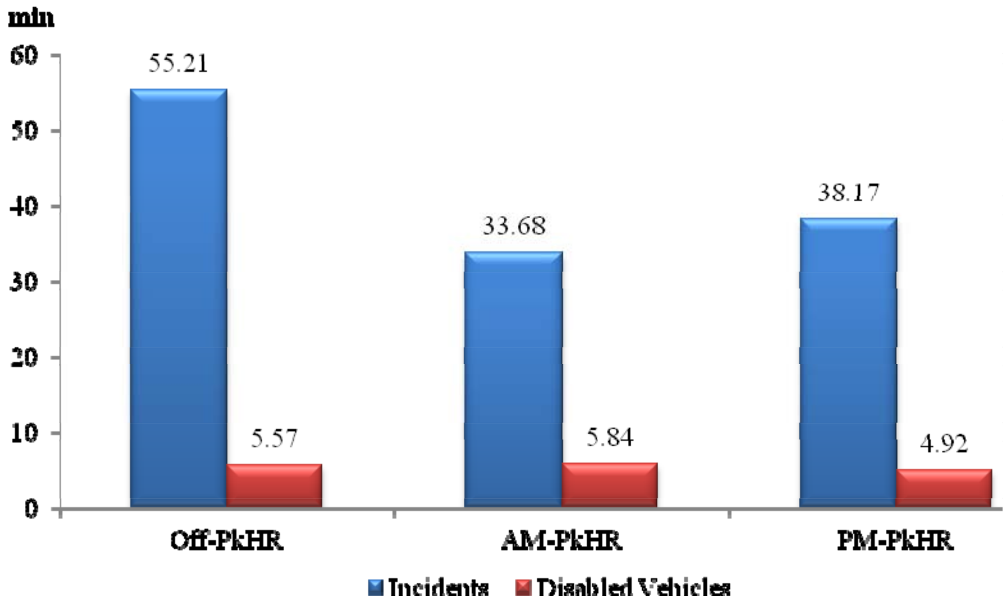

Figure A.9 Distributions of Clearance Time by Time of Day in Year 2012

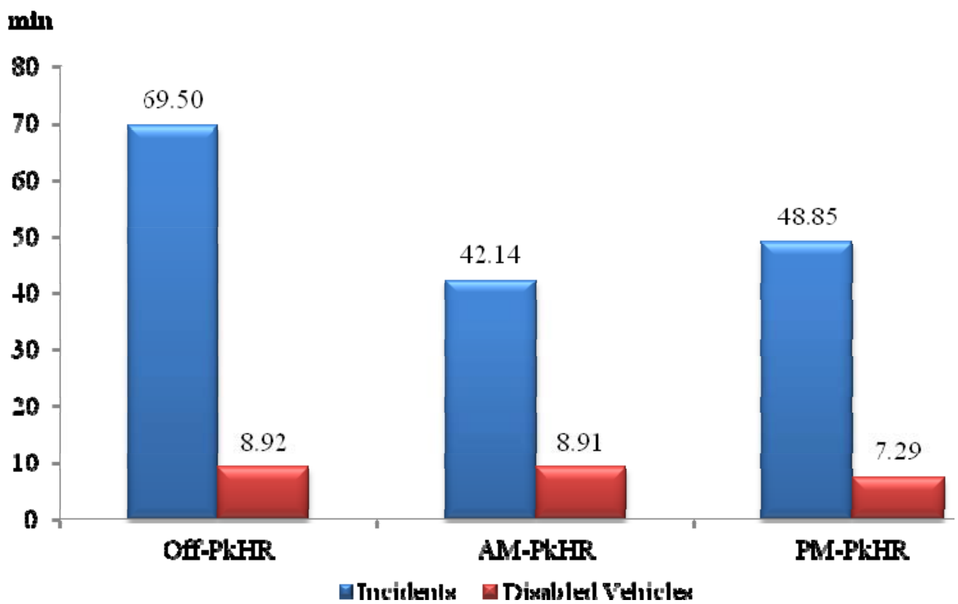

Figure A.10 Distributions of Incident Duration by Time of Day in Year 2012

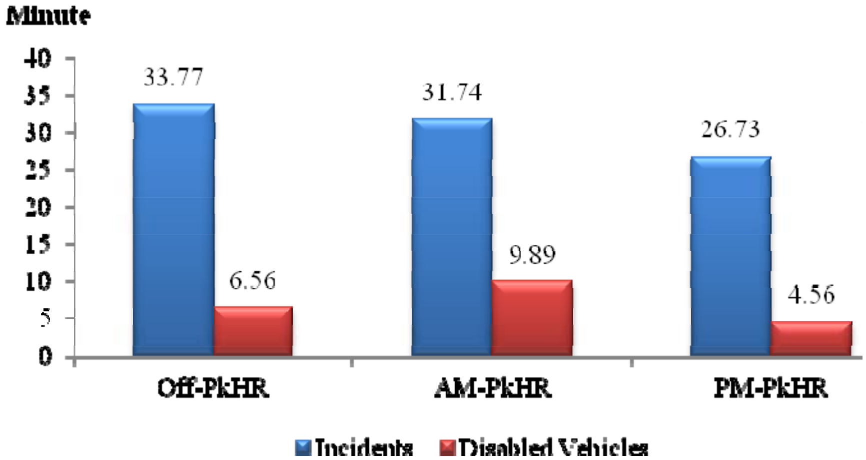

Figure A.11 Distributions of Incident Duration by Time of Day on I-95 in Year 2012

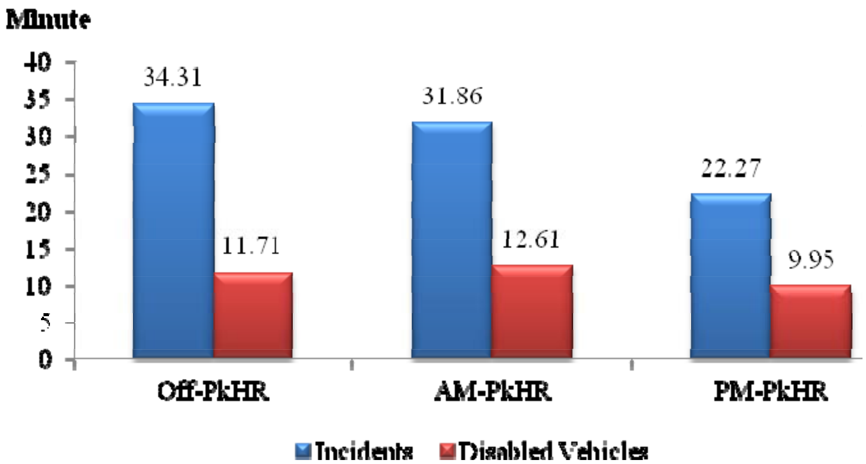

Figure A.12 Distributions of Incident Duration by Time of Day on I-495 in Year 2012

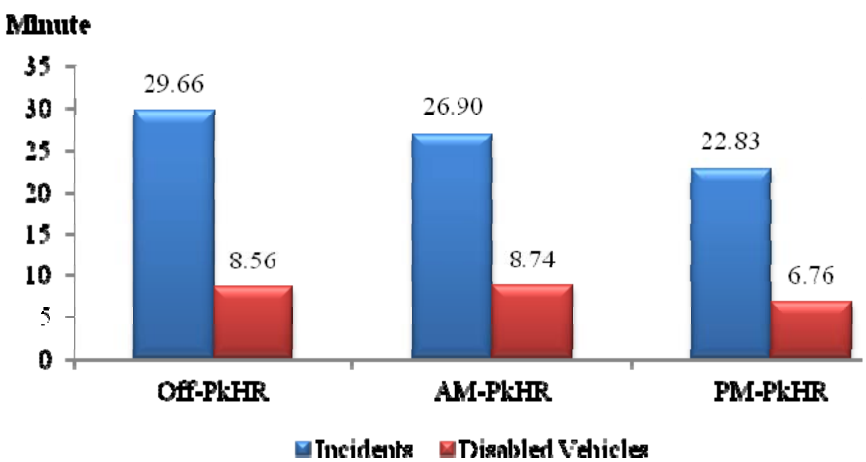

Figure A.13 Distributions of Incident Duration by Time of Day on I-270 in Year 2012

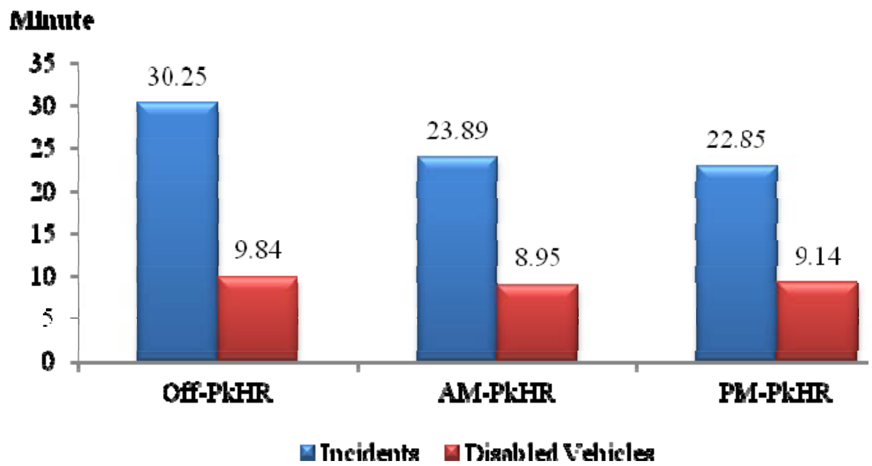

Figure A.14 Distributions of Incident Duration by Time of Day on I-695 in Year 2012

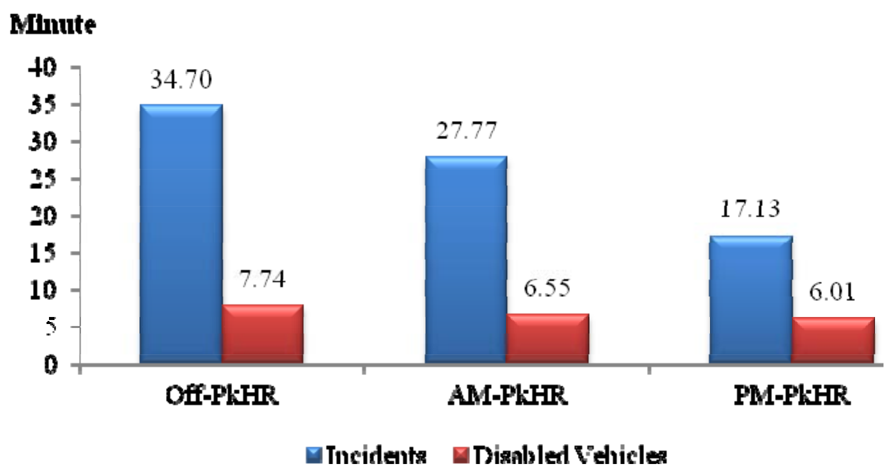

Figure A.15 Distributions of Incident Duration by Time of Day on I/MD-295 in Year 2012

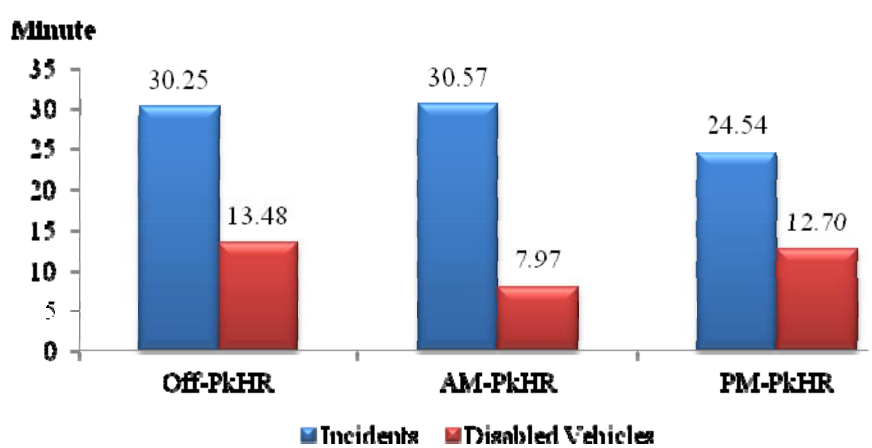

Figure A.16 Distributions of Incident Duration by Time of Day on I-83 in Year 2012

APPENDIX B- Sensitivity Analysis

Because the total benefits have been reduced from $1,096 Million in 2011 to $961 in 2012, this section is devoted to analysis of each critical factor's impact on the total benefit variation. The procedures for such sensitivity analyses include the following steps:

- Identifying key factors contributing to computation of the total CHART benefit, which are: traffic volume, the number of incidents resulting in lane blockage, incident duration difference between with and without CHART involvements, truck percentage, gas price, and value of time;
- Computing the marginal impact of the selected factor using its 2012 value, but setting all other factors identical to those in 2011; and
- Following the same procedure to analyze the sensitivity of the total 2012 benefit with respect to each key factor.

The results of sensitivity analysis for each factor are shown in the following table:

Table B-1: Sensitivity Analysis of the Benefit

(Unit: M dollars)

Benefit in 2011			1,096.61
Key Factor		**Δ ('11 - '12)**	**Benefit difference**
Sensitivity Analysis	Traffic Volume	**⇩ 2.90%**	971.14 **(⇩ 11.44%)**
	Number of incidents	**⇩ 3.50%**	1,059.31 **(⇩ 3.40%)**
	Incident duration difference between w and w/o CHART	**⇩ 4.11%**	1,069.34 **(⇩ 2.49%)**
	Truck percentage	**⇩ 0.66%**	1,091.53 **(⇩ 0.46%)**
	Monetary unit value	⇧ 1.64%	1,127.90 (⇧ 2.85%)
Benefit of the Current Year (2012)			**961.69 (⇩ 12.30%)**

- The number in each parenthesis shows the percentage of benefit change from 2011.

Notably, the compound impact of all key factors has caused CHART operations in 2012 to produce 12.30 percent less benefit than in 2011. The reduction in traffic volume by 2.9 percent in 2012 resulted in 11.44 percent benefit decrease. With respect to the benefit to truck traffic due to CHART operations, the computation of delay reduction only includes major highways (i.e., I-495, I-95, I-270, I-695, I-70, and I-83, MD295, US50, and US1). Tables B-2 and B-3 show the extended analysis of the total benefit with respect to truck volume using both major highways and all roadways covered by CHART.

Table B-2: Comparison of Delay Reduction due to CHART

(Unit: M veh-hr)

	Delay reduction for Truck from Major Roads in MD			Delay reduction for Truck from All roads in MD		
	2011	**2012**	**Δ (%)**	**2011**	**2012**	**Δ (%)**
Total	33.56	28.47	⇩ 15.17	33.56	28.47	⇩ 15.17
Truck	1.80	1.48	⇩ 17.78	3.56	2.90	⇩ 18.54
Car	31.76	26.99	⇩ 15.02	30.00	25.57	⇩ 14.77

Table B-3: Truck benefit comparison for CHART between 2011 and 2012

(Unit: M dollars)

	Benefit for Truck from Major Roads in MD			Benefit for Truck from All roads in MD		
	2011	**2012**	**Δ (%)**	**2011**	**2012**	**Δ (%)**
Total	1,096.61	961.69	⇩ 12.30	1,167.58	1010.04	⇩ 13.49%
Truck	127.55	116.33	⇩ 8.80	250.54	202.63	⇩ 19.12%
Car	969.06	845.36	⇩ 12.76	917.04	807.41	⇩ 11.95%