2015 Performance Evaluation and Benefit Analysis for CHART

– Coordinated Highways Action Response Team –

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Performance Evaluation of CHART

The Real-Time Incident Management System (Year 2015)

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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 2015, 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 seventeen years for the Maryland State Highway Administration (MSHA).

Similar to previous studies, the focus of this task was to evaluate the effectiveness of 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 2015 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 better the evaluation quality and also in view of the fact that the Statewide Operations Center (SOC) has been 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 research item 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 have been increased considerably since 1999. This results from CHART reflect 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, the documentation of lane-closure-related incidents increased from 2,567 in 1997 to 35,119 in 2015.

Table E.1 shows the total number of emergency response operations assiduously documented from 2011 to 2015.

Table E.1 Total Number of Emergency Response Records from 2011 to 2015

	2011	2012	2013	2014	2015	Δ (2014-2015)
Incidents only	22,534 (16,337)	22,328 (15,347)	24,738 (17,842)	31,535 (25,571)	35,119 (27,375)	11.37% (7.05%)
Total *	60,105 (40,480)	63,571 (41,923)	60,519 (47,707)	77,865 (70,799)	77,843 (67,990)	-0.03% (-3.97%)

Notes: 1. Total includes incidents and disabled vehicles (assists to drivers)

2. Number in the parenthesis shows the incidents or assists responded by CHART

It should be noticed that CHART has responded to more incidents this year than in the past four years. This may be due to the increase in the network-wide incidents and the enhancement of CHART's emergency response operations.

Evolution of the Evaluation Work

CHART has consistently worked to improve its data recording for both major and minor incidents over the past seventeen 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 available data and to use only reliable data in the benefit analysis. Thus, from 1999, the performance evaluation reports have included data quality analysis. This aims to ensure continued advancement in the quality of incident- related data so as to reliably estimate all potential benefits of CHART operations.

From February 2001, all incidents requesting emergency assistance have been recorded in the CHART-II information system, regardless of CHART's involvement or not. This has significantly enriched the available data for analysis. 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.

As shown in Table E.2, the results of 2015 incident data indicate that there were a total of 3,744 incidents resulting in one-lane blockage, 8,499 incidents causing two-lane closures, and 4,674 incidents blocking three or more lanes. These lane-blockage data confirm the surge of severe incidents in Year 2015. In addition, either disabled vehicles or minor incidents caused a total of 48,016 shoulder blockages. A comparison of the lane-blockage incidents and disabled vehicles data over the past five years is summarized in Table E.2:

Table E.2 List[1] of Incidents/Disabled vehicles by Lane Blockage Type

	2011	2012	2013	2014	2015	Δ (2014-2015)
Shoulder[2]	40,290	43,728	38,818	50,851	48,016	-5.58%
1 lane	2,881	2,514	2,948	3,831	3,744	-2.27%
2 lanes[3]	3,745	3,424	4,599	6,816	8,499	24.69%
3 lanes[3]	1,322	1,215	1,612	2,341	2,703	15.46%
≥ 4 lanes[3]	1,065	1,010	1,322	1,904	1,971	3.52%

**Note: 1. This analysis is based only on the samples with complete information for the lane blockage status.*

2. Shoulder Lane Blockages include events that have disabled vehicles (i.e., assists 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 11,937 incidents/disabled vehicles in 2015; I-695, I-95, US-50, I/MD-295, and I-270 with 9,464, 13,166, 7,272, 3,900, and 4,323 incidents/disabled vehicles, respectively. Slight increases in the number of incidents/disabled vehicles have been shown on I-495/95, I-270 and US-50. CHART managed an average of 36 emergency requests per day on I-95 alone, and 33, 26, 20, 11 and 12 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 2011 and 2015 is shown in Table E.3:

Table E.3 Summary* of Incidents/Disabled vehicles Distribution on Major Freeway Corridors

	2011	2012	2013	2014	2015	Δ (2014 - 2015)
I-495/95	5,702	5,383	6,103	11,821	11,937	0.98%
I-695	8,088	8,345	7,875	10,056	9,464	-5.89%
I-270	3,059	3,261	3,024	4,288	4,323	0.82%
I-95	19,411	19,594	13,699	13,958	13,166	-5.67%
US-50	5,069	5,209	6,541	7,188	7,272	1.17%
I/MD-295	1,815	3,315	2,960	3,951	3,900	-1.29%

* *This analysis is based on incidents and disabled vehicles (i.e., assists 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, about 75 percent of incidents/disabled vehicles had durations shorter than 30 minutes in 2015. 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 2011 to 2015 is summarized in Table E.4:

Table E.4 Distribution* of Incidents/Disabled Vehicle Duration from 2011 to 2015

Duration(Hrs)	2011	2012	2013	2014	2015
$D < 0.5$	83%	84%	81%	79%	75%
$0.5 \leq D < 1$	9%	9%	11%	12%	14%
$1 \leq D < 2$	5%	4%	5%	5%	6%
$2 \leq D$	3%	3%	3%	4%	5%

* *This analysis is based on incidents and disabled vehicles (i.e., assists to drivers) which have complete information on the event duration.*

In brief, it is apparent that the highway networks served by CHART still plagued by a high frequency of incidents with durations ranging from 10 to over 120 minutes. Those incidents were 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 performance indicators associated with an incident management program. Unfortunately, data needed for the 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.

The average response time is defined as the average time from receiving an emergency request to the arrival of an emergency response unit. Table E.5 shows the average response times of 13.32, 13.20, 9.06, 3.54, 11.98, 13.36, and 7.32 minutes for TOC-3, TOC-4, TOC-5, TOC-6, TOC-7, SOC and AOC, respectively, in 2015. This table also shows that TOC-7 and AOC provided more prompt response services in 2015 than in 2014. In addition, TOC-3, 4, 7 and SOC demonstrated faster responses during their operational hours than non-operational hours. In 2015, TOC-3 was temporarily closed as of October 14th and reopened at December 30th. During this period, all events for National Capital Region were recorded as SOC. Note that incidents/disabled vehicles included in this analysis were responded by various units, including CHART and non-CHART agencies:

Table E.5 Evolution of Response Times* by Center from 2011 to 2015

Response Time (mins)	2011	2012	2013	2014	2015		
					During OH	After OH	Overall
TOC-3	11.70	12.22	11.91	12.52	13.30 (3,812)	13.90 (116)	13.32 (3,928)
TOC-4	12.83	12.67	12.05	12.86	13.20 (4,639)	13.45 (93)	13.20 (4,732)
TOC-5	2.67	5.64	7.03	7.42	9.49 (68)	8.79 (109)	9.06 (177)
TOC-6	4.43	16.40	6.99	3.33	3.54 (35)	-	3.54 (35)
TOC-7	12.17	12.87	12.40	12.16	11.94 (2,614)	13.17 (93)	11.98 (2,707)
SOC	6.73	6.72	7.41	11.63	11.29 (2,379)	14.20 (5,815)	13.36 (8,194)
AOC	6.55	6.43	6.90	7.62	7.42 (4,041)	7.13 (2,070)	7.32 (6,111)
OTHER	4.42	6.15	6.40	5.49	4.54 (10)	4.70 (37)	4.67 (47)
Weighted Average	**9.87**	**9.92**	**9.84**	**11.01**	**11.41 (17,598)**	**12.31 (8,333)**	**11.70 (25,931)**

** Note: 1. This analysis is based on the data of incidents and disabled vehicles (i.e., assists 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 a seasonal basis.

Note that CHART currently operates during 5 a.m. – 9 p.m. from Monday through Friday. Table E.6 presents that incidents are likely to be responded more promptly than disabled vehicles during both operational and non-operational hours.

Table E.6 Comparisons* of CHART Response Performance during and after Operational Hours

Response Time (mins)	Operational Hours		Non-operational Hours		Total		
	Incident	Disabled Vehicle	Incident	Disabled Vehicle	Incident	Disabled Vehicle	Sub-total
TOC-3	12.74 (2,611)	16.90 (1,220)	14.60 (91)	17.94 (27)	12.81 (2,702)	16.93 (1,247)	14.10 (3,949)
TOC-4	12.12 (3,104)	17.27 (1,578)	13.36 (60)	15.20 (34)	12.15 (3,164)	17.23 (1,612)	13.86 (4,776)
TOC-5	10.01 (45)	10.19 (28)	10.41 (66)	9.00 (50)	10.24 (111)	9.43 (78)	9.91 (189)
TOC-6	8.77 (1)	-	-	-	8.77 (1)	-	8.77 (1)
TOC-7	12.67 (2,054)	15.62 (550)	15.76 (77)	14.49 (22)	12.78 (2,131)	15.58 (572)	13.37 (2,703)
SOC	13.73 (1,445)	14.33 (663)	14.41 (3,483)	18.30 (2,297)	14.21 (4,928)	17.41 (2,960)	15.41 (7,888)
AOC	8.04 (1,565)	10.17 (1,179)	7.64 (868)	9.86 (614)	7.89 (2,433)	10.06 (1,793)	8.81 (4,226)
OTHER	7.37 (4)	4.07 (6)	5.43 (22)	3.95 (16)	5.73 (26)	3.98 (22)	4.93 (48)
Weighted Average	**11.99 (10,829)**	**14.98 (5,224)**	**13.06 (4,667)**	**16.32 (3,060)**	**12.31 (15,496)**	**15.58 (7,460)**	**13.41 (23,780)**

** 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 a seasonal basis.

Also, the 2015 data show that CHART's response operations are more efficient when incidents are more severe and cause lane blockages. In general, more severe incidents, especially involving in fatalities or heavy vehicles, demand longer clearance times.

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, the difference on the incident duration for one-lane-blockage incidents between with and without CHART involvement is about 12 minutes.

The duration of incidents managed by CHART response units averaged 23.54 minutes, shorter than the average duration of 33.18 minutes for those incidents by other agencies. On average, CHART operations in Year 2015 reduced the average incident duration by about 29 percent.

Performance improvement of CHART operations from years 2011 to 2015 is summarized in Table E.7:

Table E.7 Comparison of Average Incident Duration* with and without CHART Response

Year	With CHART (mins)	Without CHART (mins)
2011	22.14	29.44
2012	21.95	28.95
2013	21.64	31.54
2014	23.32	34.82
2015	23.54	33.18

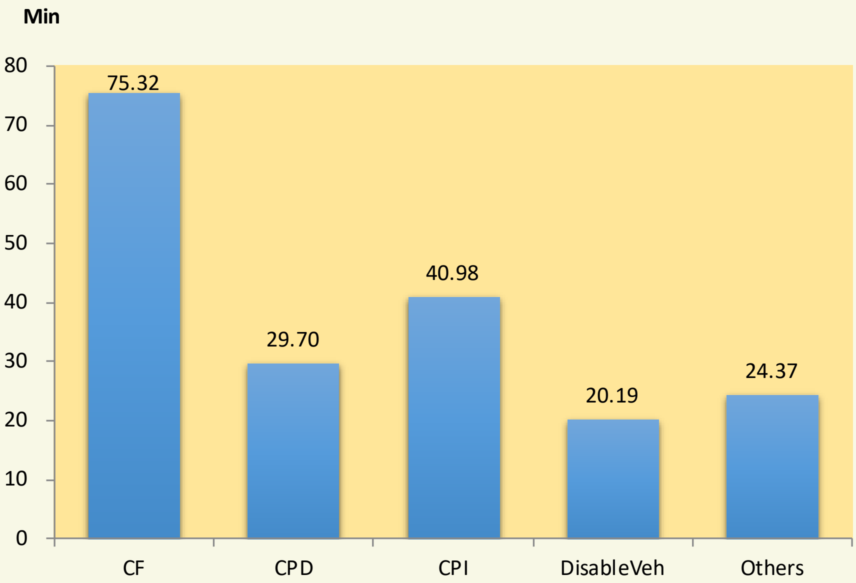
** This analysis is based on incidents which have included the information of event duration, lane blockage, and response units.*

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 those operational strategies, a reliably predicted/estimated incident duration will certainly play an essential role.

Hence, this study conducted a statistical analysis of incident durations, which provides some further insights into the characteristics of incidents under various conditions. In this analysis, the distributions of average incident duration are identified by predefined 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 (CF) was 75 minutes, while incidents with property damage (CPD) and personal injuries (CPI) lasted, on average, 30 and 41 minutes, respectively (see Figure E.1). The average duration of disabled vehicle incidents was 20 minutes, shorter than those classified as “Others” (e.g., debris, vehicles on fire, police activities, etc.), which have an average duration of approximately 24 minutes.



** Note: 1. This analysis is based on incidents which have included the information of event duration and nature.*

2. This analysis includes those sample data which have incident durations between 1 minute and 120 minutes.

Figure E.1 Distribution of Average Incident Duration by Nature

Resulting Benefits

The benefits due to CHART operations were estimated directly from the available data, including assistance to drivers and reductions in delay times, fuel consumption, emissions, and secondary incidents. In 2015, CHART responded to a total of 27,375 (out of 35,119) lane blockage incidents, and assisted 40,615 (out of 42,724) 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 442. In addition, the efficient removal of stationary vehicles and large debris from travel lanes by CHART patrol units may have prevented 797 potential lane-changing-related collisions in 2015, as vehicles approaching 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 attributed to delay reduction 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 resulting delay (see Chapter 7 for further information on benefits estimate). For instance, in 2015 several primary factors, such as AADT and the number of incident responses have been noticeably increased, compared with Year 2014, while other factors such as incident duration difference between with and without CHART and truck percentage have been decreased. The reduction in delay due to CHART's services in 2015 (39.20 million vehicle-hours) has been increased by 8 percent in comparison with the performance in 2014 (36.31 million vehicle-hours). The performance improvement consequently results in an increase of the total benefits by approximately 7 percent from $1,264.53 to $1,356.42. A comparison of the direct benefits from reduced delay times, fuel consumptions, and emissions, from 2011 to 2015, is summarized in Table E.8:

Table E.8 Comparison of Direct Benefits from 2011 to 2015

	Total Direct Benefits (million)[1,2,3,4]	# of Incidents Eligible for the Benefit Estimate[5]
2011	$1,096.61	20,547
2012	$961.69	19,920
2013	$1,162.97	23,706
2014	$1,264.53	27,014
2015	$1,356.42	29,827

** 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).

The main contributing factors on estimating benefits are listed and tabulated as follows:

- The total number of eligible incidents for the benefit estimate increased by about 10 percent from year 2014 to year 2015 as shown in Table E.9.
- The ratio reflecting the difference between incident duration with CHART and those without CHART decreased from 33 percent in 2014 to 29 percent in 2015 as shown in Table E.10.
- Table E.11 shows that the adjusted AADT with peak hour factors in 2015 for major roads in Maryland compared with 2014 generally increased by 3.23 percent.
- The truck percentage in 2015 decreased on all major roads, as shown in Table E.12.

Table E.9 The Total Number of Incidents Eligible for the Benefit Estimate

	2014	2015	Δ('14 ~ '15) *
No. of Incidents	27,014	29,827	**10.41%**

Note: 1. They only include the incidents causing main lanes blockage. To estimate benefits, the incidents causing only shoulder lanes blockage are excluded.

2. The percentage change in No. of Incidents (X) from Year 2014 to Year 2015 is calculated as follows:

$$\Delta\mathbf{X}(\%) = \frac{X_{2015} - X_{2014}}{X_{2014}} \times 100$$

Table E.10 Incident duration reduction in year 2014 and 2015

	With CHART(mins) (A)	Without CHART(mins) (B)	Difference(mins) (B-A)	Ratio in Difference ((B-A)/B)
2014	23.32	34.82	11.50	***33.03%***
2015	23.54	33.18	9.64	***29.05%***
Δ('14 ~ '15) *	*0.94%*	*-4.71%*	***-16.17%***	-

Note: The percentage change in incident duration (X) from Year 2014 to Year 2015 is calculated as follows: $\Delta\mathbf{X}(\%) = \frac{X_{2015}-X_{2014}}{X_{2014}} \times 100$

Table E.11 The adjusted AADT (with peak hour factor) for Major Roads from 2014 to 2015

	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	**2014**	11,677	7,979	7,164	10,680	4,343	1,891	4,203	2,936	3,181	54,054
	2015	12,051	8,217	7,176	11,085	4,499	2,344	4,348	2,909	3,171	55,800
Δ('14 ~ '15) (%)*		3.20	2.98	0.17	3.79	3.59	23.96	3.45	-0.92	-0.31	3.23

Note: The percentage change in the adjusted AADT(X) from Year 2014 to Year 2015 is calculated as follows: $\Delta\mathbf{X}(\%) = \frac{X_{2015}-X_{2014}}{X_{2014}} \times 100$

Table E.12 Truck percentage for Major Roads from year 2014 to 2015

	Year	I-495	I-95	I-270	I-695	MD 295	US 50	US 1	I-83	I-70	Average
Truck %	**2014**	10.69	14.78	8.15	9.97	3.53	9.03	5.26	9.03	11.68	**9.12**
	2015	9.24	13.86	7.90	9.96	3.30	9.32	5.21	9.24	12.17	8.91
Δ('14 ~ '15)(%)*		-13.53	-6.21	-3.02	-0.06	-6.47	3.17	-1.04	2.29	4.23	-2.33

Note: The percentage change in the truck percentage from Year 2014 to Year 2015 is calculated as follows: $\Delta\mathbf{X}(\%) = \frac{X_{2015}-X_{2014}}{X_{2014}} \times 100$

The following procedures are used for performing the above sensitivity analyses:

- Identifying key factors contributing to the total CHART benefits, which are: traffic volume, the number of blocked lanes, incident duration with and without CHART involvements, truck percentage, value of time, and gas price;
- Computing the marginal impact of each selected factor, using its 2015 value, but setting all other factors identical to those in 2014; and
- Following the same procedures to analyze the sensitivity of the total 2015 benefits with respect to each key factor.

The results of sensitivity analysis for each factor are shown in the Table E.13. Notably, the increase of 3.23 percent in the AADT adjusted with the peak hour factor result in 10.14 percent benefit increase. Also, the number of incidents increased by 10.41 percent in 2015 resulted in the 10.41 percent benefit increase. The difference between incident duration with CHART and those without CHART decreased by 16.17 percent in 2015 and it leads to 12.03 percent benefit reduction. The decrease of 2.33 percent in truck percentage resulted in 0.17 percent reduction in benefits. Since the unit rate of gas price is much lower than the unit rate of time value, the total benefits decrease only by 0.49 percent despite the significant decrease in gas price by 28.15 percent and the slight increase in the value of time by 0.57 percent.

Table E.13 Sensitivity Analysis of key factors contributing to the Benefits (Unit: M dollar)

<table>
<tr><th colspan="3">Benefit of the Previous Year (2014)</th><th>1,264.53</th></tr>
<tr><th colspan="2">Key Factor</th><th>Δ ('14 - '15)</th><th>Benefit difference</th></tr>
<tr><td rowspan="6">Sensitivity Analysis</td><td>Adjusted AADT</td><td>▲ 3.23 %</td><td>1,392.73(▲10.14%)</td></tr>
<tr><td>Number of incidents</td><td>▲ 10.41 %</td><td>1,396.23(▲10.41%)</td></tr>
<tr><td>Incident duration difference between w/ and w/o CHART</td><td>▼ 16.17 %</td><td>1,112.40(▼12.03%)</td></tr>
<tr><td>Truck percentage</td><td>▼ 2.33 %</td><td>1.262.34(▼0.17%)</td></tr>
<tr><td>Monetary unit value of time</td><td>▲ 0.57 %</td><td rowspan="2">1,258.35 (▼0.49%)</td></tr>
<tr><td>Monetary unit of gas price</td><td>▼ 28.15 %</td></tr>
<tr><td colspan="3">Benefit of the Current Year (2015)</td><td>1,356.42 (▲7.27%)</td></tr>
</table>

** The number in each parenthesis shows the percentage of benefit change from year 2014.*

Conclusions and Recommendations

Grounded on the lessons from the earlier studies, this study has conducted a rigorous evaluation of CHART's performance in 2015 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 overall 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 2015 was 11.70 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 2015, are listed below:

- Increase the resources for CHART to sustain the high quality incident response operation, including more staffs and hardware supports.
- Provide practical training to staffs in the control center responsible for recording incident related information to ensure the data quality.
- Develop and update a strategy to allocate CHART's resources between different response centers, based on their respective performance and efficiency so that they can effectively contend with the ever-increasing congestion and accompanying incidents both in urban and suburban areas.
- 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 data quality evaluation report available to the centers' operators for their continuous improvement of data recording and documentation.
- Implement training sessions to educate/re-educate operators on the importance of high-quality data, and discuss how to effectively record critical performance-related information.
- Improve the data structure used in the CHART-II system for recording incident locations to eliminate the current laborious and complex procedures.
- Document and re-investigate the database structure on a regular basis to improve the efficiency and quality of collected data.
- Document possible explanations for extremely short or long response and/or clearance times so that the results of performance analysis can be more reliable.
- 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.

Summary of Key Findings from the 2015 CHART Performance Evaluation

- A significant increase (about 11 percent) in the incident response frequency, but a significant decrease (about 8 percent) in the number of assists to drivers. The total number of emergency responses are at the same level as in 2014.
- A significant increase (about 10 percent) in the response frequency of incidents which caused more than two lanes blockage.
- A significant decrease (about 29 percent) in incident duration between with and without CHART involvement.

The aforementioned changes along with other factors contributed to the substantial increase (about 7 percent) on the direct benefits by CHART performance in 2015.

CHAPTER 1

INTRODUCTION

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 "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, 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.

1 INTRODUCTION

The 1997 CHART performance evaluation, compared with 1996, 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 35,119 reports in 2015. A summary of total emergency response operations documented from 2011 to 2015 is presented in Table 1.1.

Table 1.1 Total Number of Emergency Response Operation Records*

Records	2011	2012	2013	2014	2015
Incidents	22,534 (16,337)	22,328 (15,347)	24,738 (17,842)	31,535 (25,571)	35,119 (27,375)
Disabled Vehicles	37,571 (24,143)	41,243 (26,576)	35,781 (29,865)	46,330 (45,228)	42,724 (40,615)
Total	60,105 (40,480)	63,571 (41,923)	60,519 (47,707)	77,865 (70,799)	77,843 (67,990)

* *1. "Incidents" indicate any events interrupting traffic flows on main lanes; "disabled vehicles" indicate assists to drivers; and "Total" is the sum of incidents and disabled vehicles.*

2. Number in each parenthesis shows the incidents and assists by CHART .

INTRODUCTION

1

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 2014 and 2015, 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 2015 CHART performance evaluation. This includes the total available incident reports, the percentage of missing data for each critical performance parameter, and a comparison of 2015 data quality with that of 2014.

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.

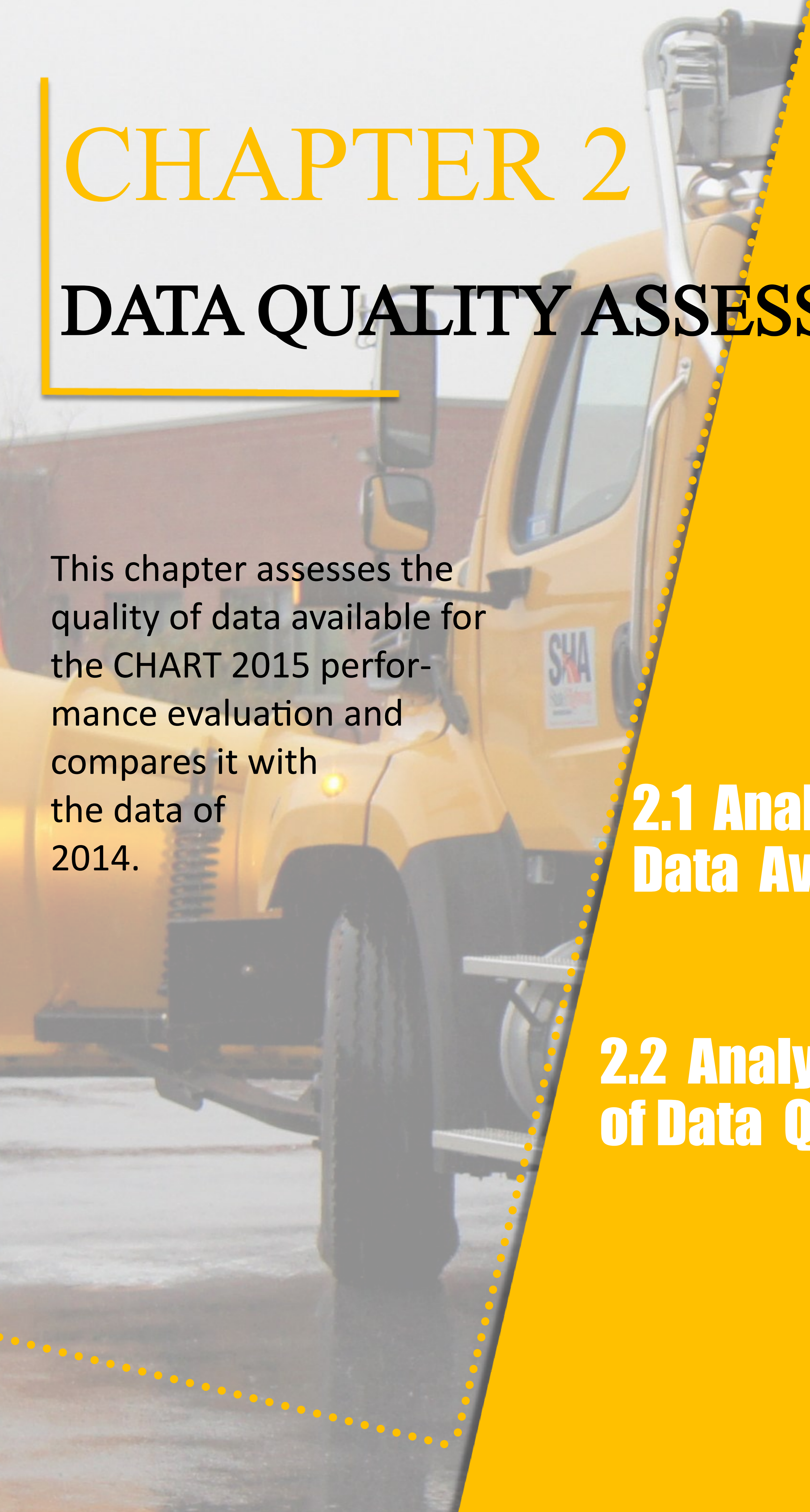
Chapter 4 provides a detailed report on the efficiency and effectiveness of incident detection. Issues discussed are the detection rate, the distribution of detection sources for various types of incidents, and driver requests for assistance. The chapter also touches on an evaluation of incident response 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 2015 performance evaluation and compares it with the data of 2014.

2.1 Analysis of Data Availability

2.2 Analysis of Data Quality

2

2.1 Analysis of Data Availability

In 2015, CHART recorded a total of 77,843 emergency response cases. These are categorized into two groups: incidents and disabled vehicles. A summary of the total available incident reports for the years 2013, 2014 and 2015 is shown in Table 2.1.

Table 2.1 Comparison of Available Data for 2013, 2014, and 2015

Available Records		2013		2014		2015	
		Records	Ratios (%)	Records	Ratios (%)	Records	Ratios (%)
CHART II Database	**Disabled Vehicles**	35,781	59.1	46,330	59.5	42,724	54.9
	Incidents	24,738	40.9	31,535	40.5	35,119	45.1
Total		60,519	100	77,865	100	77,843	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 2014 and 2015.

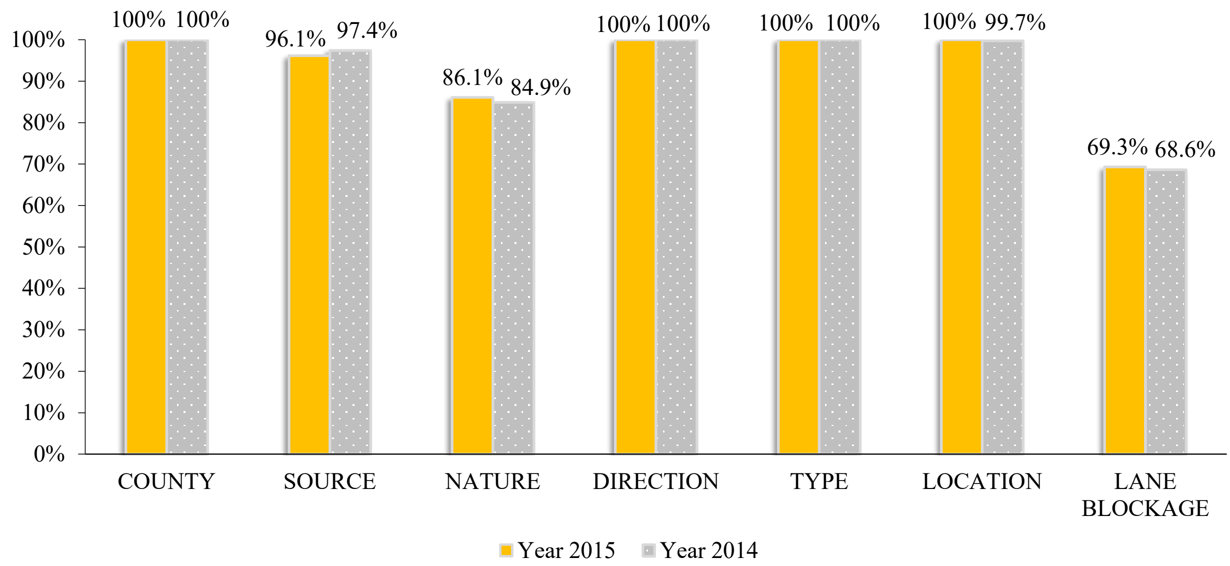


Figure 2.1 Summary of Data Quality for Critical Indicators

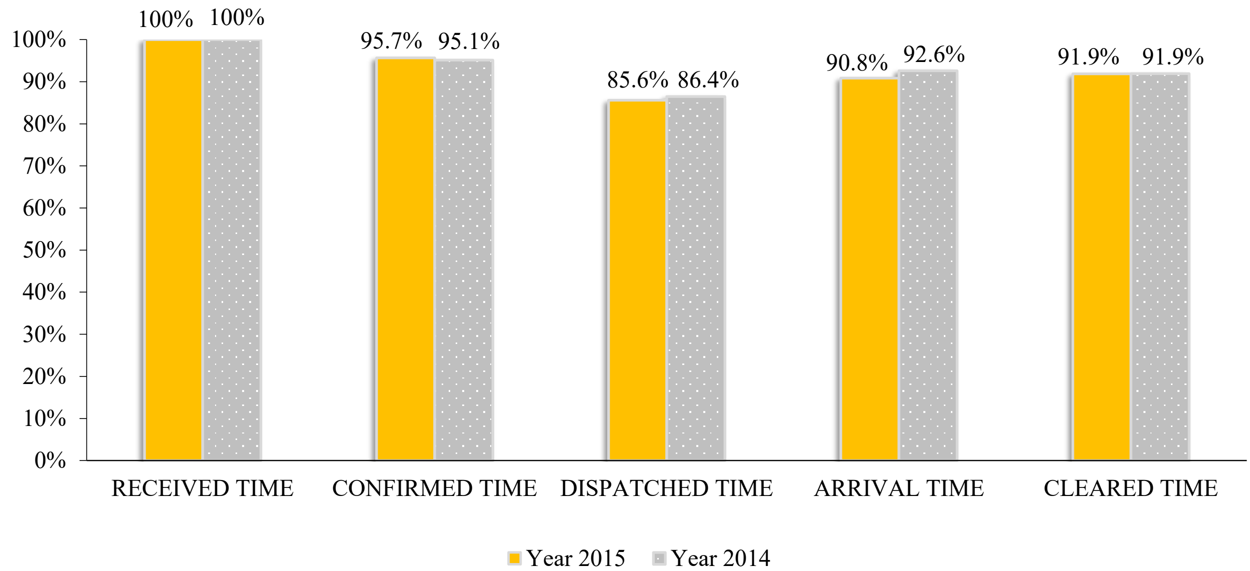


Figure 2.2 Summary of Data Quality for Time Indicators

ANALYSIS OF DATA QUALITY

2.2

Nature of incident/ disabled vehicle

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 86.1 percent of emergency responses reported in 2015 recorded the nature of incidents the source of detection.

Detection Sources

As Figure 2.1 shows, about 96.1 percent of all emergency responses recorded in 2015 contained the source of detection, which is almost the same as the previous year's data. In 2015, about 92.3 percent of incidents reported and 99.3 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 2015 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.

2.2 ANALYSIS OF DATA QUALITY

Type of Reports

The total number of incidents/disabled vehicles managed by each operation center in 2015 is summarized in Table 2.2. Overall, CHART responded to a total of 27,375 (out of 35,119) incidents in 2015. Over the same period, the response team also took care of 40,615 (out of 42,724) disabled vehicle requests.

Table 2.2 Emergency Assistance Reported in 2015

Operations Center	TOC3	TOC4	SOC	TOC6	TOC7	AOC	OTHER	TOTAL
Disabled Vehicles	6,964	7,889	13,861	10	5,530	7,248	1,222	42,724 (46,330)
Incidents	5,106	5,546	12,767	75	3,946	7,190	489	35,119 (31,535)
Total	12,070	13,435	26,628	85	9,476	14,438	1,711	77,843 (77,865)

Note: numbers in each parenthesis are the corresponding data from 2014

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.

ANALYSIS OF DATA QUALITY

2.2

Table 2.3 shows the percentage of data with road names and highway segment location information (i.e., exit numbers) for incidents and disabled vehicles in the CHART II Database for 2015. Note that almost 100 percent of data have some information related to the locations but about 54.45 percent of data in the database clearly identify the highway segment where the event occurred. For the remaining 45.55 percent, the location information is either unclear or not specified, and therefore cannot be used for performance analysis.

Table 2.3 Data Quality Analysis with Respect to Road and Location

Data Quality	Incident	Disabled Vehicles	Total
Road	99.23%	99.62%	99.45%
Location	99.98%	99.96%	99.97%
Valid Data for Road & Location	50.62%	57.60%	54.45%

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 2015 shows that up to 69.29 percent of emergency response reports involved lane/shoulder blockage. This value is higher than the 68.63 percent in 2014 (Figure 2.1).

In summary, in 2015, 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

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 77 percent) of incidents/disabled vehicles in 2015 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	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014
Weekdays	98%	99%	98%	99%	38%	29%	100%	98%	97%	99%
Weekends	2%	1%	2%	1%	62%	71%	0%	2%	3%	1%

Center	SOC		AOC		Other*		Total	
Year	2015	2014	2015	2014	2015	2014	2015	2014
Weekdays	54%	55%	75%	76%	29%	36%	77%	81%
Weekends	46%	45%	25%	24%	71%	64%	23%	19%

** Includes RAVENS TOC and REDSKINS TOC*

3.1 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY DAY AND TIME

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 28 percent of incidents/disabled vehicles reported in 2015 occurred during peak hours, which is slightly lower than the one in 2014.

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

Center	TOC3		TOC4		TOC5		TOC6		TOC7	
Year	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014
Peak**	37%	37%	40%	40%	20%	16%	40%	32%	46%	46%
Off-Peak	63%	63%	60%	60%	80%	84%	60%	68%	54%	54%

Center	SOC		AOC		Other*		Total	
Year	2015	2014	2015	2014	2015	2014	2015	2014
Peak**	13%	13%	26%	25%	13%	9%	28%	29%
Off-Peak	87%	87%	74%	75%	87%	91%	72%	71%

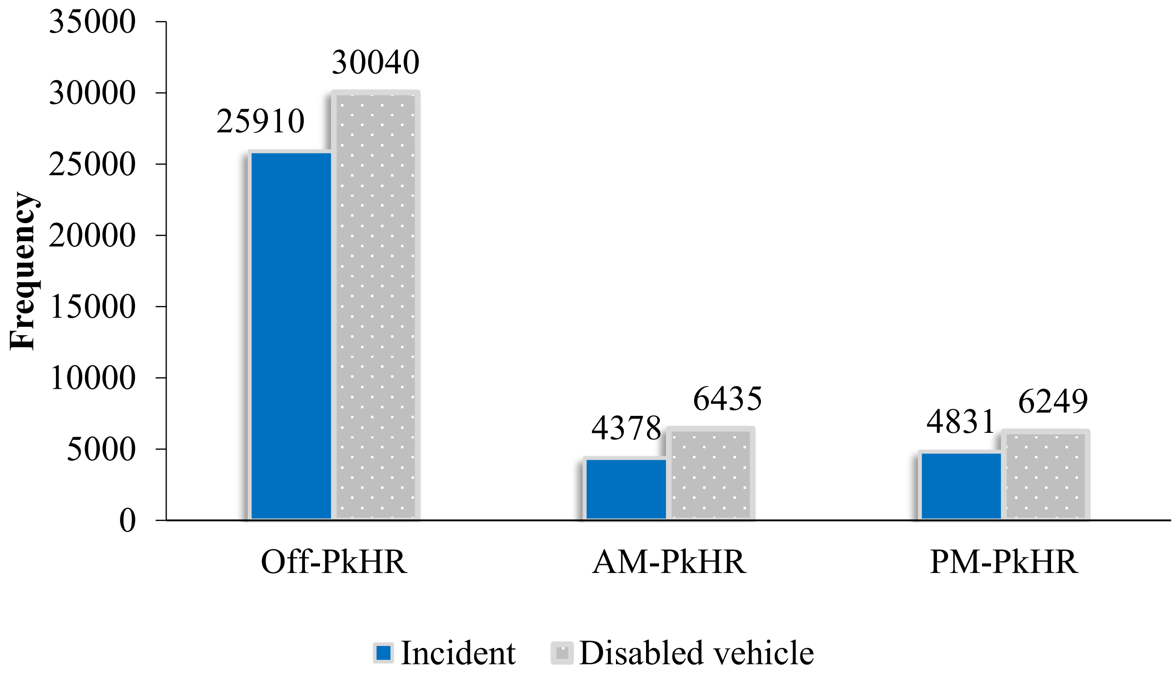
** Includes RAVENS TOC and REDSKINS TOC*

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

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY DAY AND TIME

3.1

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 A.



** 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 2015

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

Figure 3.2 compares the frequency distribution among roads between 2015 and 2014, and Figure 3.3 depicts the frequency distribution of incidents and disabled vehicles for 2015.

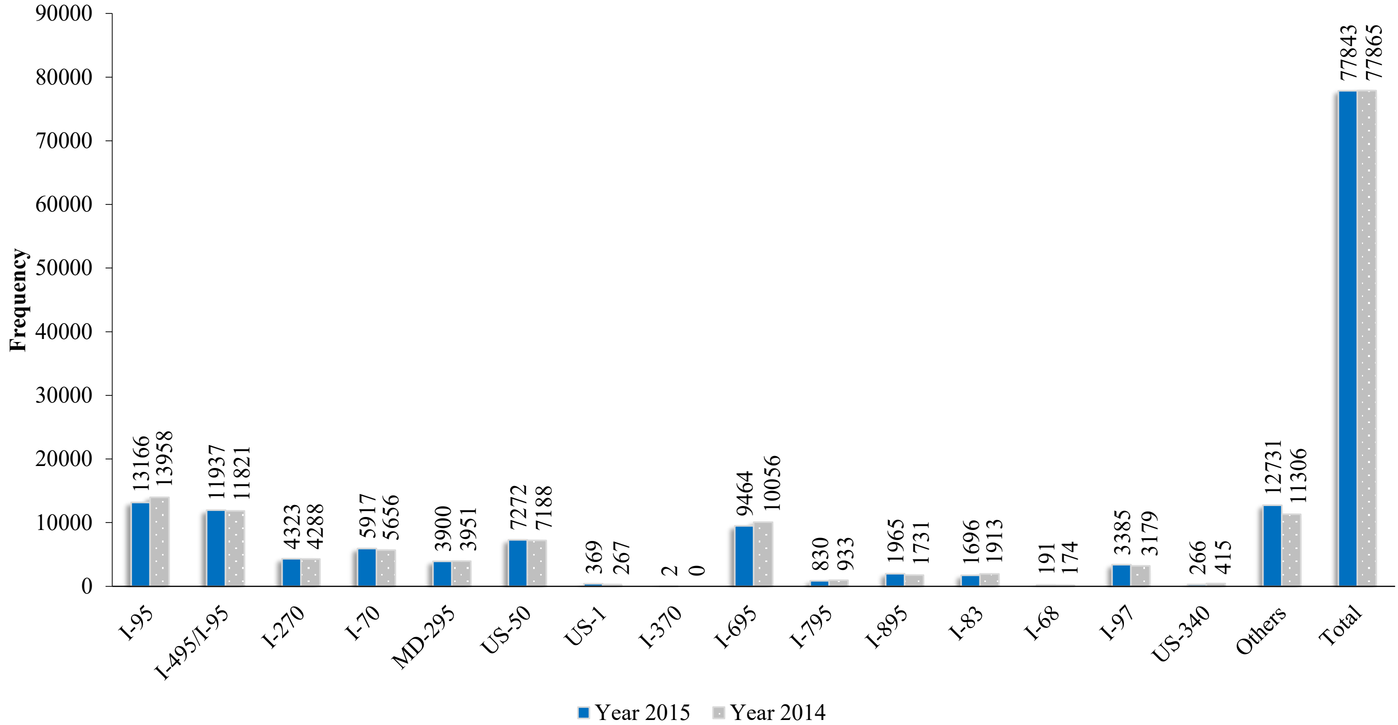


Figure 3.2 Distributions of Incidents/Disabled Vehicles by Road in 2015 and 2014

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

3.2

Based on the statistics shown above, the roadways with high incident frequencies for 2015 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-270. I-95 experienced a total of 13,166 incidents/disabled vehicles in 2015, while I-695 had 9,464 incidents/disabled vehicles within the same period. I-495/95, US-50, I-70 and I-270 had 11,937, 7,272, 5,917, and 4,323 incidents/disabled vehicles, respectively. Also, notice that the CHART-II database includes 429 incidents/ disabled vehicles detected by CHART with incomplete information for road names in 2015.

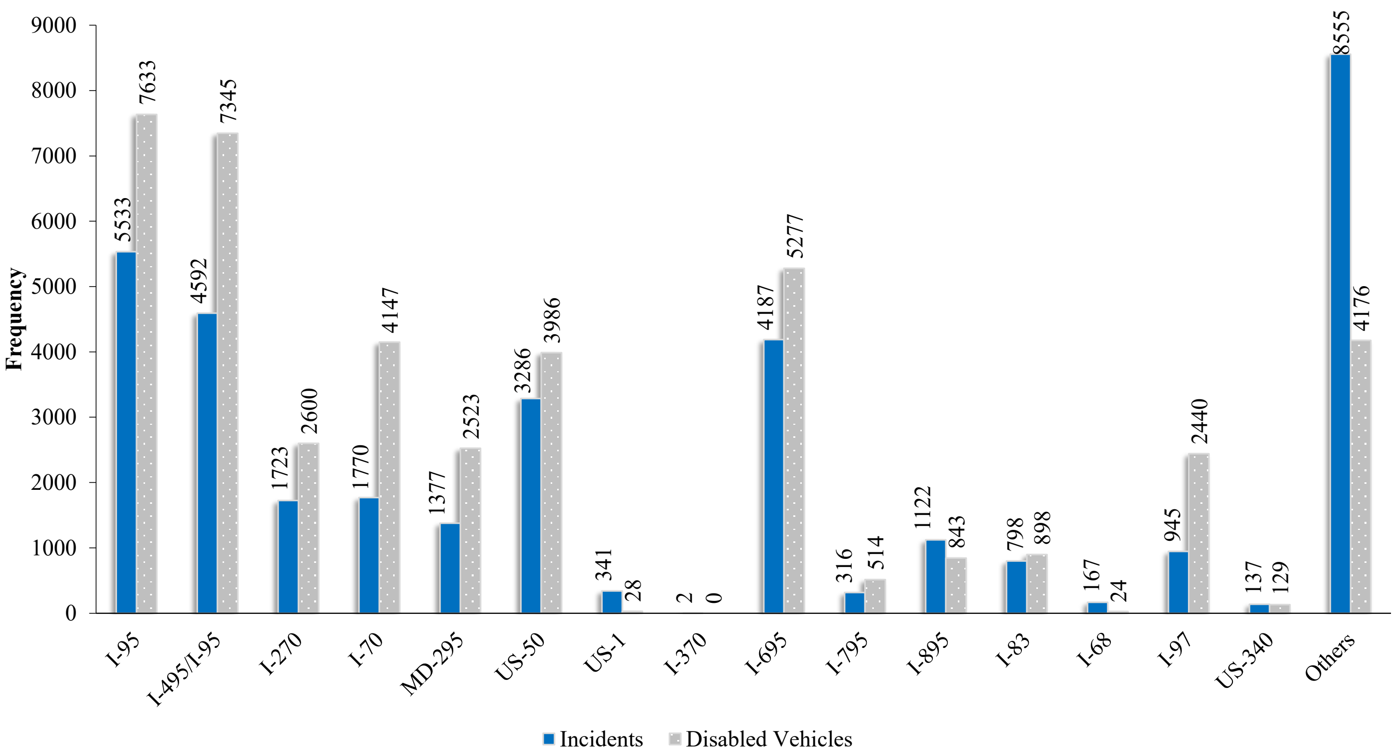


Figure 3.3 Distributions of Incidents/Disabled Vehicles by Road in 2015

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

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, incidents occurred more frequently during p.m. peak hours than in a.m. peak hours on most major roads, but more disabled vehicles occurred during a.m. peak hours than in p.m. peak hours on I-95, I-495/I-95, I/MD-295 and I-695.

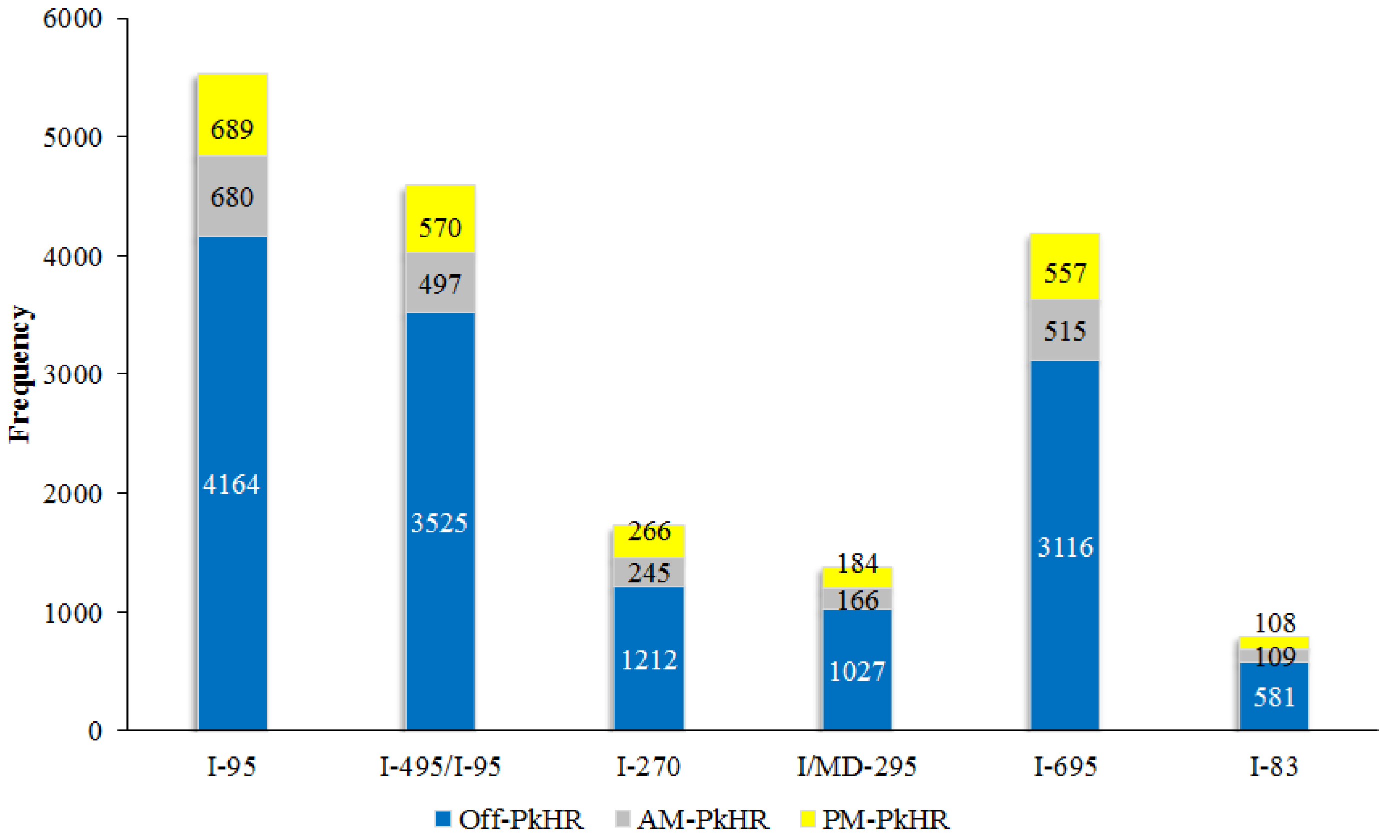


Figure 3.4 Distributions of Incidents by Time of Day on Major Roads in 2015

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

3.2

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 .

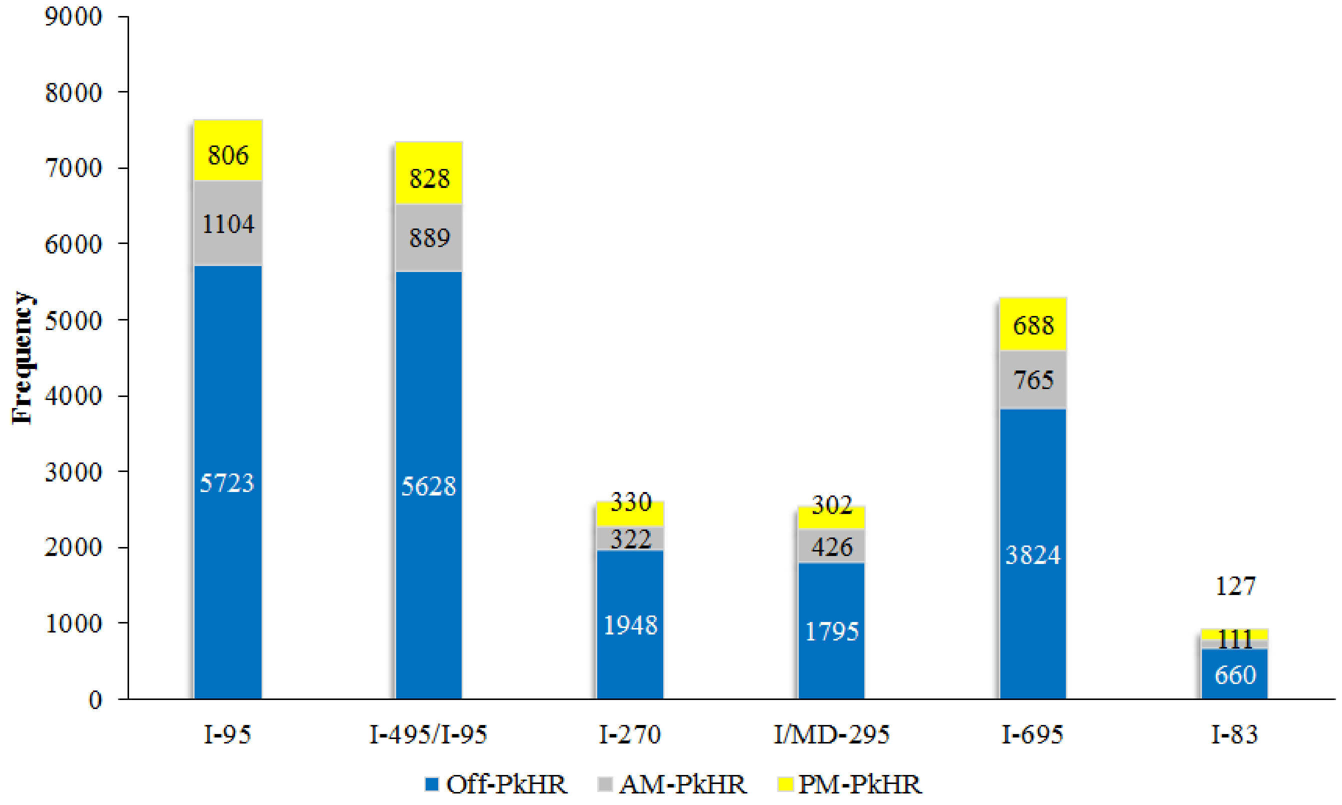


Figure 3.5 Distributions of Disabled Vehicles by Time of Day on Major Roads in 2015

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

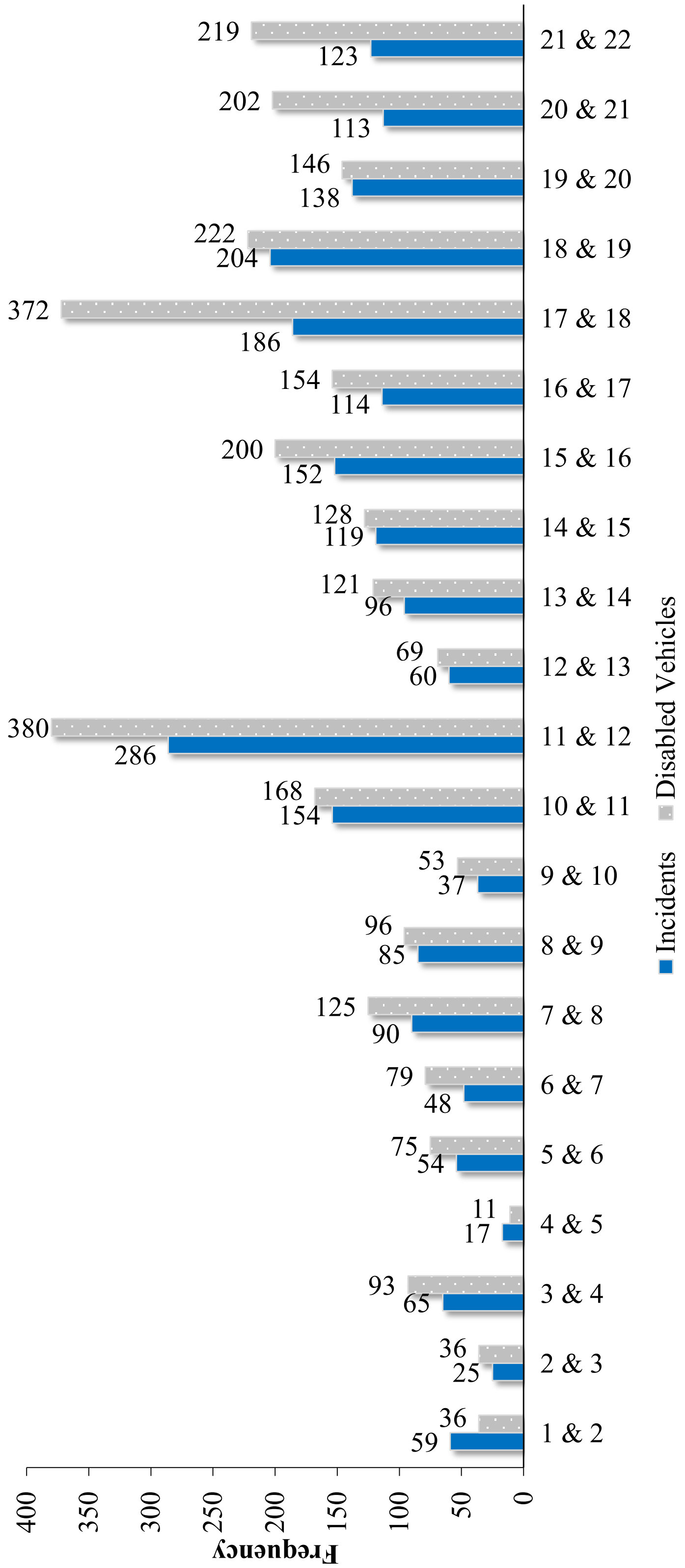


Figure 3.6 Distributions of Incidents/Disabled Vehicles by Location on I-695

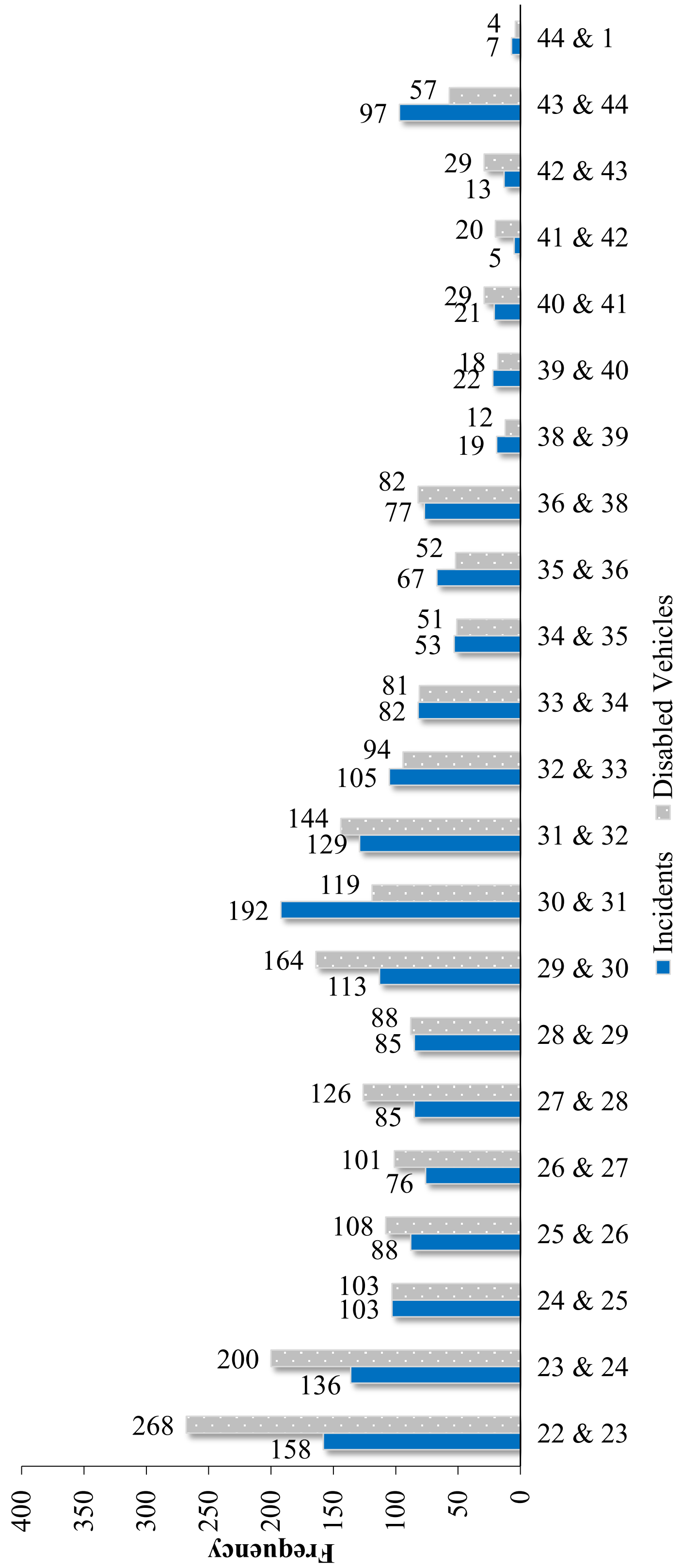


Figure 3.6 Distributions of Incidents/Disabled Vehicles by Location on I-695 (cont.)

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

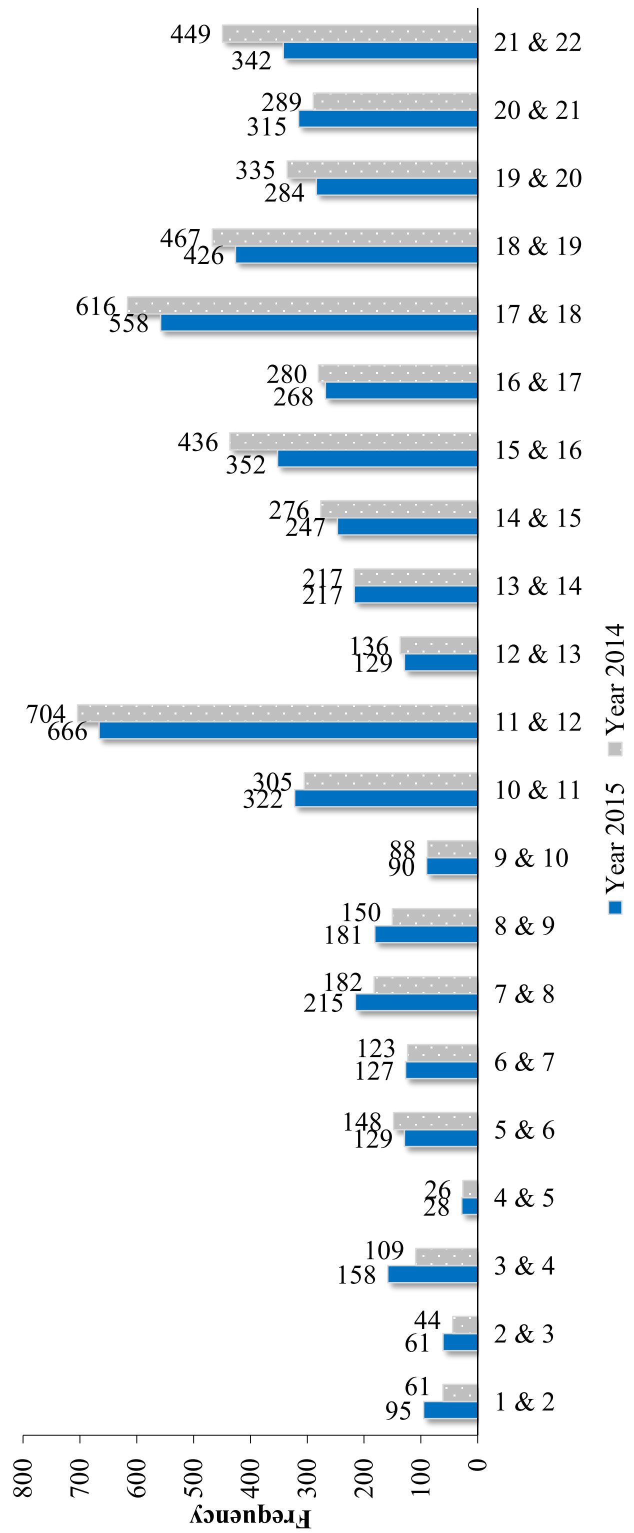


Figure 3.7 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-695

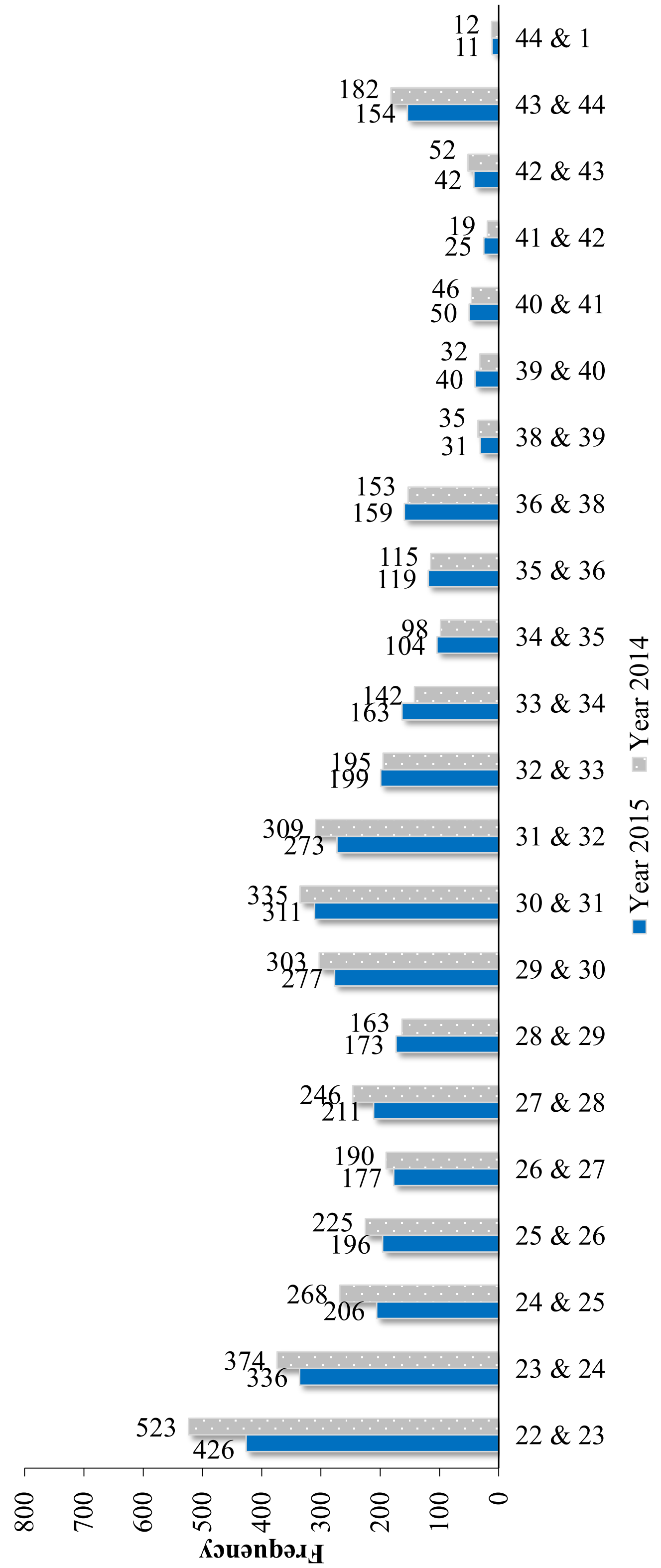


Figure 3.7 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-695 (Cont.)

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

Figure 3.6 shows the distribution of incidents and disabled vehicles by location on I-695 in 2015, while Figure 3.7 compares these values with the results in 2014. The high-incident segments are from Exits 11 to 12, Exits 18 to 19, and Exit 30 to 31 (286, 204 and 192, respectively). The two high frequencies of disabled vehicles (380 and 372 cases) were recorded on the segments between Exits 11 and 12 and Exits 17 and 18, which are close to the I-95 and I-70 interchanges, respectively.

The subsequent figures present the comparison between 2015 and 2014 incident 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 (319 cases) occurred between Exits 31 and 33 of I-495. The location with the highest frequency of disabled vehicles (509 cases) occurred between Exits 20 and 22. A comparison with the data in 2014 is illustrated in Figure 3.9.

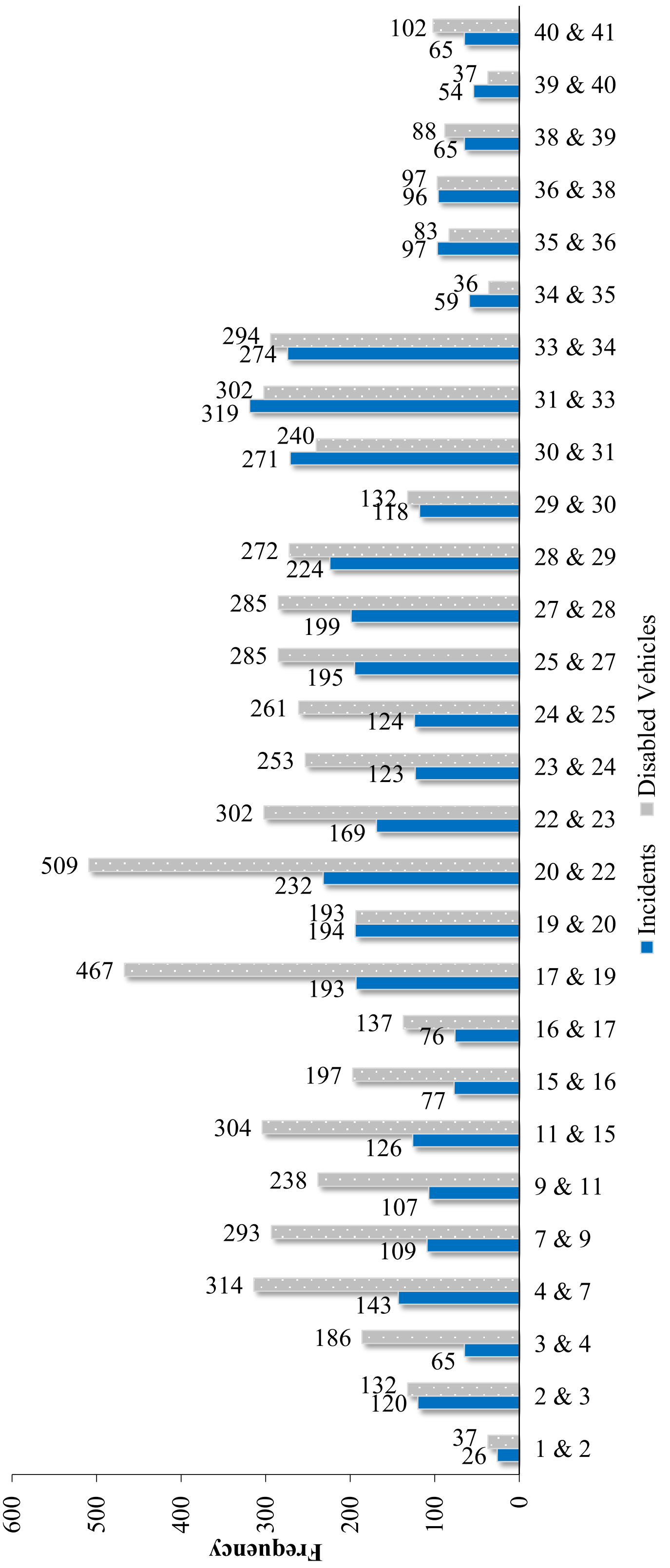


Figure 3.8 Distributions of Incidents/Disabled Vehicles by Location on I-495/I-95

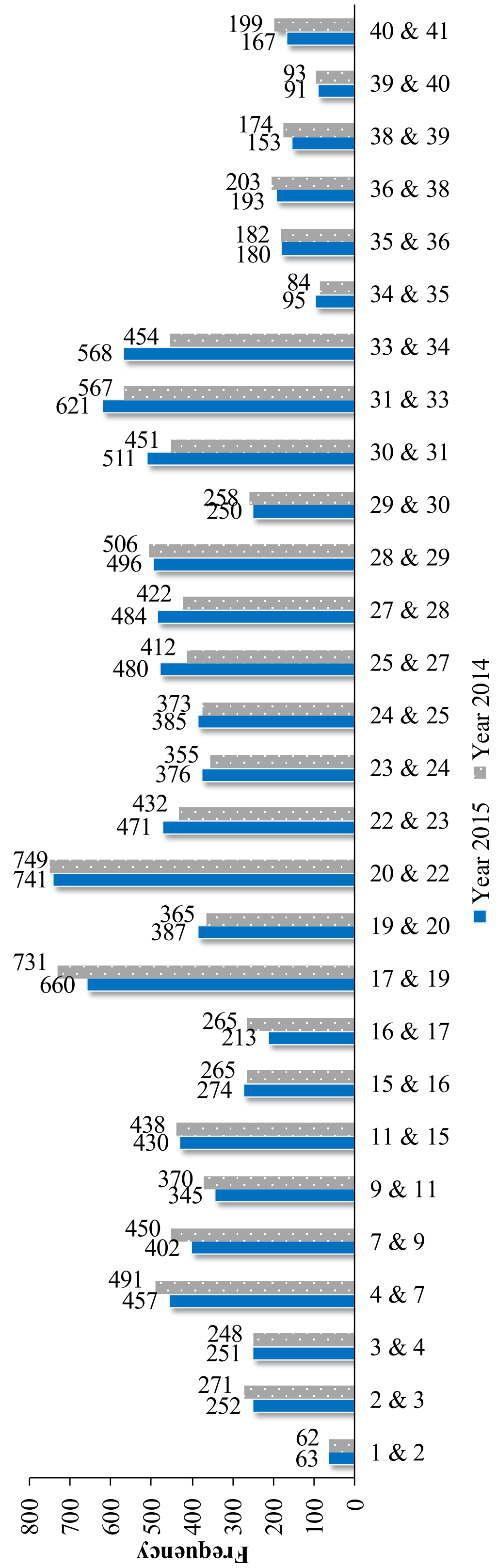


Figure 3.9 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-495/I-95

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 2015 and 2014. As shown in Figure 3.10, the highest number of incidents occurred at the segment between Exits 55 and 56 (506 cases). The segments between Exits 67 and 74 experienced a high number of disabled vehicles (769 cases).

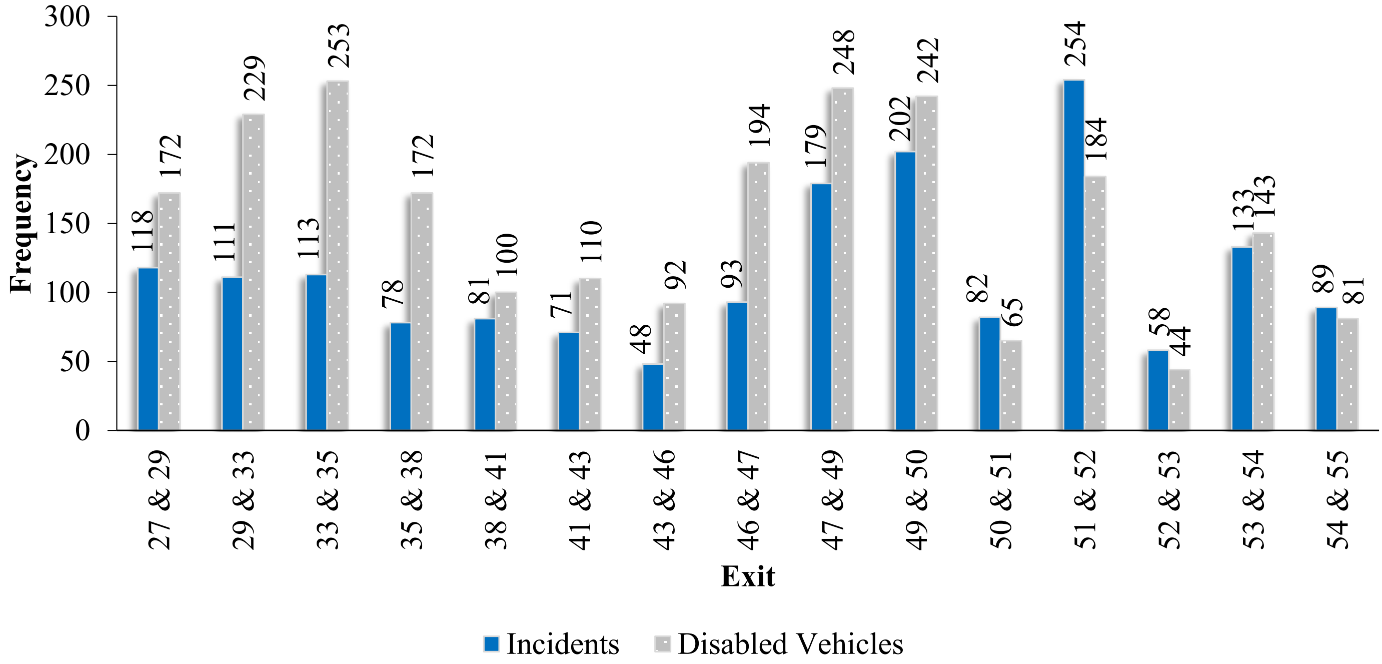


Figure 3.10 Distributions of Incidents/Disabled Vehicles by Location on I-95

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

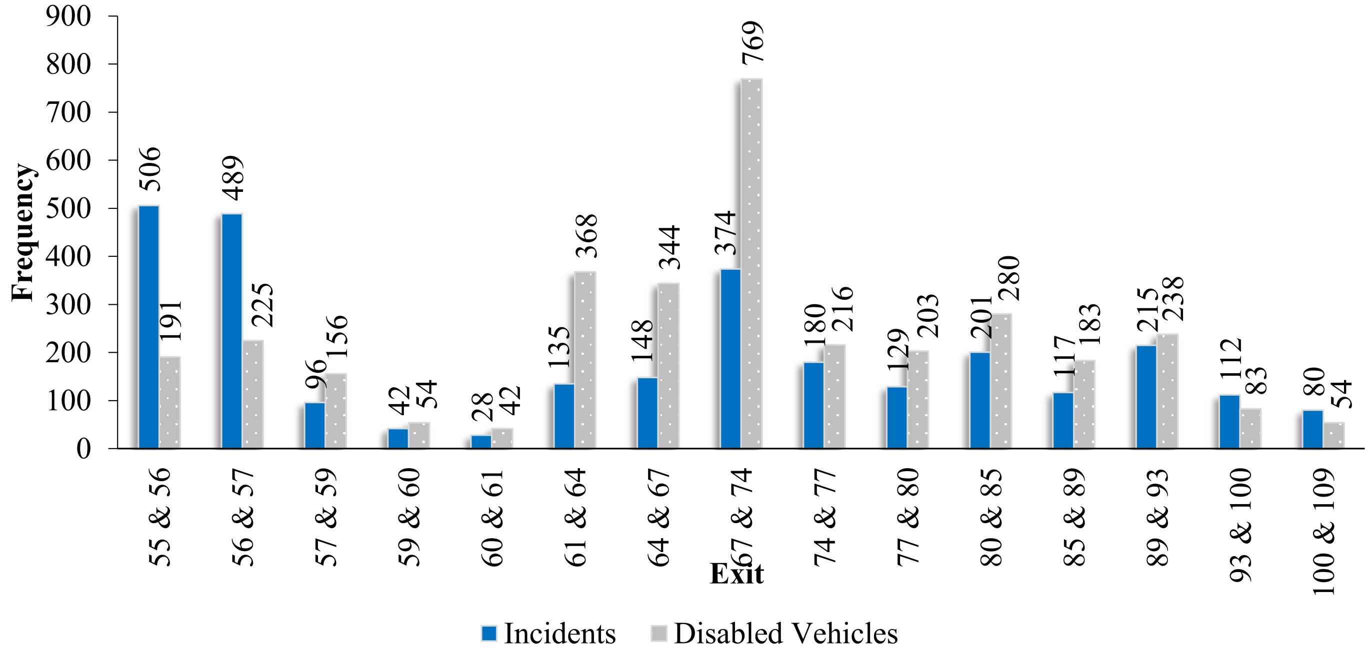


Figure 3.10 Distributions of Incidents/Disabled Vehicles by Location on I-95 (cont.)

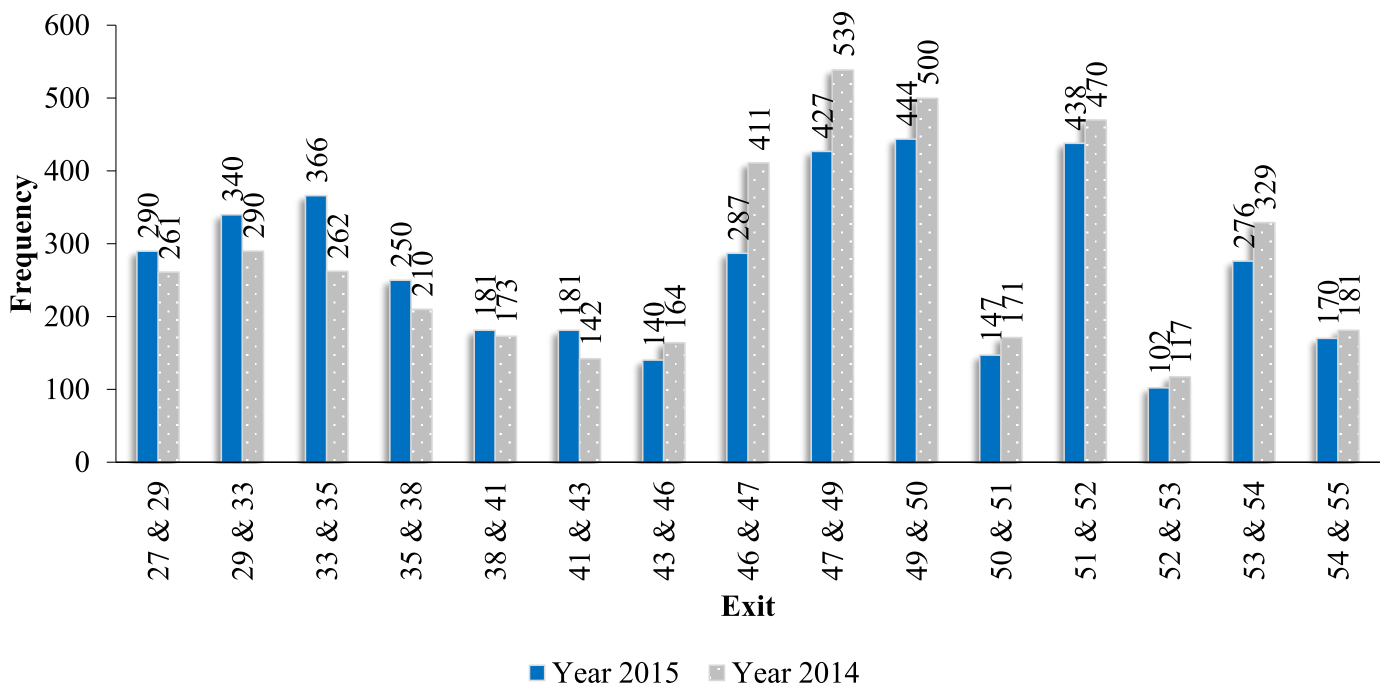


Figure 3.11 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-95

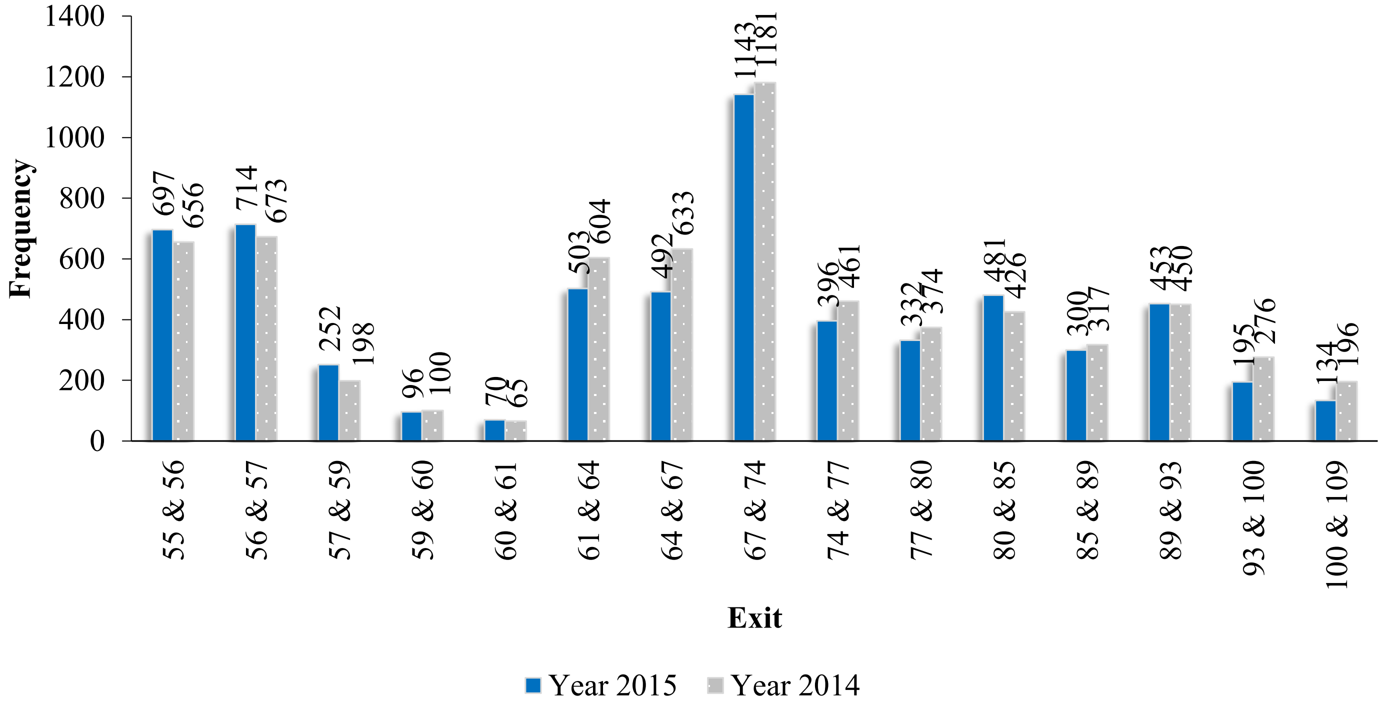


Figure 3.11 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-95 (cont.)

In 2015, the incidents and disabled vehicles recorded for the I-95 segment between Exits 67 and 74 received the maximum number of records, with a total frequency of 1,143. The segments on I-95 between Exits 56 and 57 sustained the second largest number of incidents/disabled vehicles requests (714) in 2015. These trends are similar to those observed in 2014.

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

Figure 3.12 represents the spatial distribution of incidents/disabled vehicles data on I-270 for 2015. The segment between Exits 6 and 8 on I-270 experienced the highest numbers of incidents (130) and the segment between Exits 11 and 13 experienced the highest number of disabled vehicles (119).

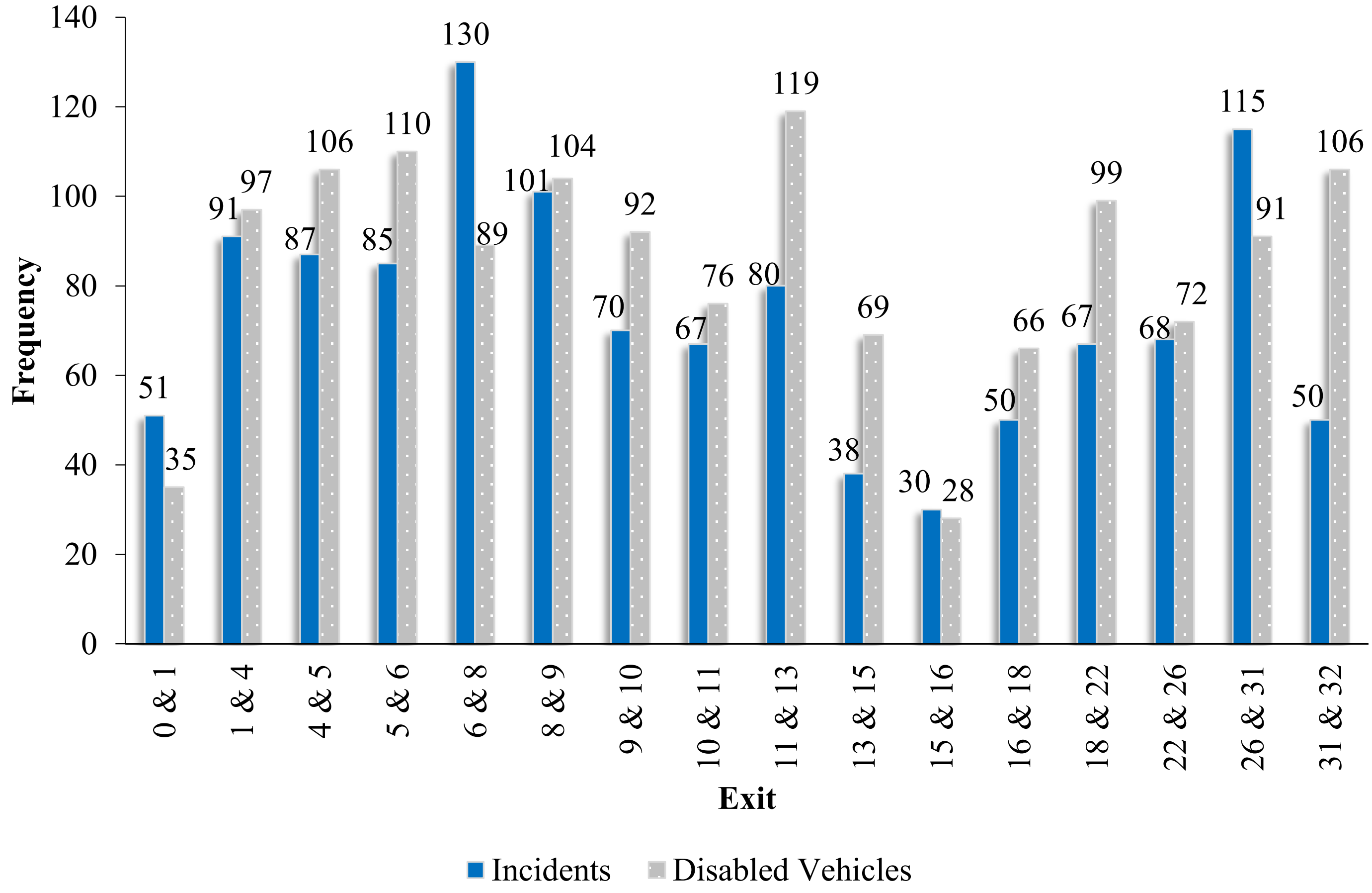


Figure 3.12 Distributions of Incidents/Disabled Vehicles by Location on I-270

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

3.2

Figure 3.13 shows a comparison between 2015 and 2014 data; apparently, the 2015 data recorded more incidents/disabled vehicles between Exits 5 and 6, Exits 6 and 8, and Exits 8 and 9 than in 2014 while it recorded fewer between Exits 4 and 5 and Exits 16 and 18 than in 2014.

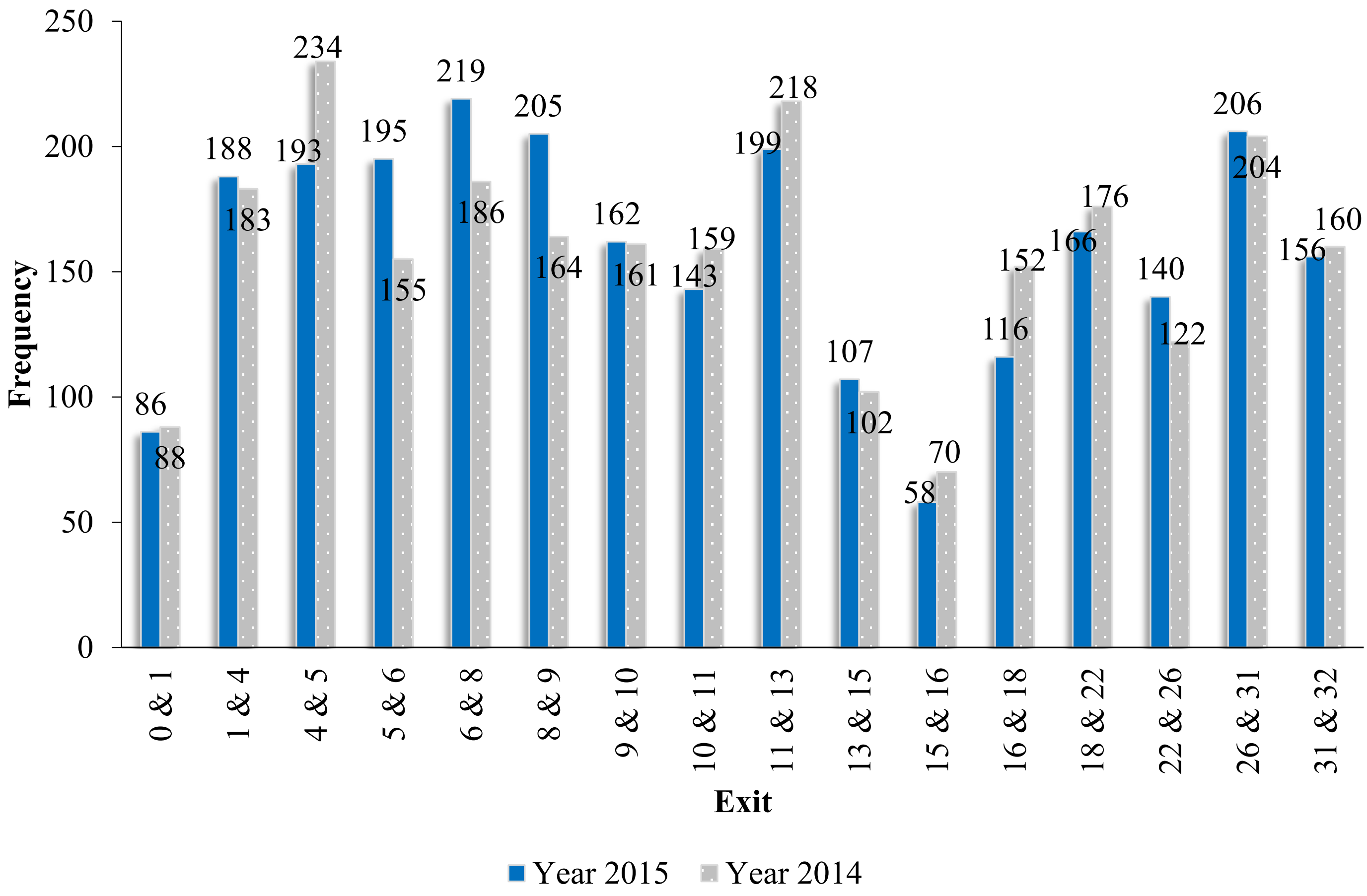
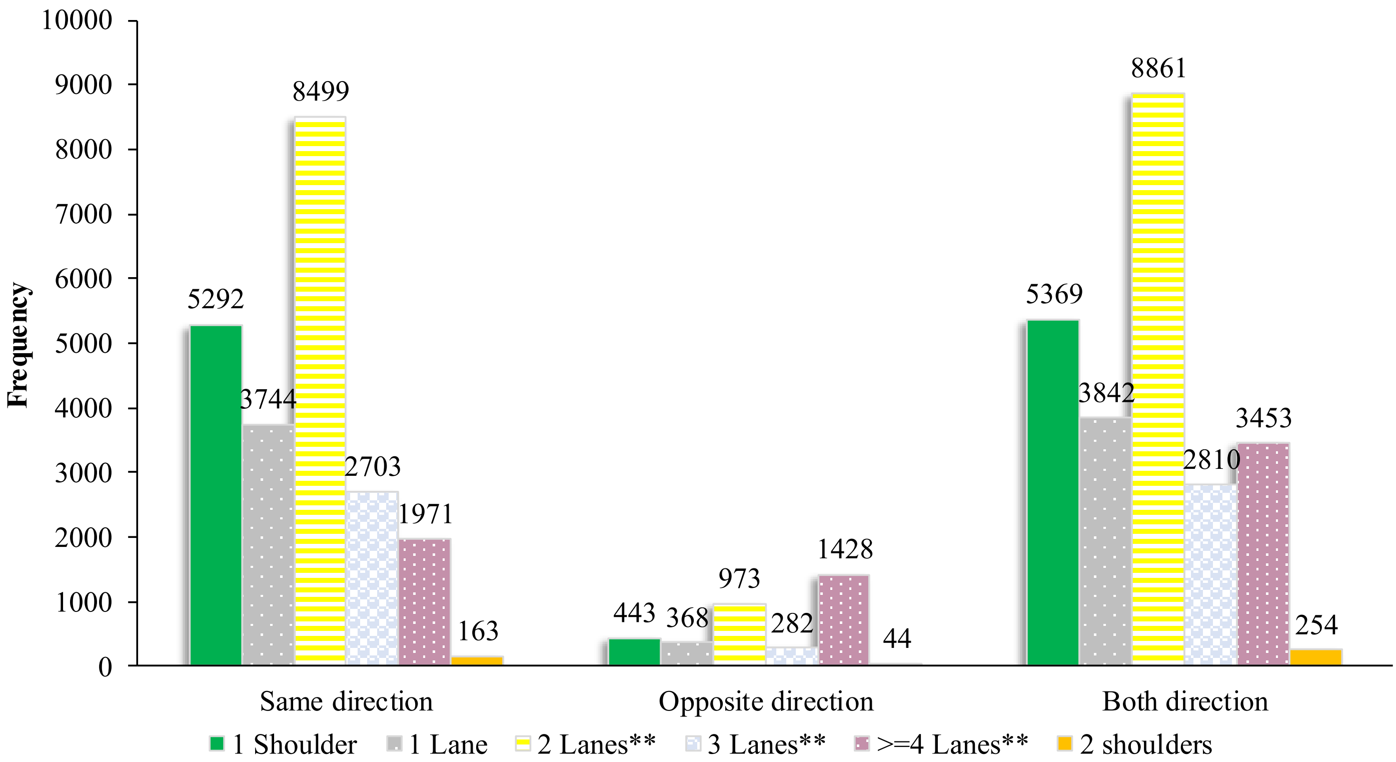


Figure 3.13 Comparisons of Incidents/Disabled Vehicles Distribution by Location on I-270

3.3 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY LANE BLOCKAGE TYPE

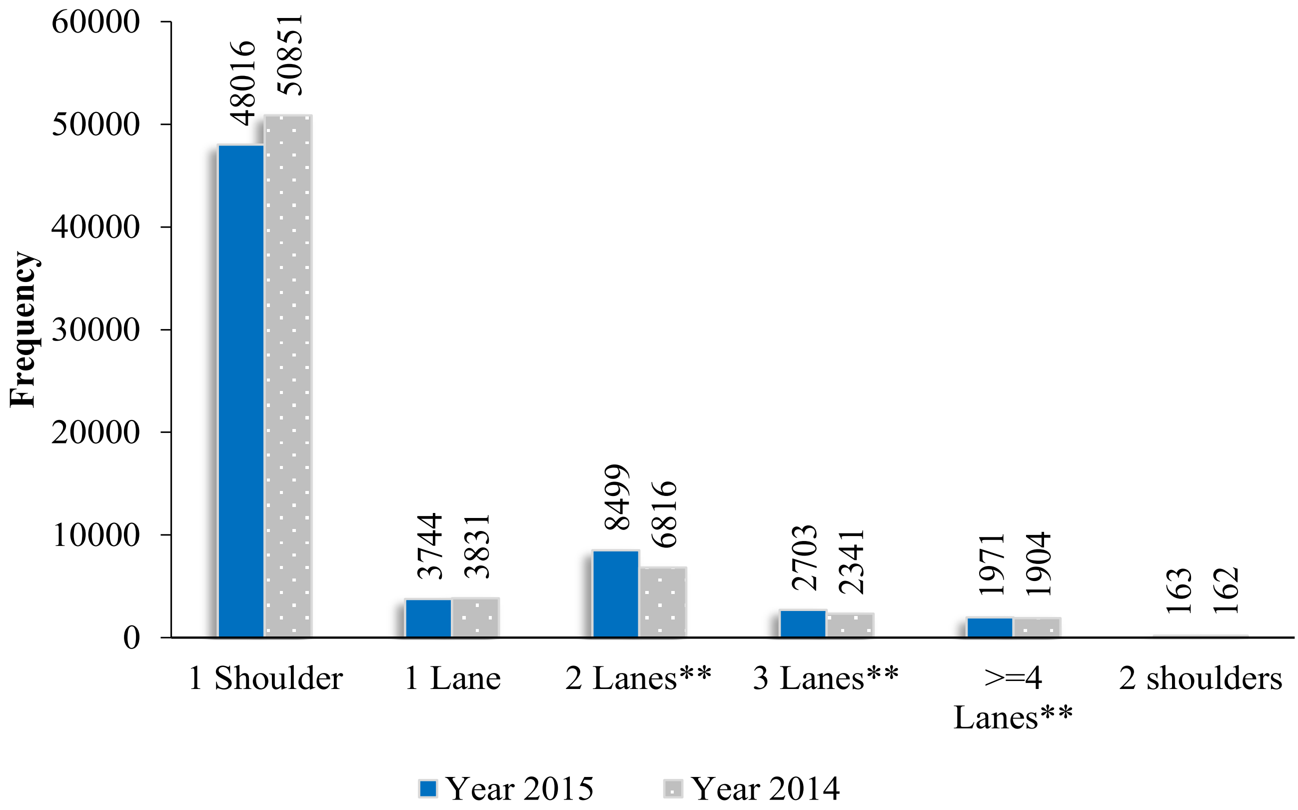
Figure 3.14 illustrates the distribution of incidents by lane blockage in 2015. A large percentage of those incidents resulted in one-shoulder or two-lane blockages. The comparison of 2015 incidents/disabled vehicles distribution by lane blockage with 2014 data is illustrated in Figure 3.15. Note that all reported disabled vehicles are classified as shoulder lane blockages.



Note: *This analysis uses only incidents (not including "Disabled Vehicles")
** Also includes Shoulder Lane Blockages

Figure 3.14 Distributions of Incidents by Lane Blockage

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY LANE BLOCKAGE TYPE

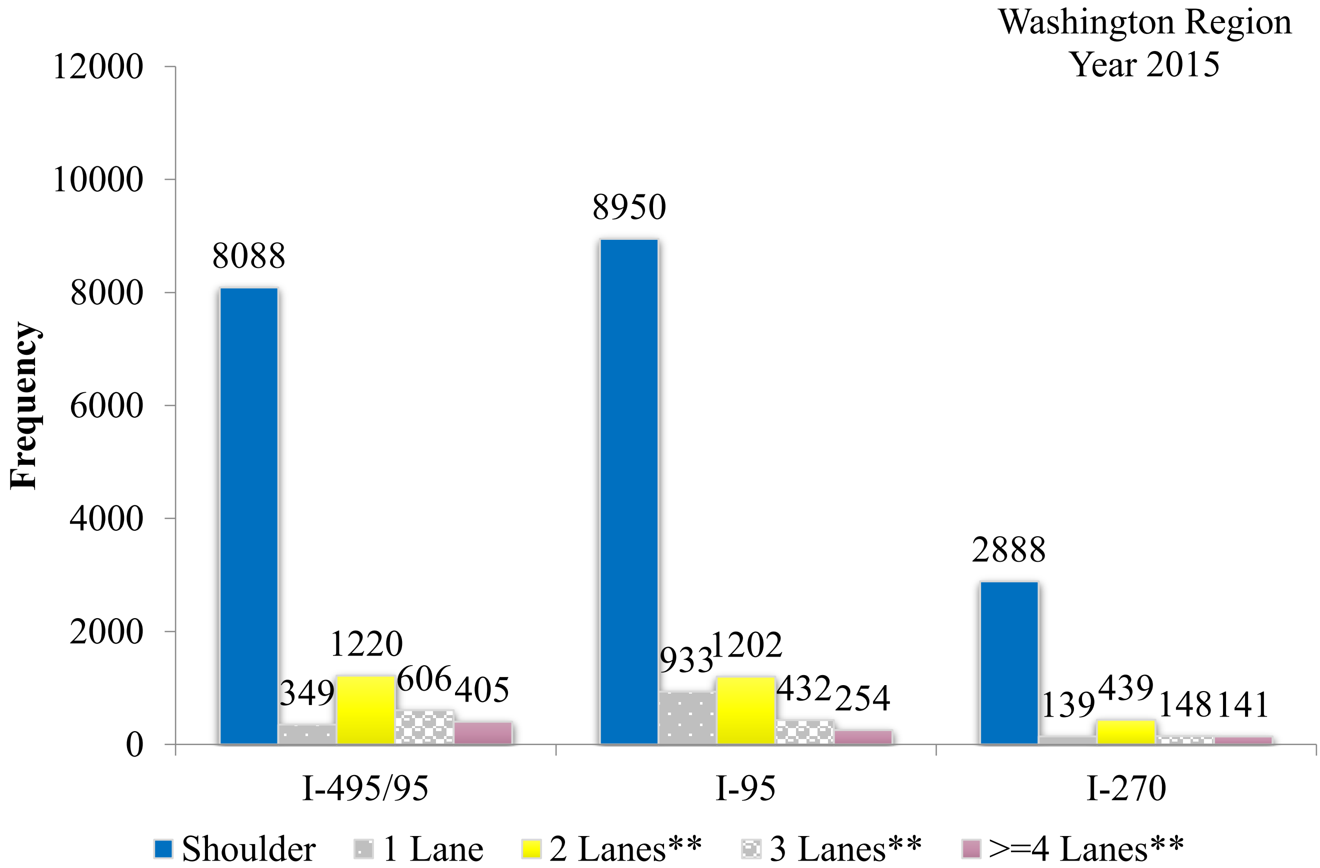


Note: * Disabled Vehicles are all classified as Shoulder Lane Blockages.
** Also includes Shoulder Lane Blockages.

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

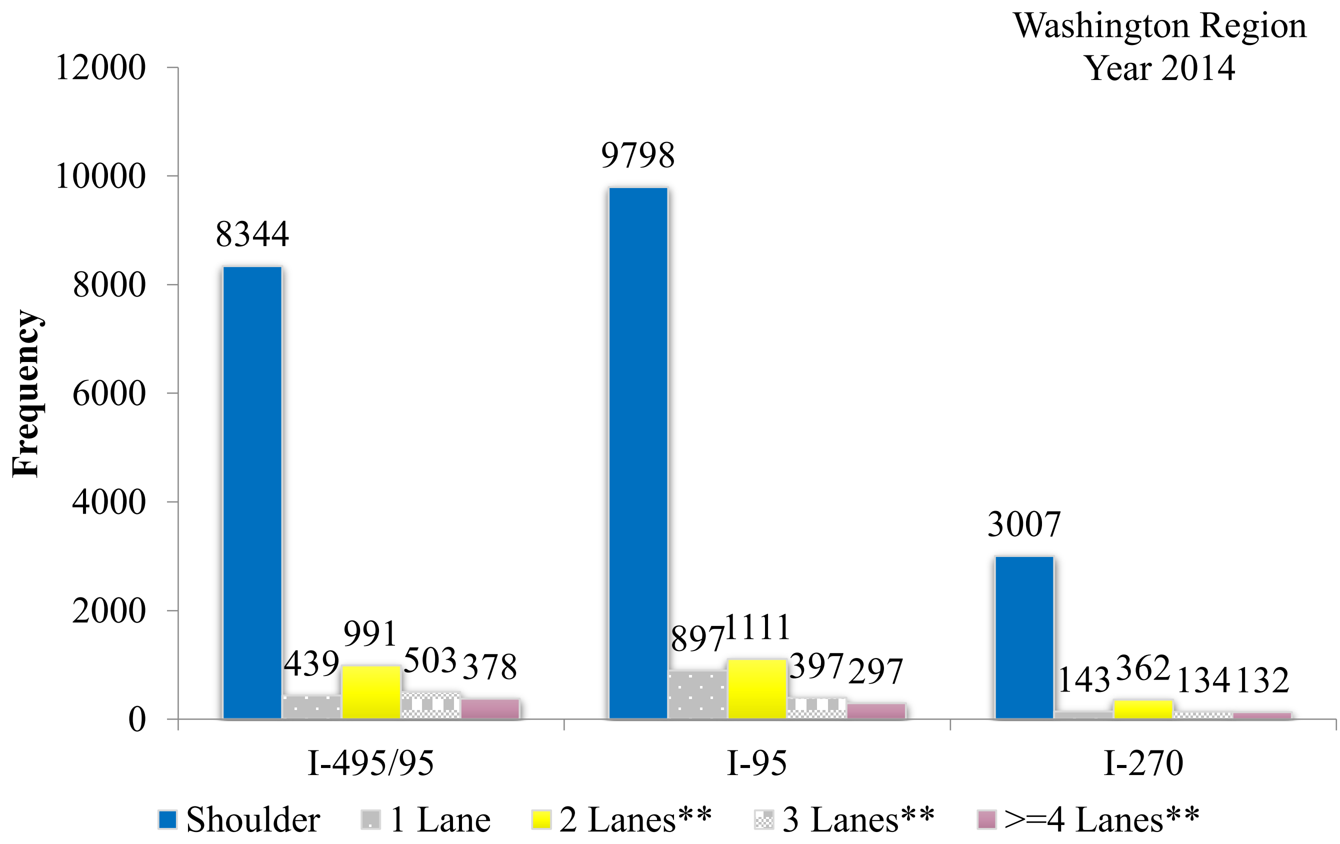
3.3 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY LANE BLOCKAGE TYPE

Figures 3.16 and 3.17 depict a comparison of lane blockage incidents between 2015 and 2014 for major roads in the Washington Metropolitan and Baltimore areas. Note that disabled vehicles are classified as shoulder lane blockages.



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 3.16 Distributions of Lane Blockages Occurring on Major Freeways in the Washington Area (Cont.)

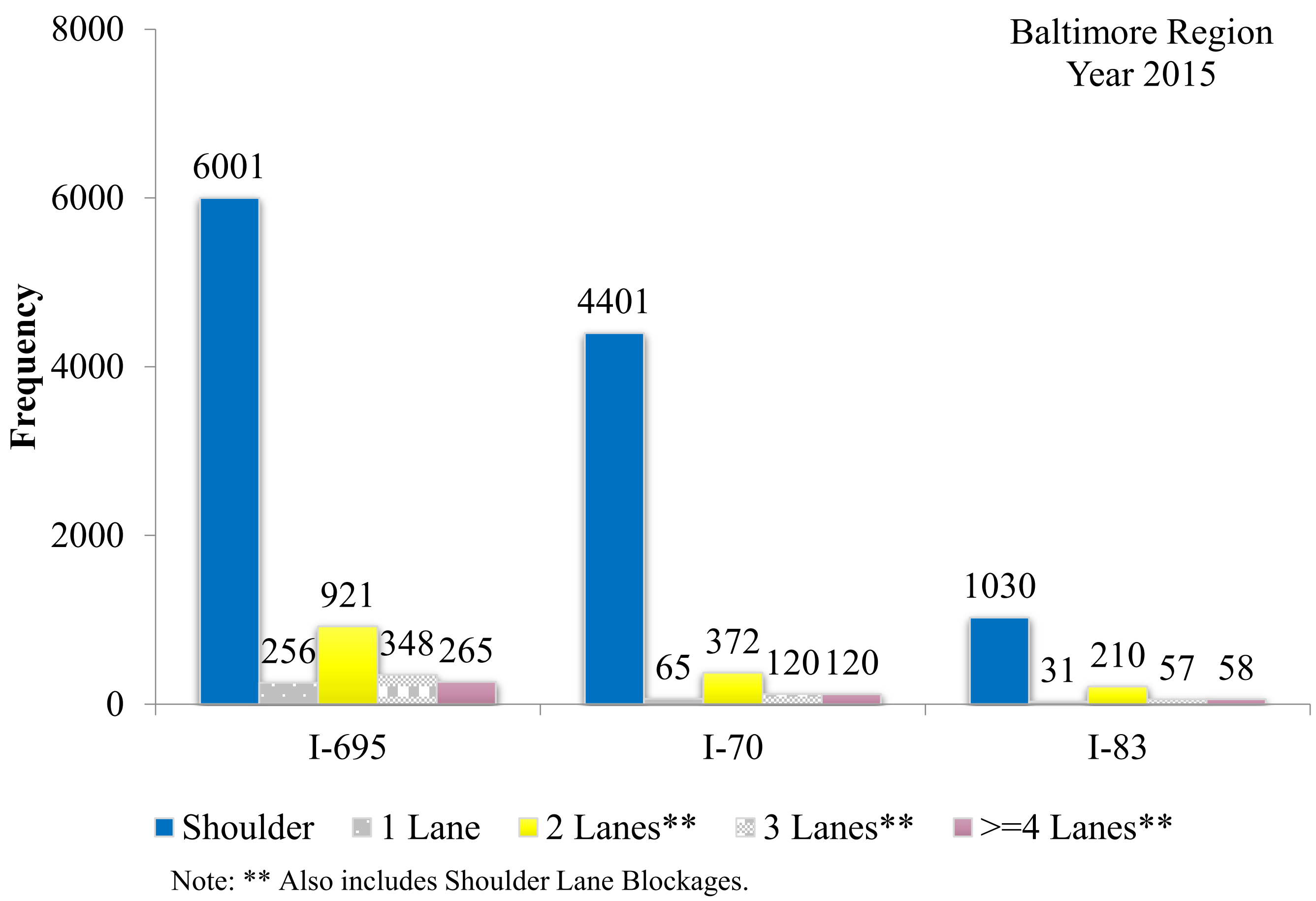


Figure 3.17 Distributions of Lane Blockages Occurring on Major Highways in the Baltimore Region

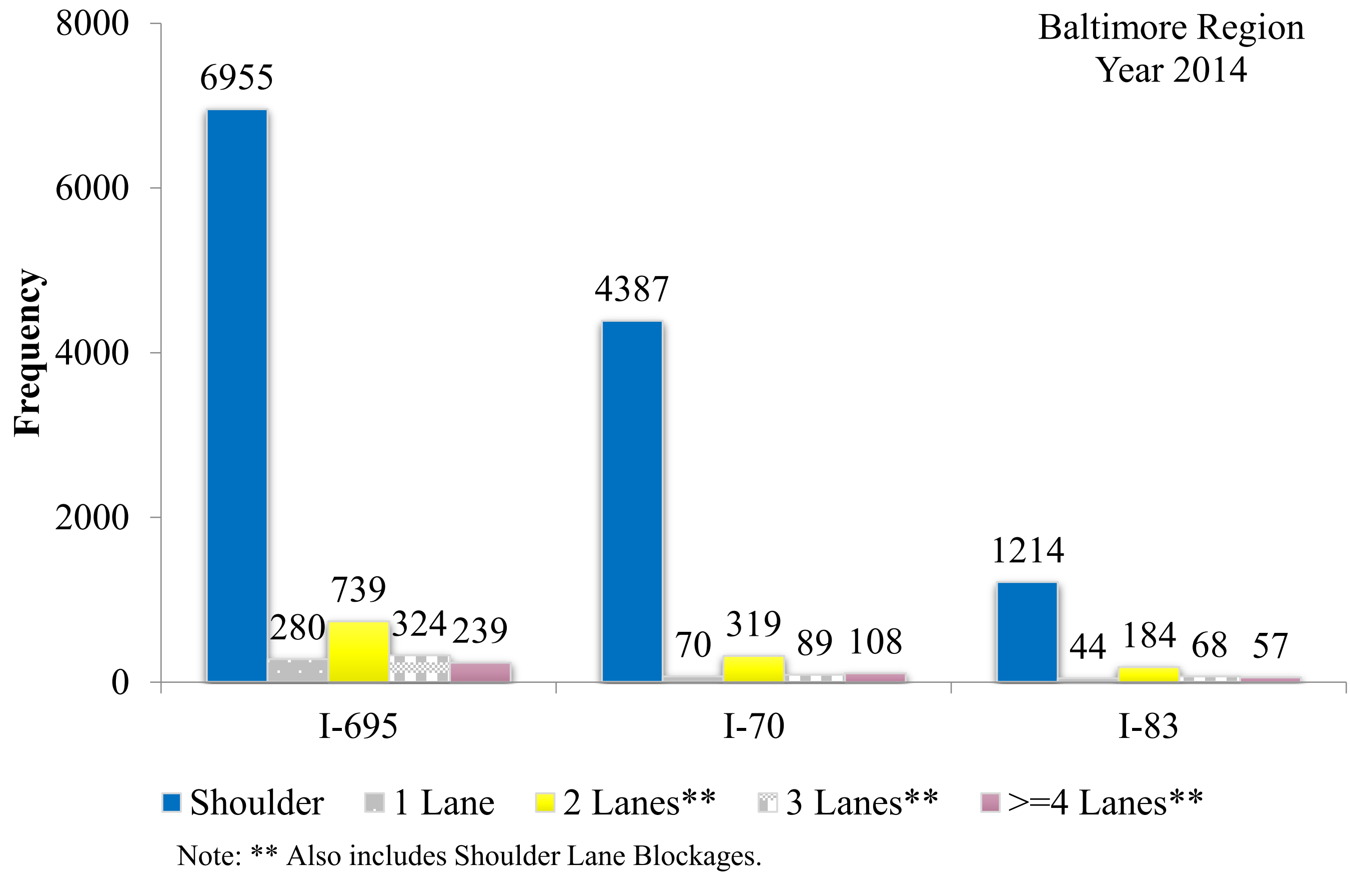
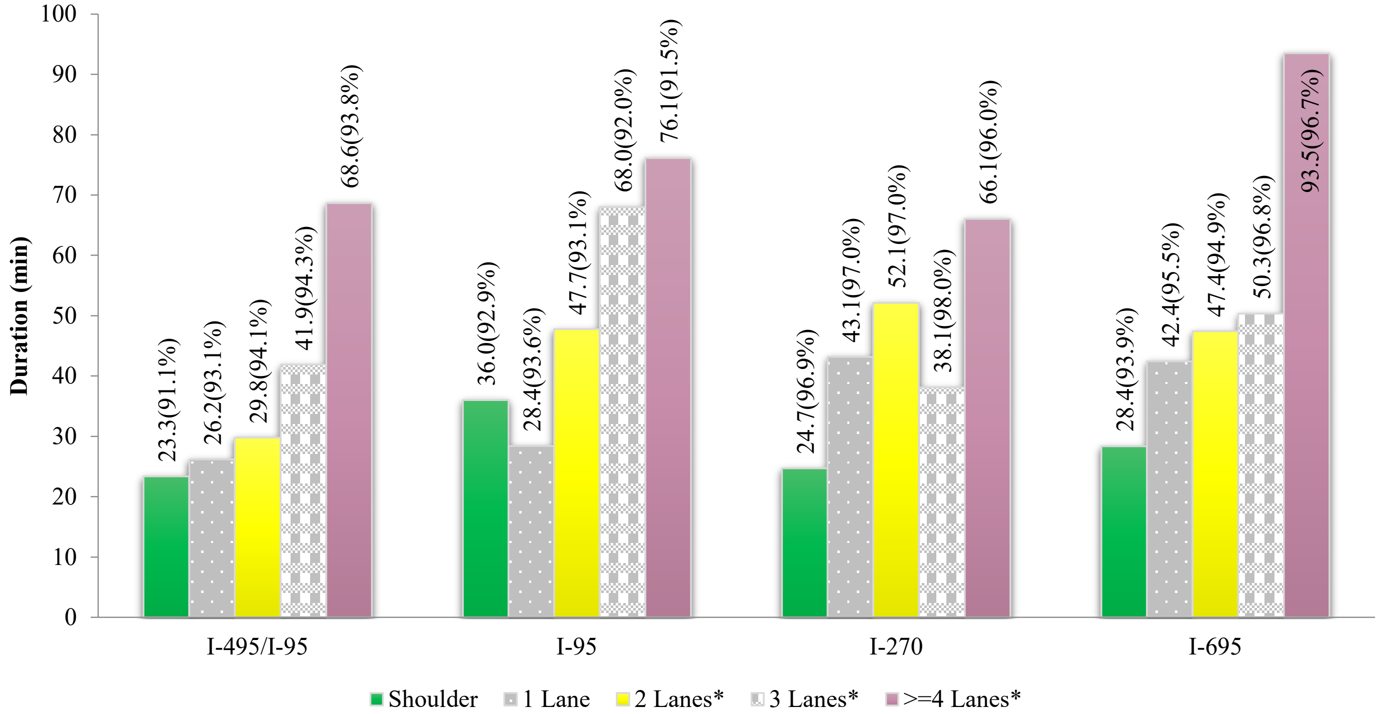


Figure 3.17 Distributions of Lane Blockages Occurring on Major Highways in the Baltimore Region (Cont.)

Note that disabled vehicles caused most of the shoulder lane blockages. Most of the disabled vehicles were recorded as a result of driver assist 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 Incident Duration by 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.

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY BLOCKAGE DURATION

3.4

As shown below, most disabled vehicles did not block traffic for more than half an hour. About 70 percent of incidents and disabled vehicles had durations of less than 30 minutes.

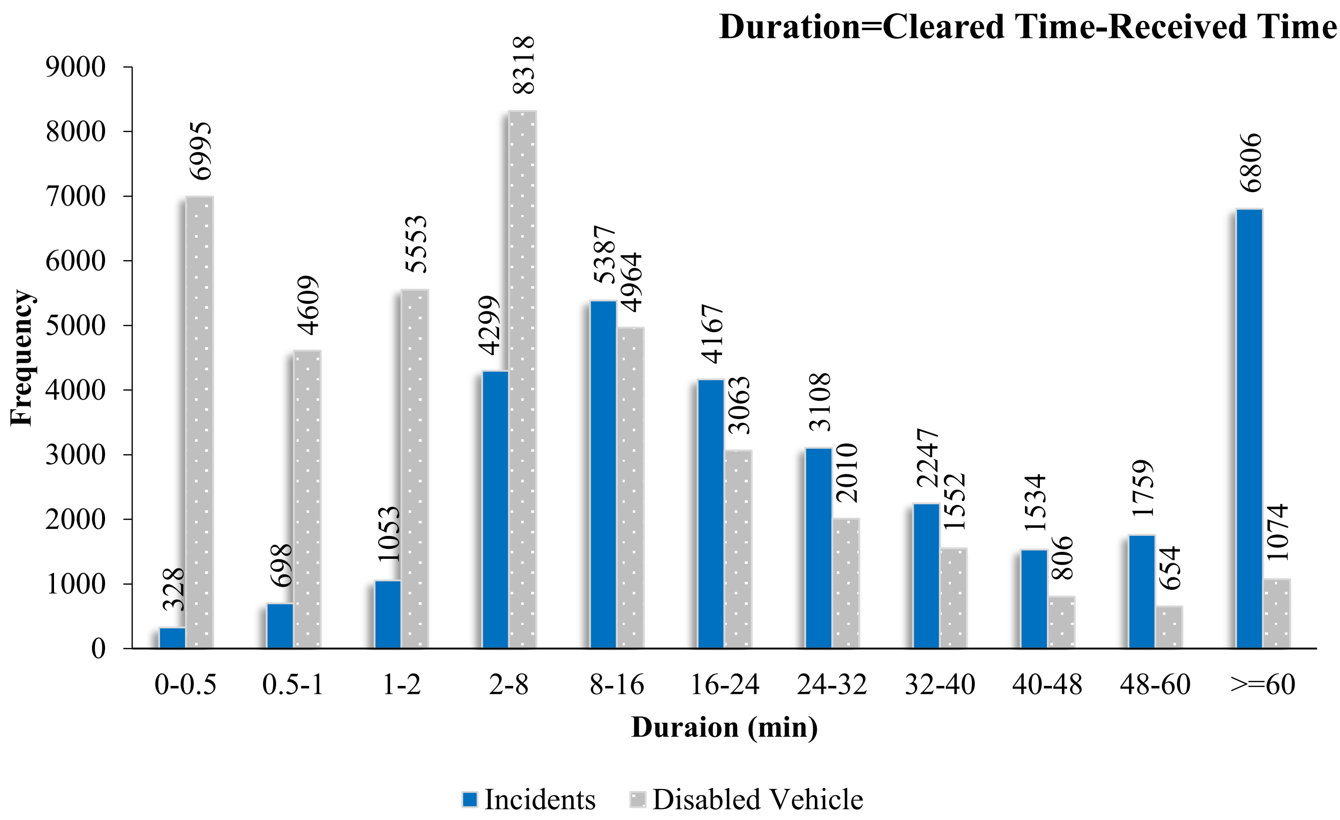


Figure 3.19 Distributions of Incidents/Disabled Vehicles by Duration in 2015

Although most incidents in 2015 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.

3.4 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY BLOCKAGE DURATION

Figure 3.20 presents the distribution of records in 2015 and its comparison with 2014 data. About 19 percent, 21 percent, and 18 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 34 percent of reported incidents lasted longer than 30 minutes. This implies that only 25 percent of reported incidents/disabled vehicles lasted more than 30 minutes in 2015.

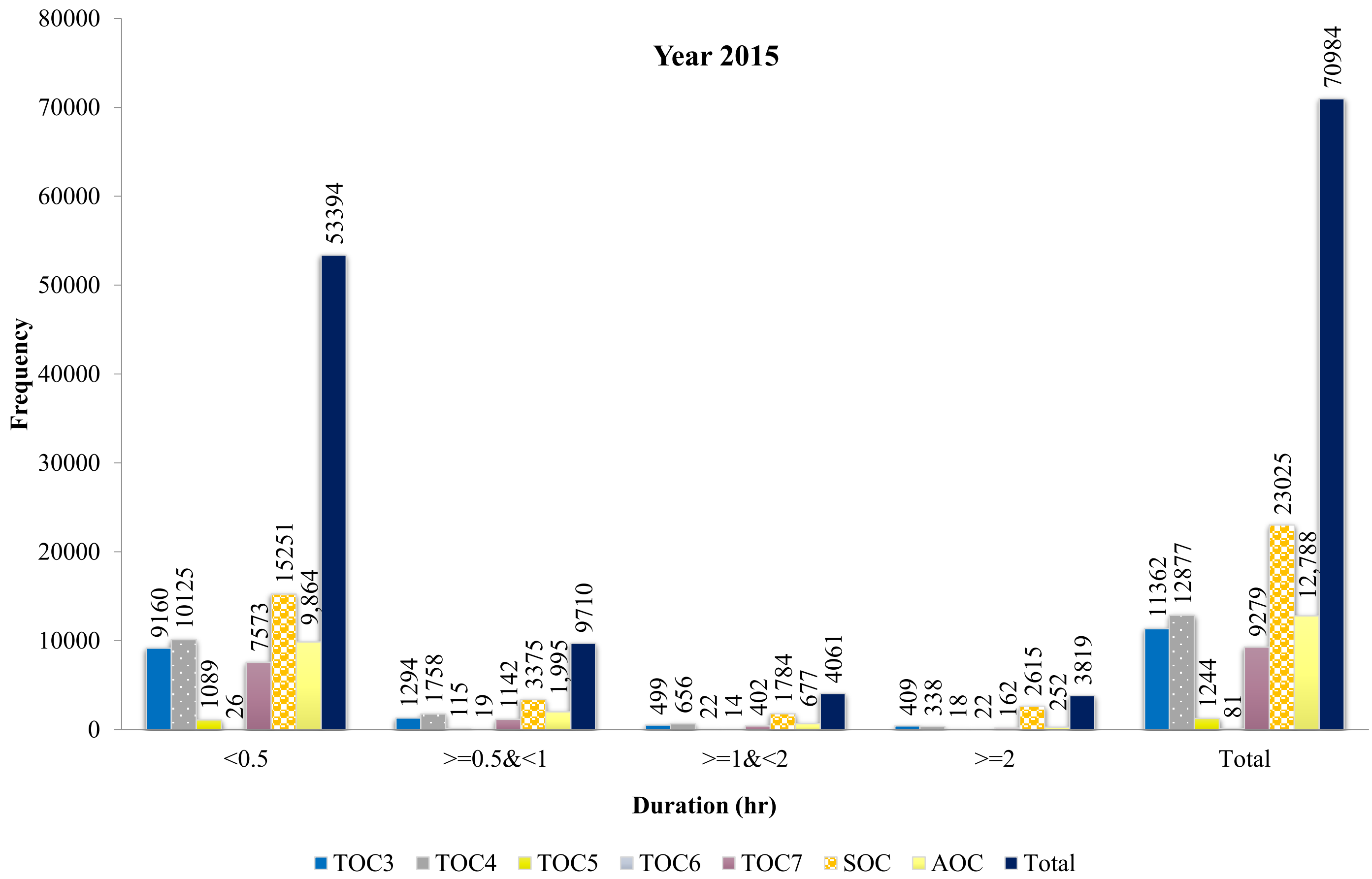


Figure 3.20 Comparisons of Incidents/Disabled Vehicles Distributions by Duration and Operation Center

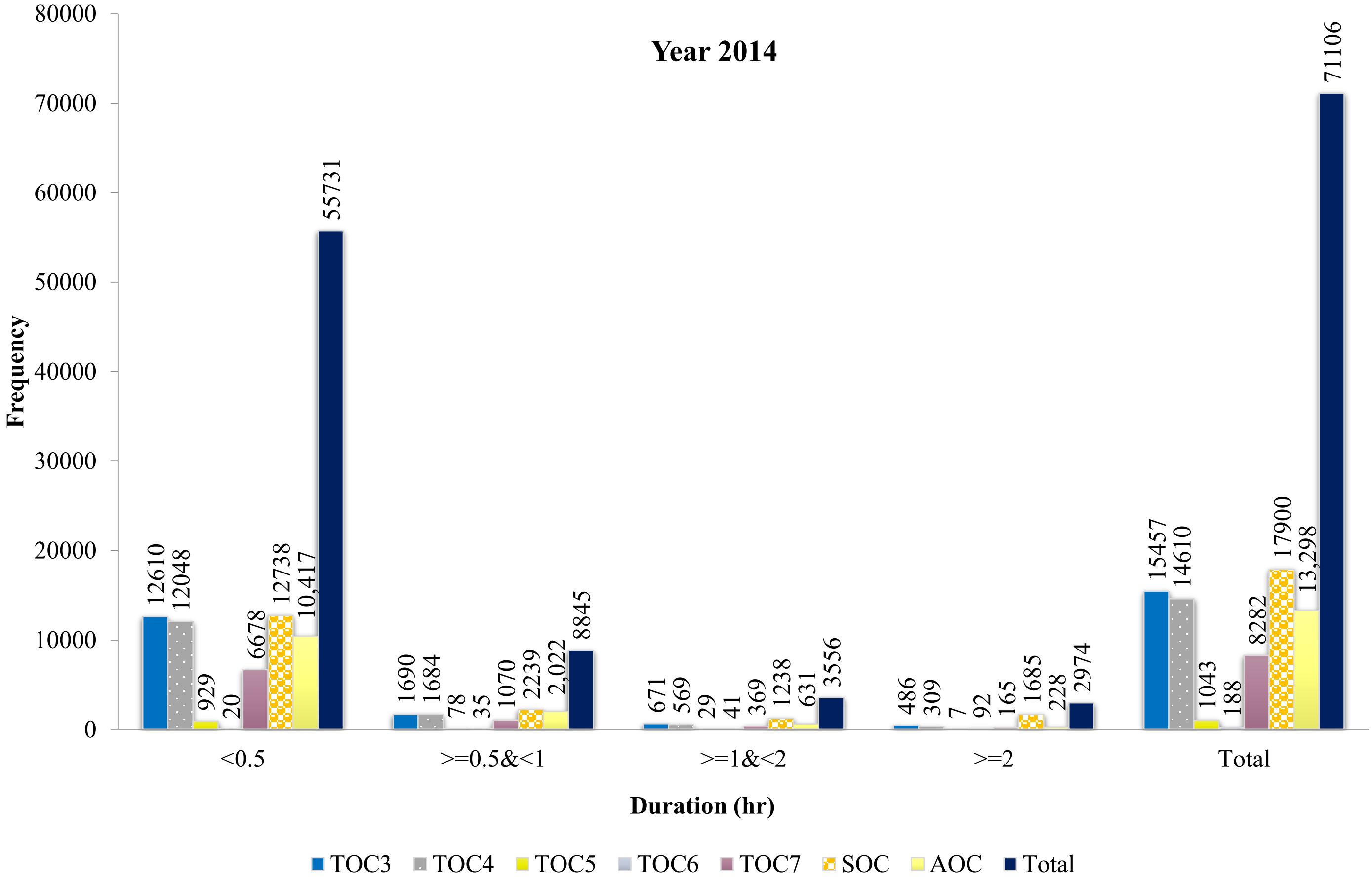


Figure 3.20 Comparisons of Incidents/Disabled Vehicles Distributions by Duration and Operation Center (Cont.)

CHAPTER 4

EVALUATION OF EFFICIENCY AND EFFECTIVENESS

4.1 Evaluation of Detection Efficiency and Effectiveness

4.2 Analysis of Response Efficiency

4.3 Analysis of Clearance Efficiency

4.4 Reduction in Incident Duration

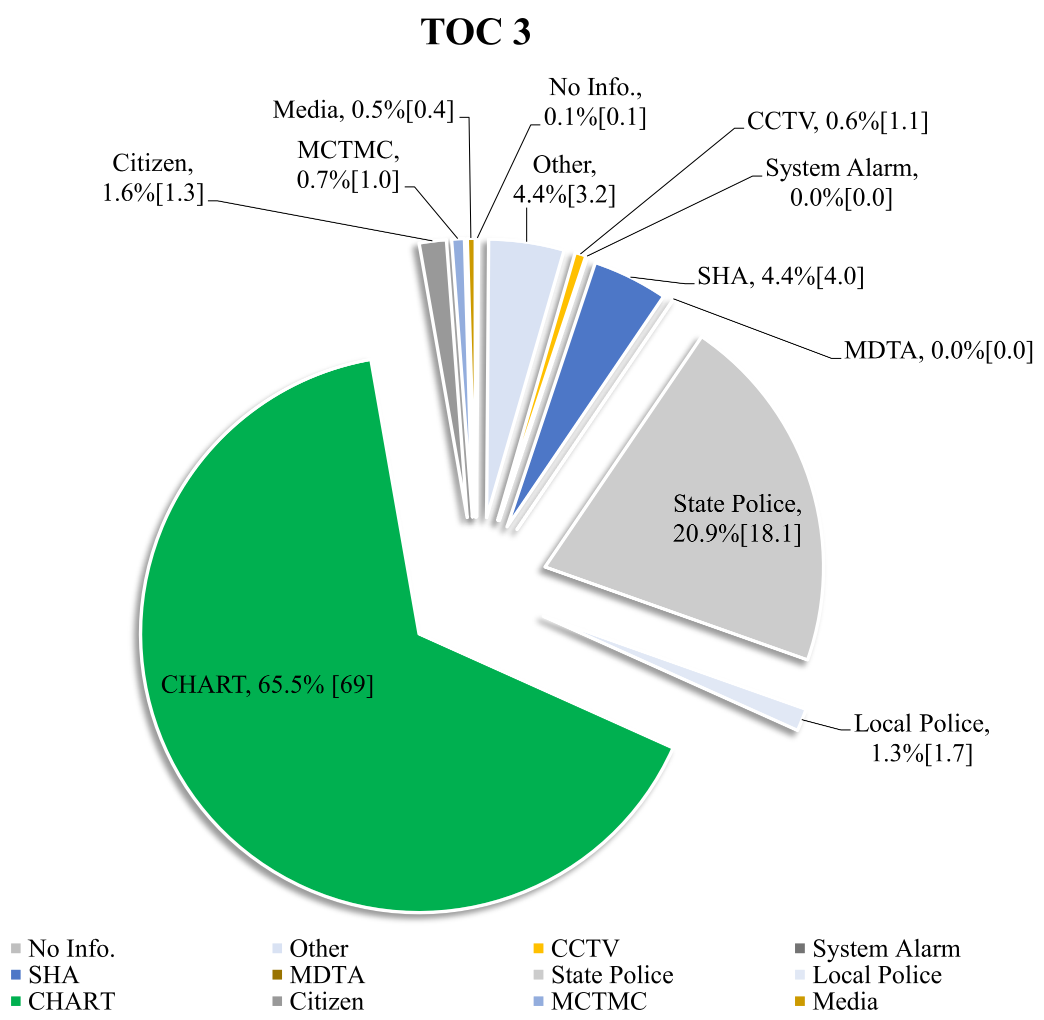
4

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.

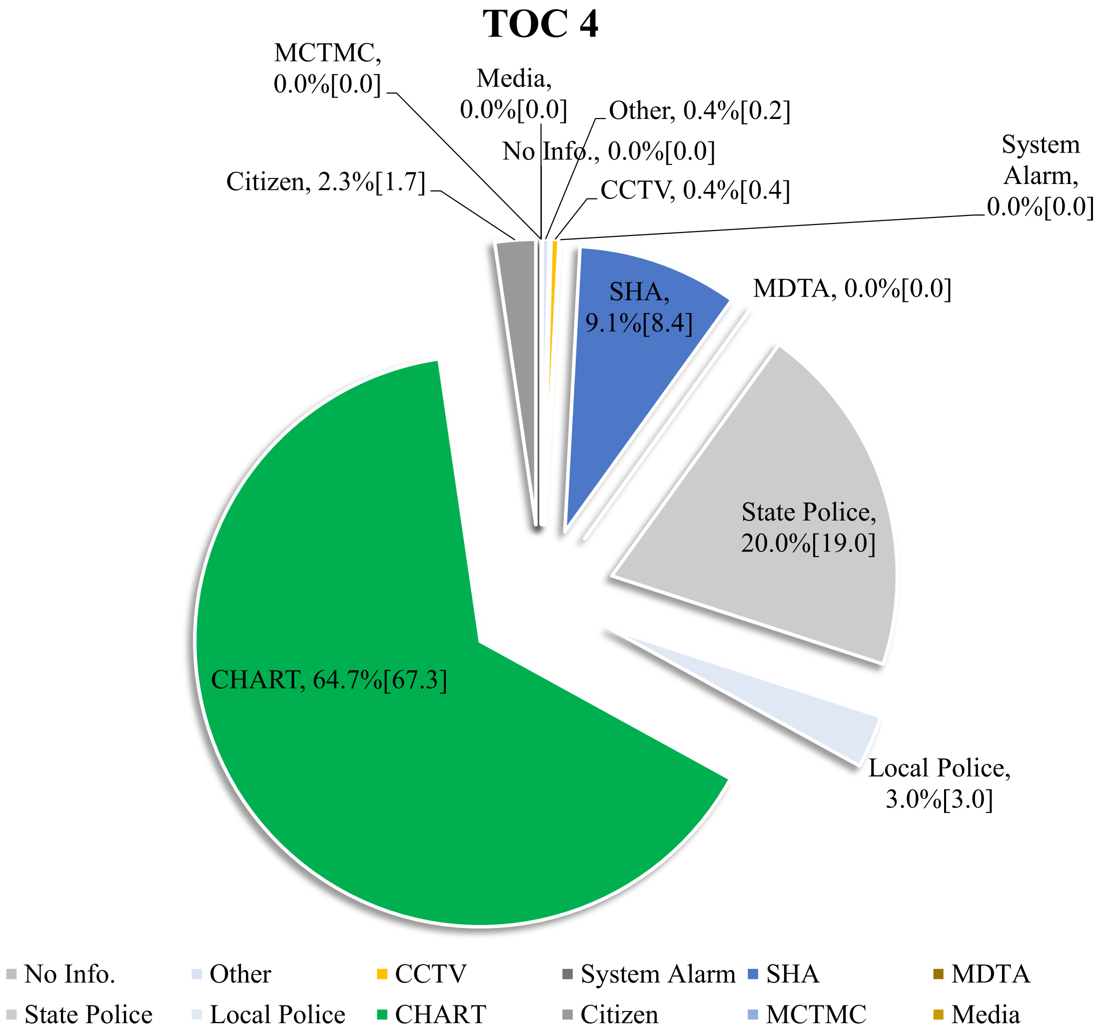
The response rate is defined as the ratio of the total number of traffic incidents reported to the CHART control center to those managed by the CHART/MSHA emergency response teams. Based on 2015 incident management records, the overall response rate was 99.96 percent. As in the previous year, existing 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 that the numbers in parentheses indicate the 2014 statistics.



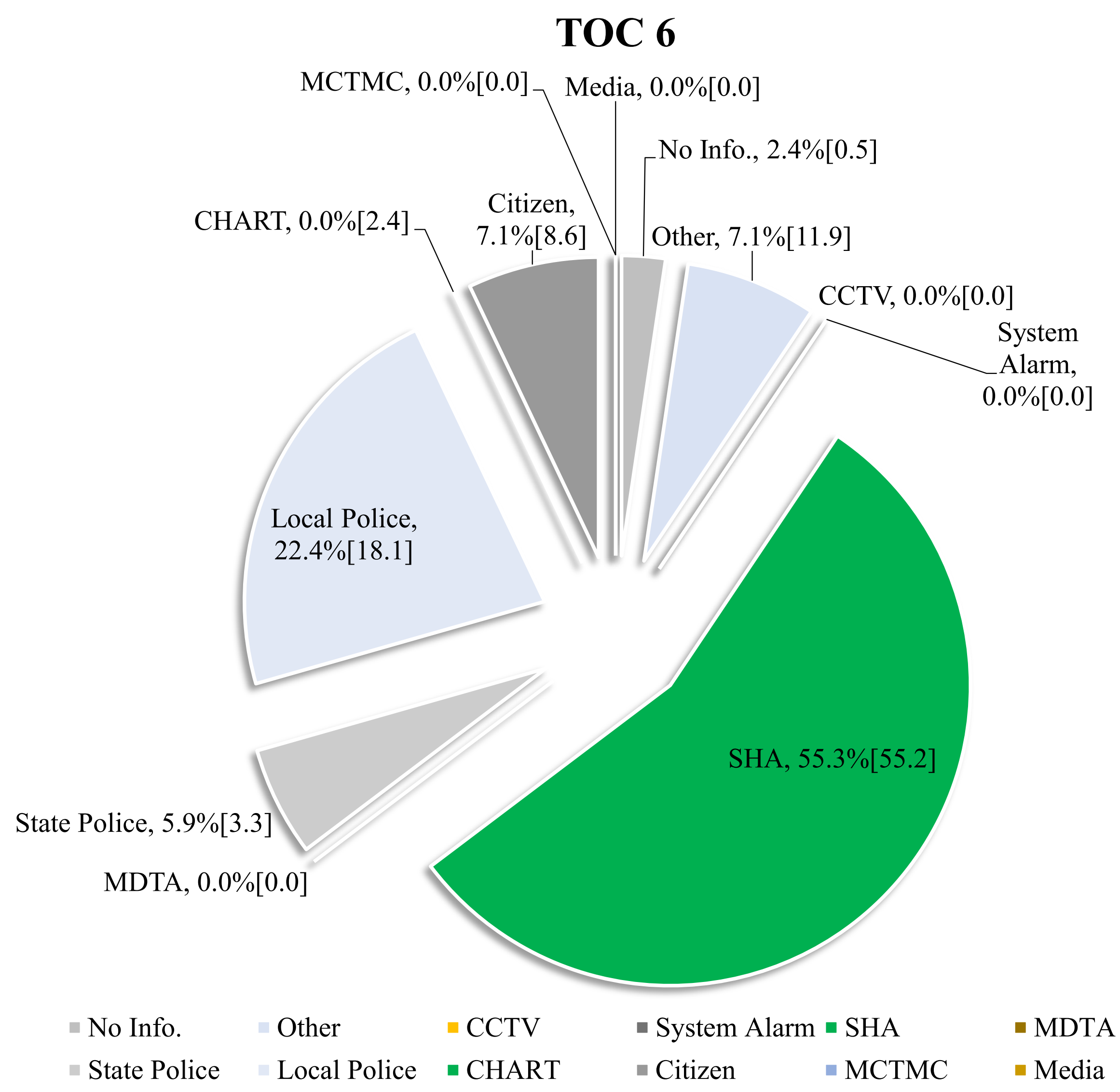
Note: 1. Numbers in [ ] show the percentages from Year 2014.
2. Actual frequencies for incidents/disabled vehicles detected by system alarm and MDTA are 1and 1 in the CHART-II database of year 2015

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



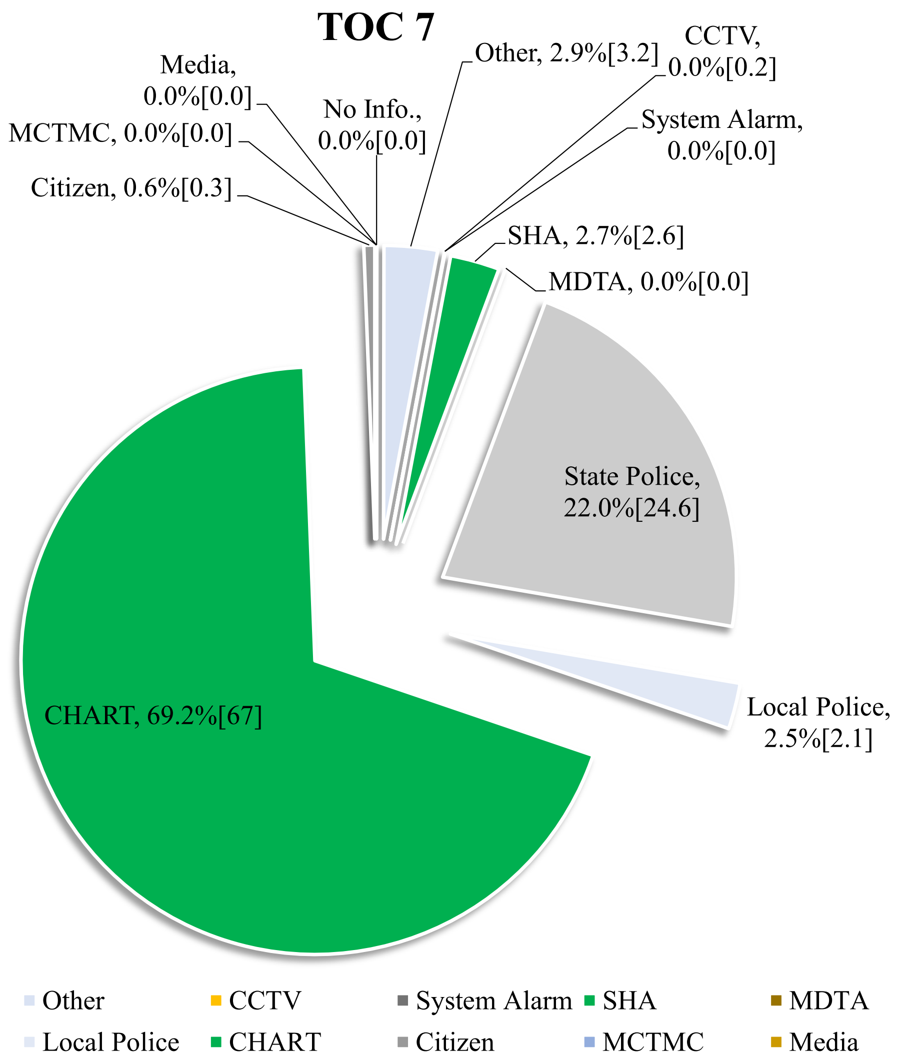
Note: 1. Numbers in [ ] show the percentages from Year 2014.
2. Actual frequencies for incidents/disabled vehicles detected by MCTMD, Media, System Alarms, No Info. and MDTA are 0, 0, 1, 2 and 2 in the CHART-II database of Year 2015

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



Note: 1. Numbers in [ ] show the percentages from Year 2014.
2. Actual frequencies for incidents/disabled vehicles detected by MDTA, CHART, MCTMC, Media, CCTVs and system alarms are all zero in the CHART-II database of Year 2015
3. TOC 6 operates on a seasonal basis.

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

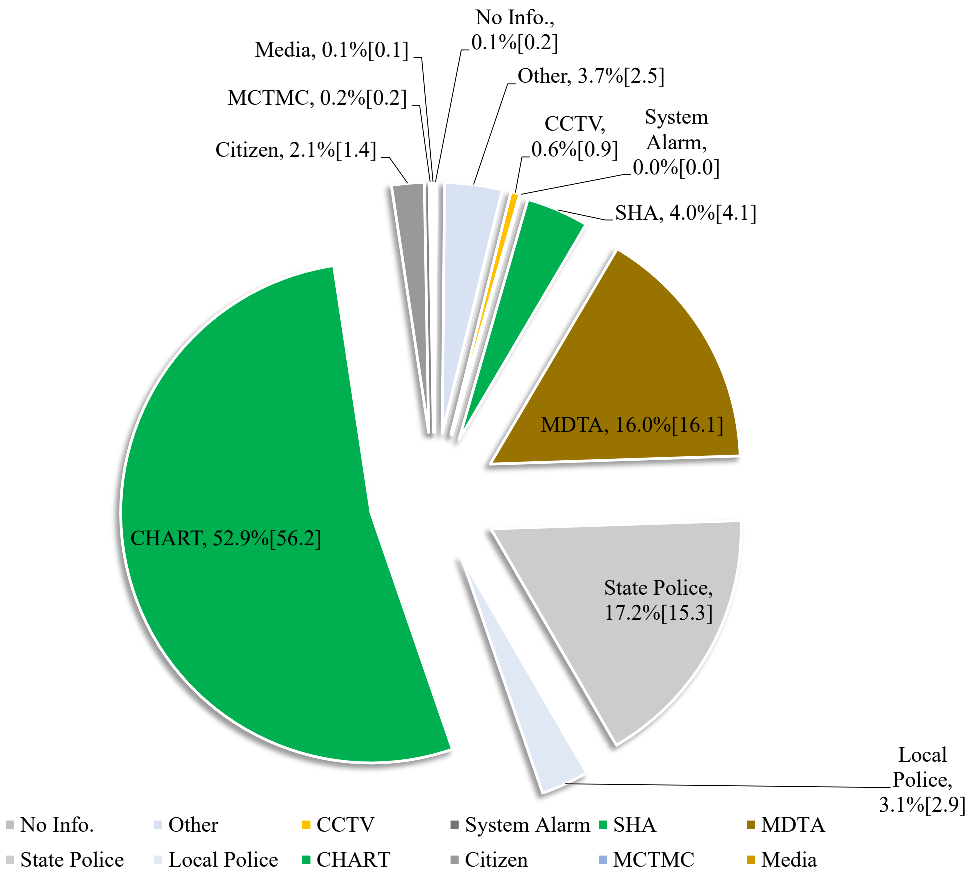


Note: 1. Numbers in [ ] show the percentages from Year 2014.
2. Actual frequencies for incidents/disabled vehicles detected by MCTMC, Media, No Info., System Alarms, CCTVs and MDTA in 2015 are all zeros in the CHART-II database of Year 2015.

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

4.1 EVALUATION OF DETECTION EFFICIENCY AND EFFECTIVENESS

With respect to the distribution of all detection sources, the statistics in Figure 4.5 clearly show that about 53 percent of incidents in 2015 were detected by MSHA/CHART patrols, i.e., a lower percentage than in 2014. About 17.2 percent were reported by the MSP, also higher than 15.3 percent of 2014.



Note: 1. Numbers in [ ] show the percentages from Year 2014.
2. Actual frequencies for incidents/disabled vehicles detected by System Alarms in Year 2015 is 4 in the CHART-II database.

Figure 4.5 Distributions of Incidents/Disabled Vehicles by Detection Source

ANALYSIS OF RESPONSE EFFICIENCY 4.2

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 that 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/disabled vehicles in 2015 is given in Figure 4.6. The average response time in 2015 was 11.70 minutes, slightly higher than that of 2014 (11.01 minutes).

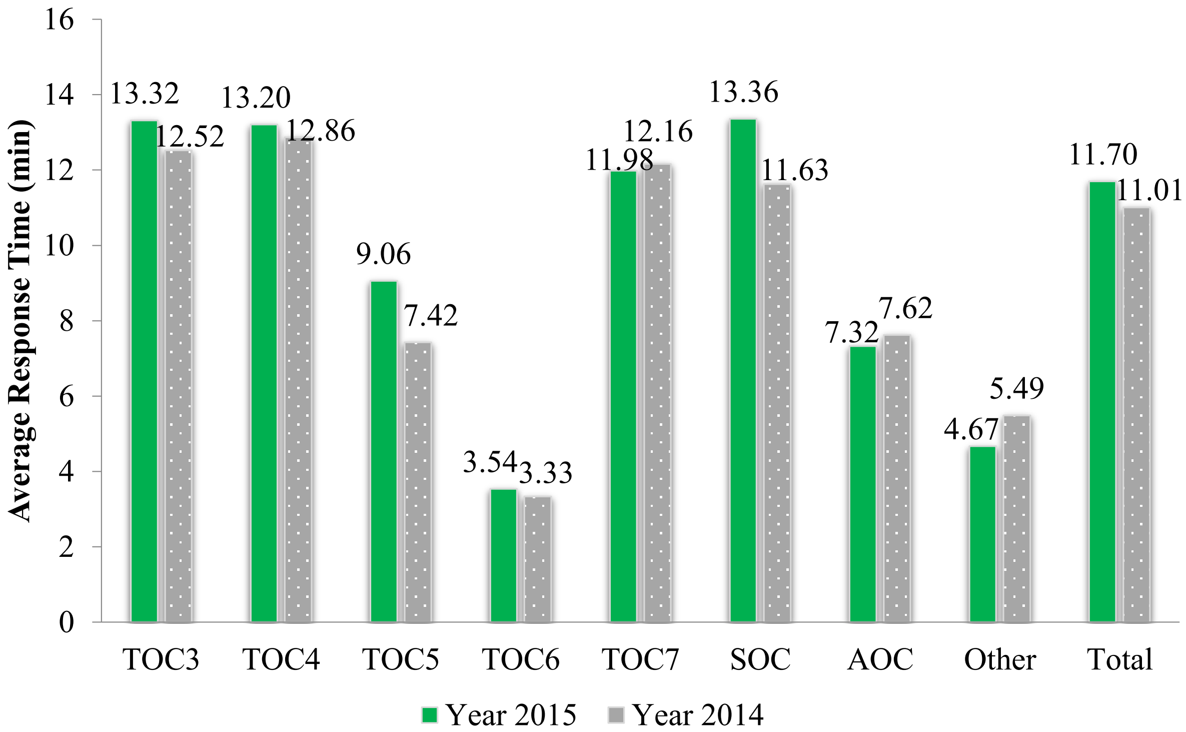
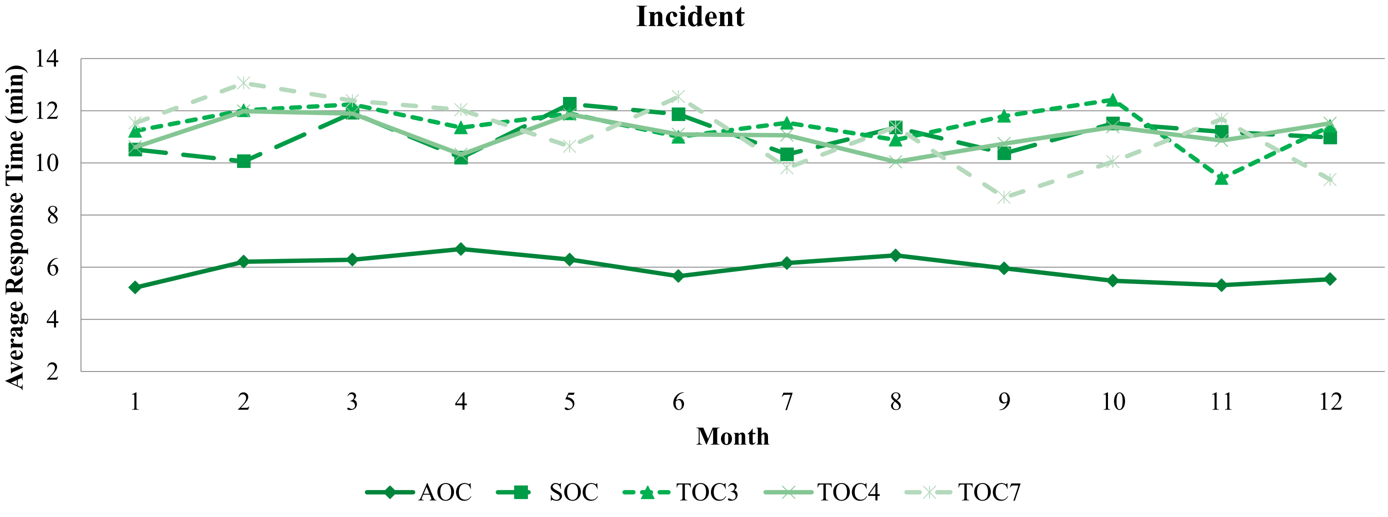
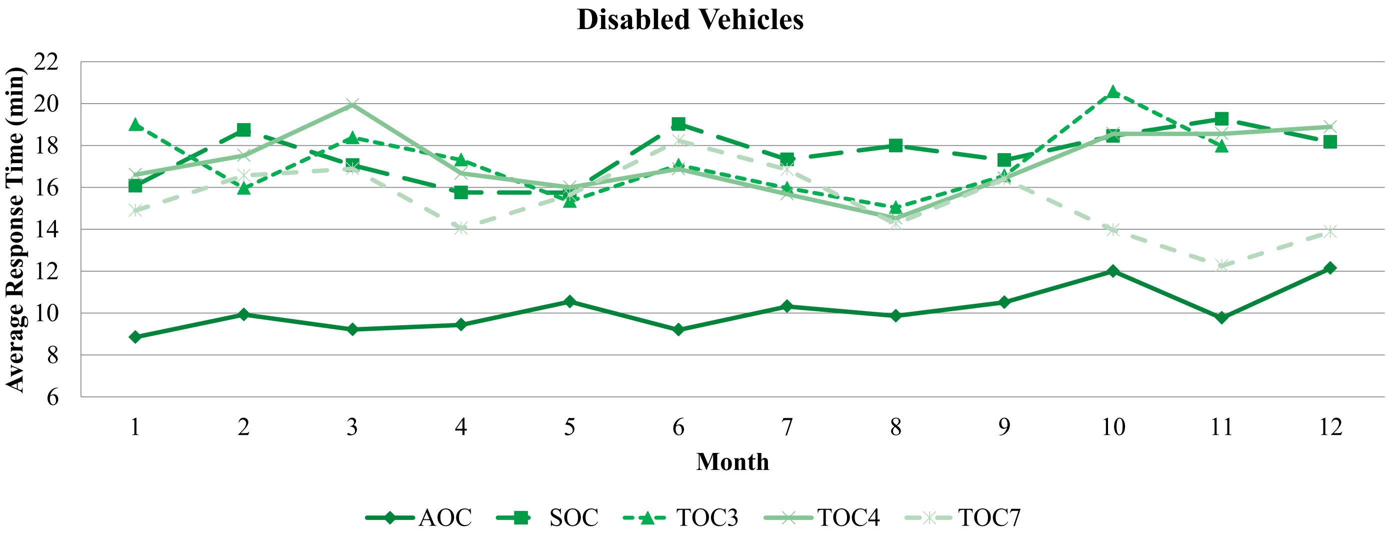


Figure 4.6 Distributions of Average Response Times

4.2 ANALYSIS OF RESPONSE EFFICIENCY

In Figure 4.7 average response times of incidents by TOC 3, TOC 4, TOC 7 and SOC are fairly consistent throughout the year and are between eight and thirteen minutes. AOC also shows fairly consistent response times around six minutes through year 2015. On the other hand, average response times of disabled vehicles show significant fluctuations for all operations centers. Overall, the average response times of AOC are shorter than for TOCs and SOC throughout the entire year.



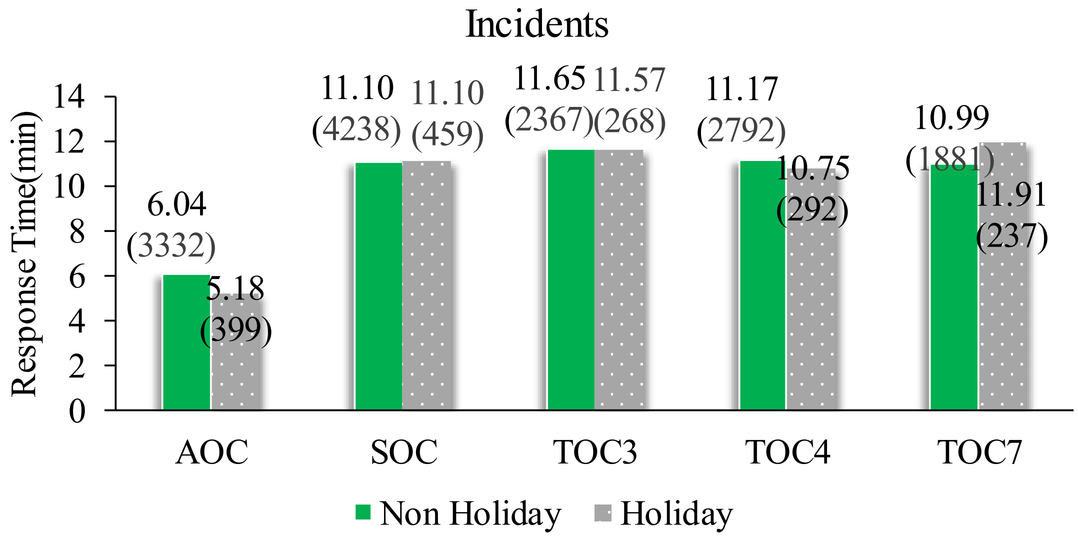


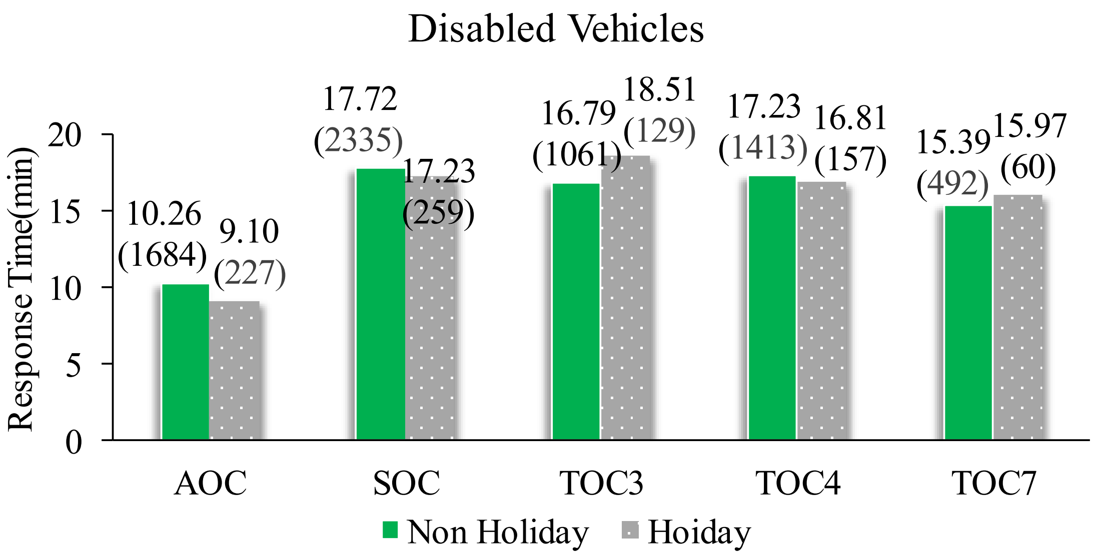
Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. TOC 3 was closed mostly in December 2015
3. TOC 5 and TOC 6 were excluded in this analysis, since they operate on a seasonal basis.

Figure 4.7 Average Response Times for Operation Centers by Month in 2015

ANALYSIS OF RESPONSE EFFICIENCY

Figure 4.8 illustrates the fact that most operation centers show slightly faster response times for incidents and for disabled vehicles during holidays in 2015.





Note: 1. Data only for response times between 1 minute and 60 minutes are used for this analysis.

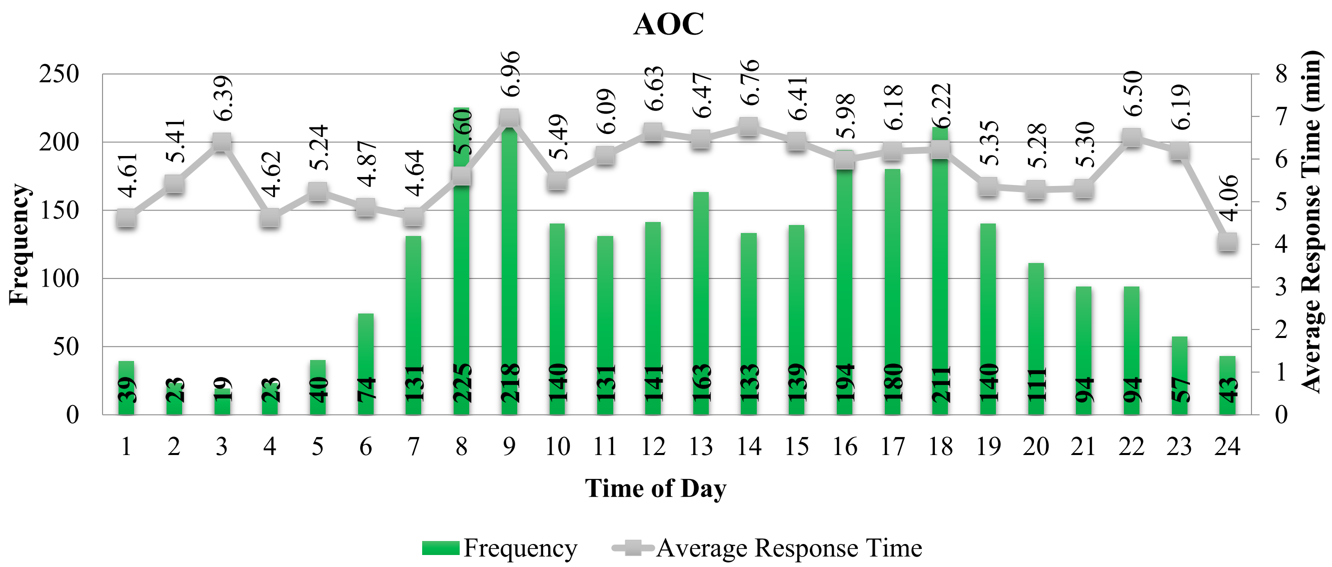
2. Numbers in each parenthesis show the data availability.

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 Times by Operation Centers on Holidays and Non-holidays in 2015

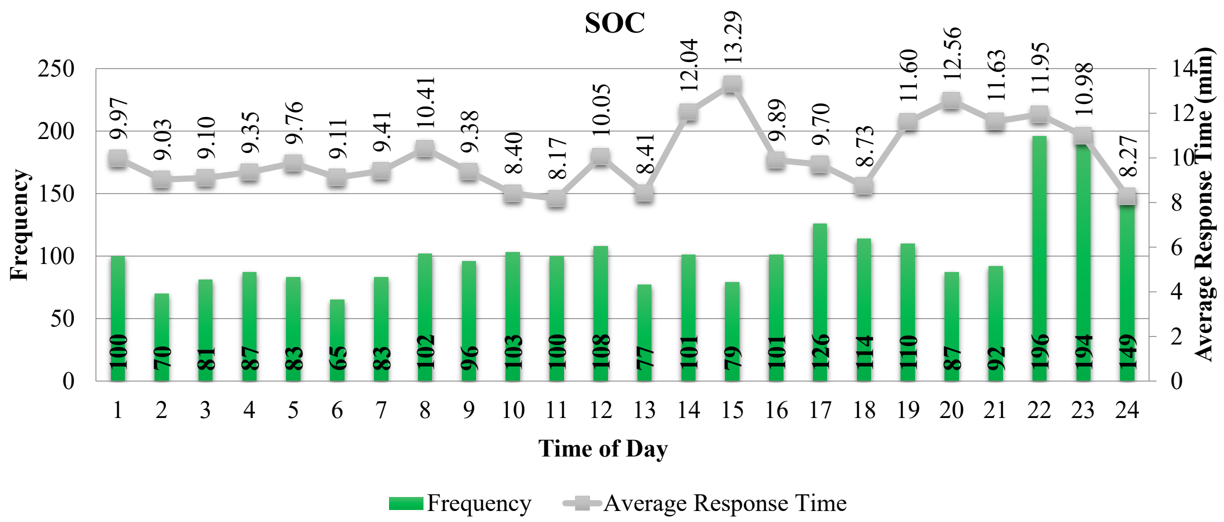
4.2 ANALYSIS OF RESPONSE EFFICIENCY

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 managed, 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. Since AOC and SOC operate as a backup of TOCs 3, 4 and 7 after their operational hours (5 a.m. - 9 p.m.), the frequencies of incident responses during non-operational hours are much larger than those in major TOCs (see Figures 4.11 to 4.13).



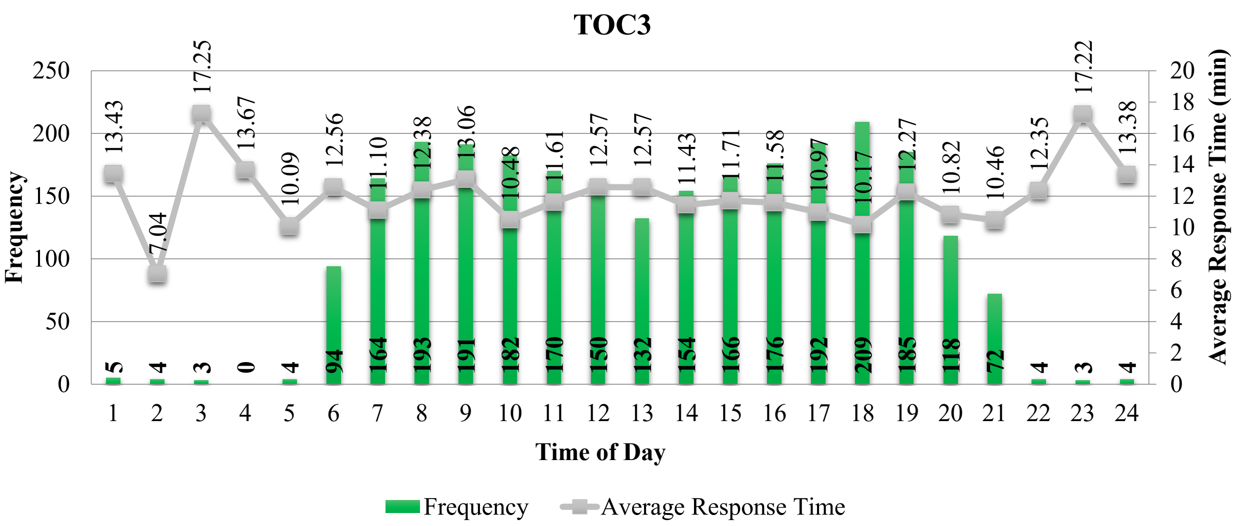
Note: Incident data only for response times between 1 minute and 60 minutes are used for this analysis.

Figure 4.9 Average Response Times for AOC by Time of Day on Weekdays in 2015



Note: Incident data only for response times between 1 minute and 60 minutes are used for this analysis.

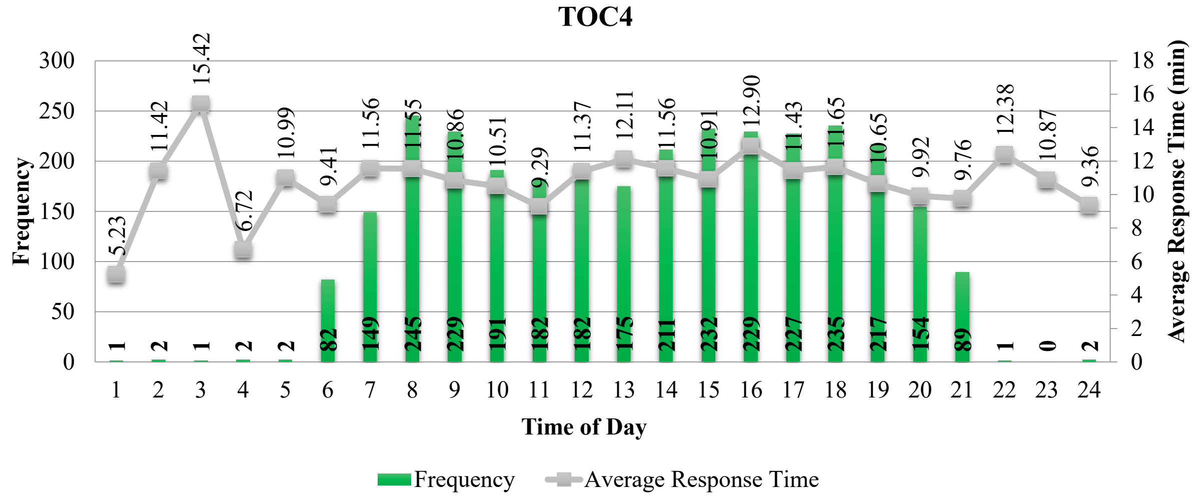
Figure 4.10 Average Response Times for SOC by Time of Day on Weekdays in 2015



Note: Incident data only for response times between 1 minute and 60 minutes are used for this analysis.

Figure 4.11 Average Response Times for TOC3 by Time of Day on Weekdays in 2015

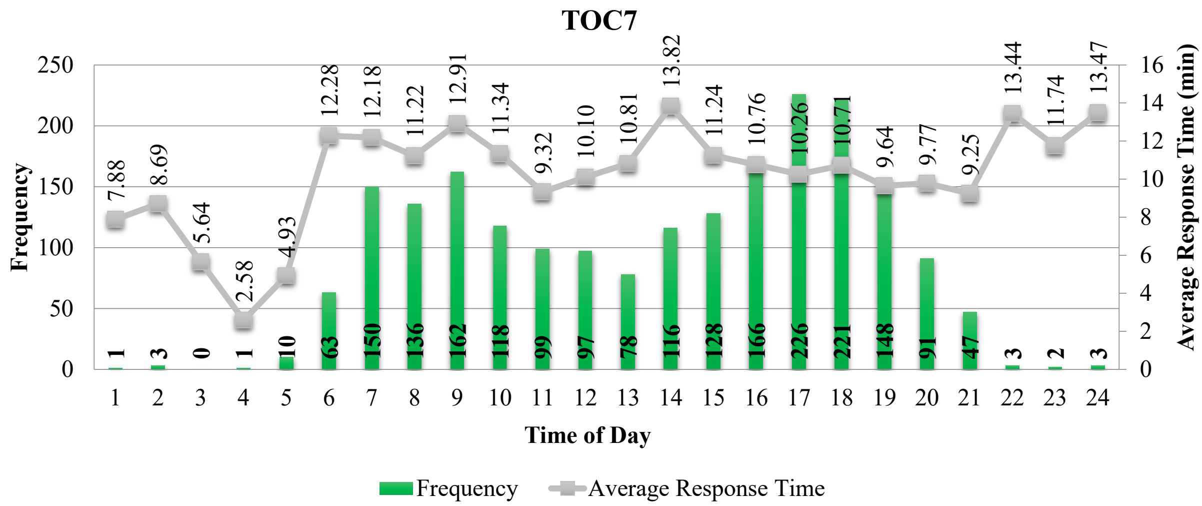
The response times by TOC 3 and TOC 4 are quite consistent during their operational periods (5 a.m. – 9 p.m.), and the responded incident frequencies also exhibit distinct patterns during peak periods. On the other hand, the response times for TOC 3 and TOC 4 showed significant fluctuation during non-operational hours.



Note: Incident data only for response times between 1 minute and 60 minutes are used for this analysis.

Figure 4.12 Average Response Times for TOC4 by Time of Day on Weekdays in 2015

TOC 7 shows a significantly different pattern where the average response time decreases as the time elapses from the PM peak. As shown in the incident frequency chart, the highest incident frequency has been exhibited around the PM peak period (4:00 p.m. - 6:30 p.m.), but their average response times are relatively shorter than those during most other operational hours.

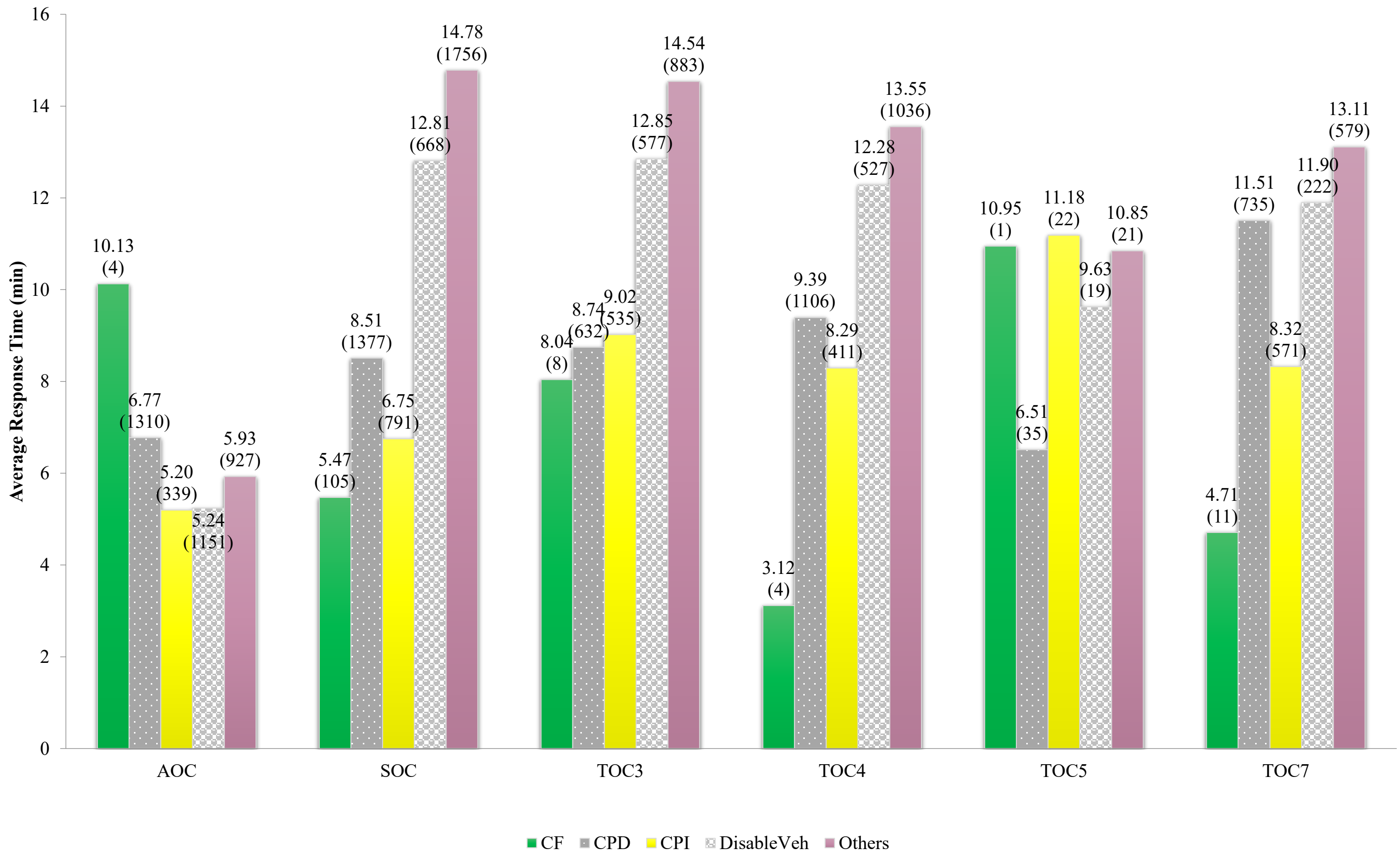


Note: Incident data only for response times between 1 minute and 60 minutes are used for this analysis.

Figure 4.13 Average Response Time for TOC7 by Time of Day on Weekdays in 2015

ANALYSIS OF RESPONSE EFFICIENCY 4.2

Figure 4.14 shows a further analysis of response efficiency, where SOC, TOC3, TOC4 and TOC7 demonstrated faster responses for incidents involving fatalities (CF). On the other hand, most operation centers took relatively longer response times for disabled vehicles and other types of incidents (e.g., fire, debris, police activities, etc.) than for collision incidents.



Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.

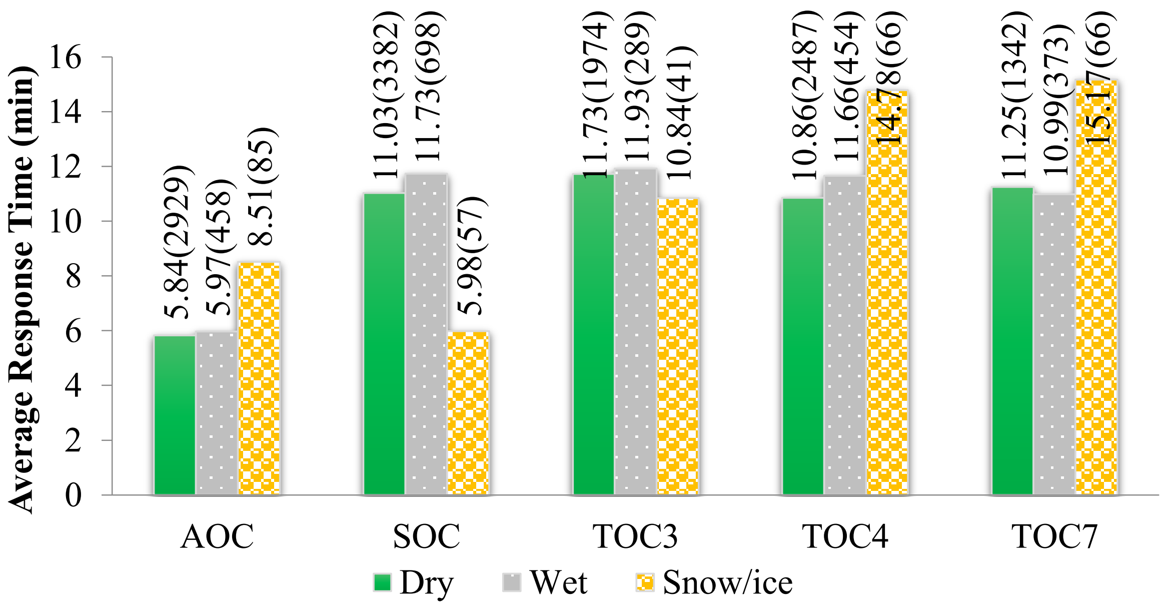
2. Numbers in each parenthesis show frequencies.

3. CF, CPD, and CPI represent collision-fatality, collision-property damage, and collision-personal injury, respectively. Others include weather closures, 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 2015

4.2 ANALYSIS OF RESPONSE EFFICIENCY

With respect to the pavement conditions, most operation centers, except SOC and TOC3, took shorter response times under dry or wet conditions than snow/ice conditions. Overall, AOC showed a shorter average response time than any other operation centers (See Figure 4.15) in 2015.



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 Different Operation Centers by Pavement Conditions in 2015

ANALYSIS OF RESPONSE EFFICIENCY

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 state police detects the most incidents to which SOC responded. For SOC, on average, the incidents detected by CHART units have relatively fast responses.

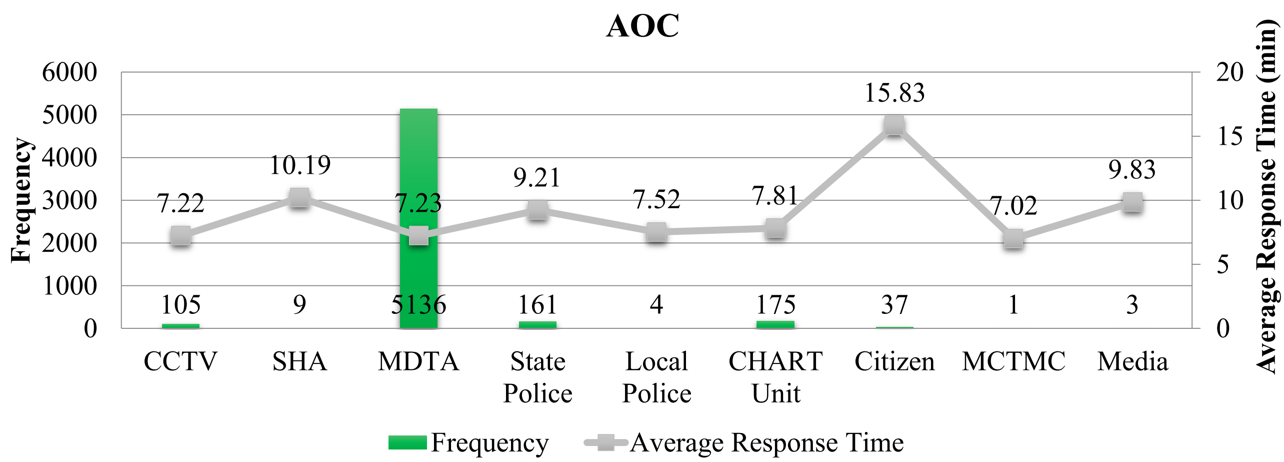


Figure 4.16 Average Response Times for AOC by Detection Source in 2015

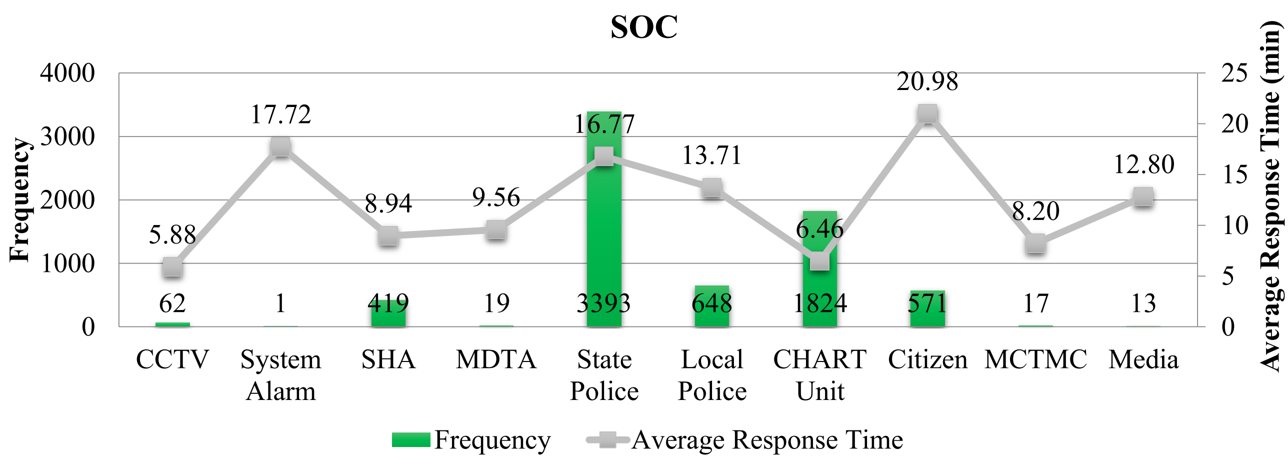


Figure 4.17 Average Response Times for SOC by Detection Source in 2015

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

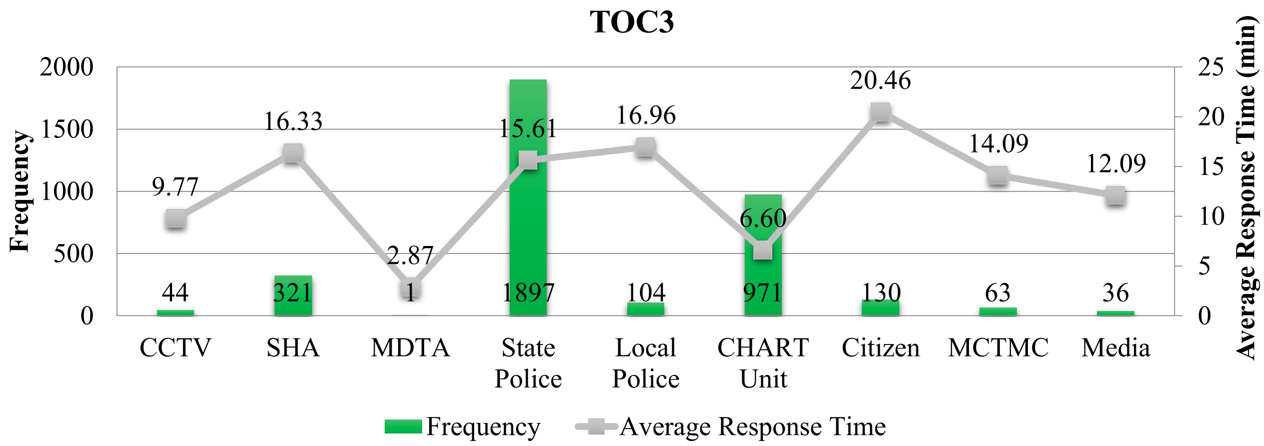


Figure 4.18 Average Response Times for TOC 3 by Detection Source in 2015

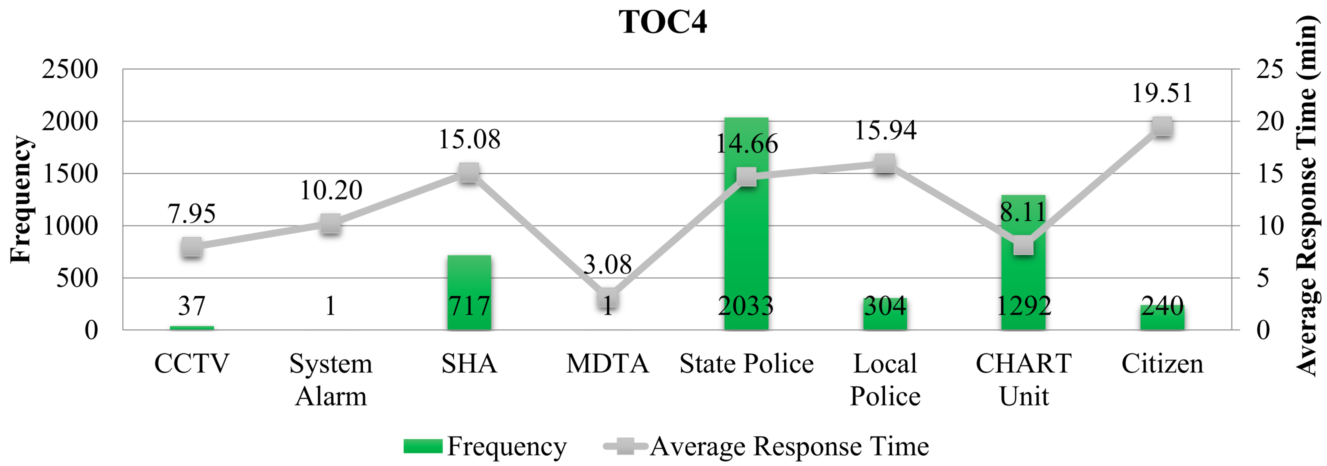


Figure 4.19 Average Response Times for TOC 4 by Detection Source in 2015

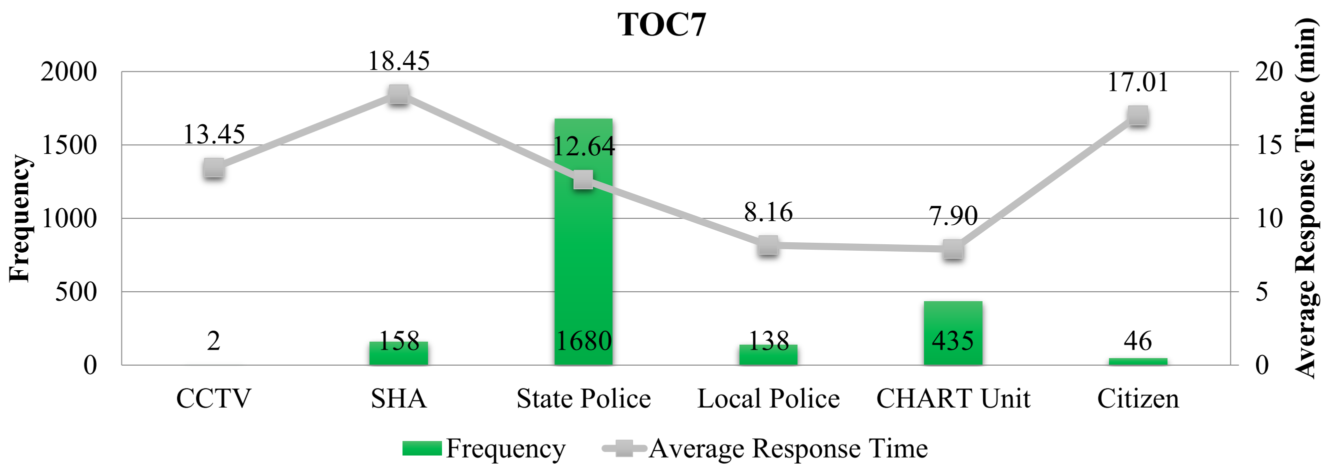
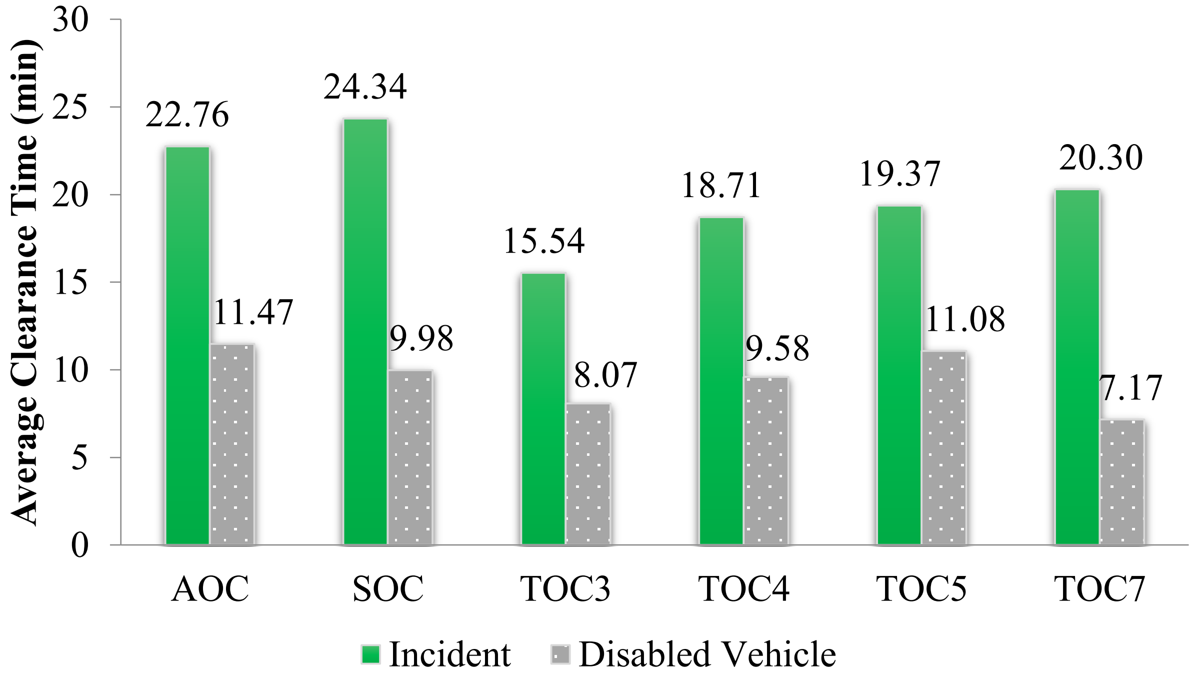


Figure 4.20 Average Response Times for TOC 7 by Detection Source in 2015

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 clearance efficiency of incidents/disabled vehicles by operation center. The average clearance time by SOC is longer than any other for incidents, while AOC has a longer average clearance time than any other for disabled vehicles. On the other hand, TOC 3 and TOC 7 show the smallest average clearance times for incidents and disabled vehicles, respectively. Further analyses of incident clearance times are 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 2015

REDUCTION IN INCIDENT DURATION 4.4

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 2015 for non-responded incidents and those to which CHART responded. Since CHART's incident management team responded to most incidents in 2015, 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 23.54 minutes and 33.18 minutes in 2015. 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 2015 contributed to a reduction in blockage duration of about 29.05 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 92 percent of incident reports contain all the required information (i.e., received time and cleared time) for incident duration computation.

4.4 REDUCTION IN INCIDENT DURATION

Table 4.1 Comparisons of Incident Durations for Various Types of Lane Blockages in 2015 (Duration= Cleared Time-Received Time)

Blockage	With SHA Patrol		Without SHA Patrol	
	Duration (min)	Sample Frequency	Duration (min)	Sample Frequency
Shoulder	19.49	5,140	30.30	1,230
1 lane	21.52	11,991	33.09	1,546
2 lanes	34.81	2,523	40.10	324
3 lanes	39.24	645	50.16	63
>=4 lanes	45.07	295	49.55	23
Weighted Average	23.54 (22.99)	20,594 (19,468)	33.18 (33.45)	3,186 (2,846)
Unknown	17.69	7,025	32.09	993

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 2014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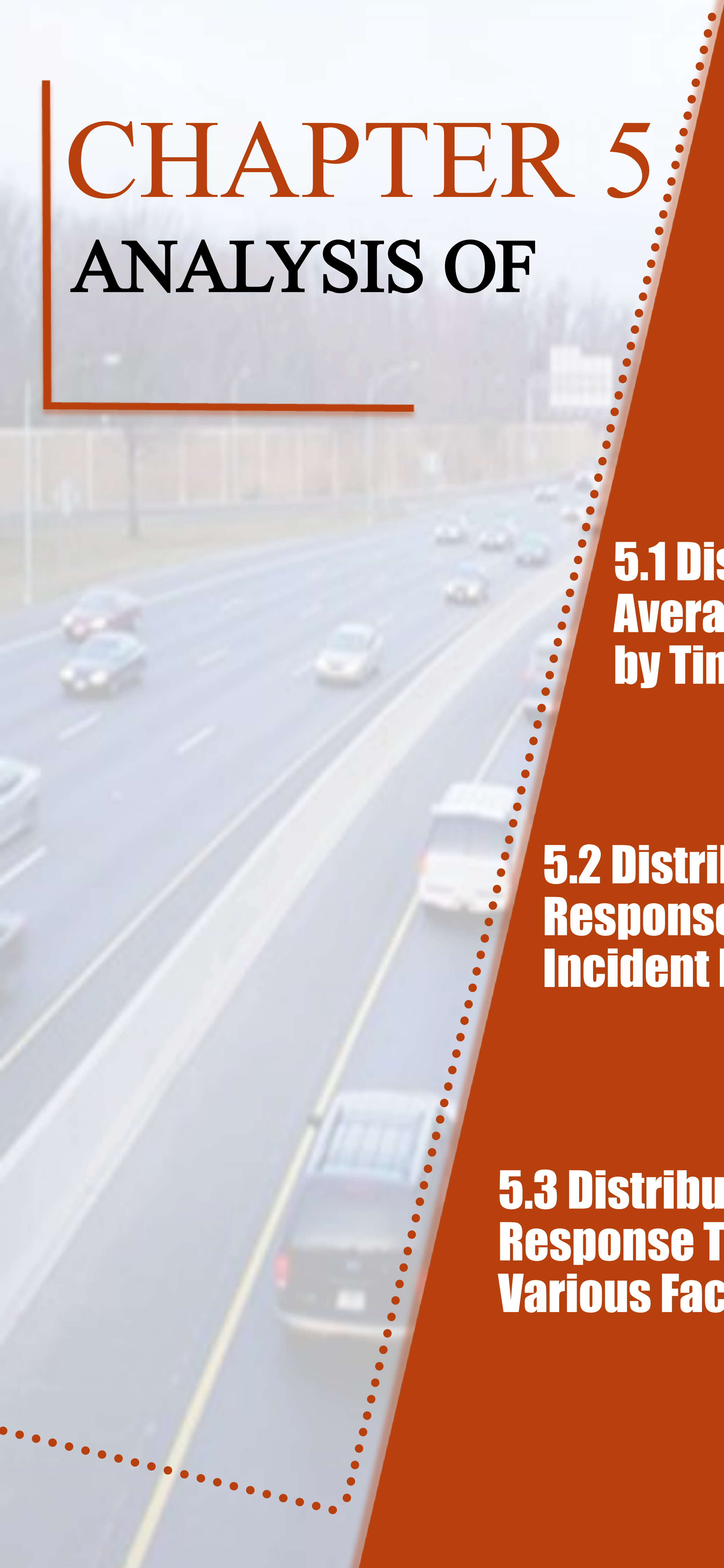
CHAPTER 5

ANALYSIS OF



5.1 Distribution of Average Response Times by Time of Day

5.2 Distribution of Average Response Times by Incident Nature

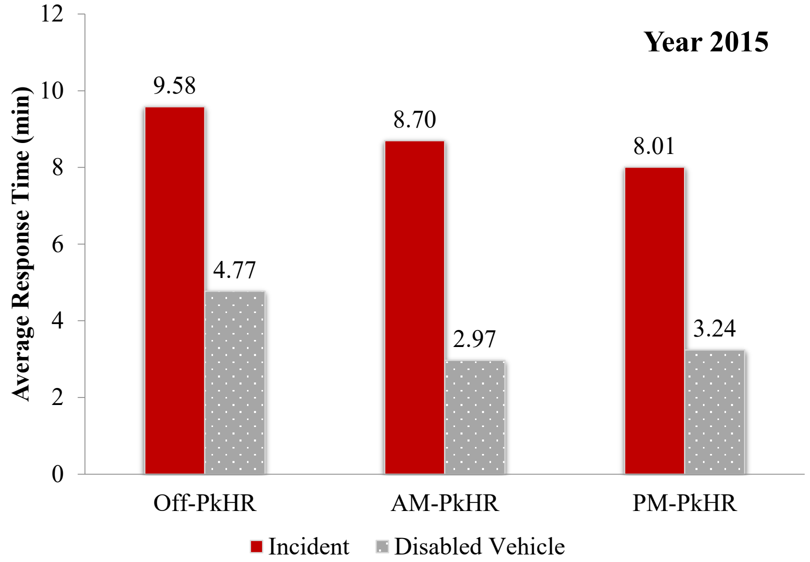
5.3 Distribution of Average Response Times by Various Factors

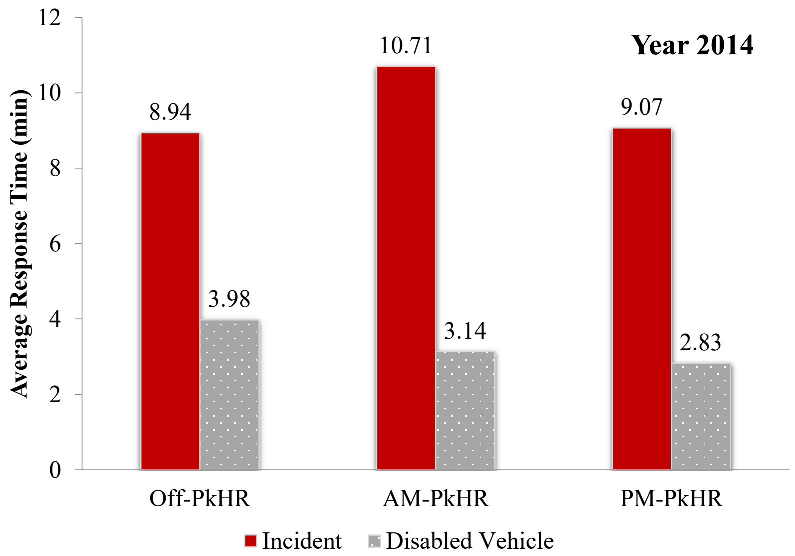
5

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

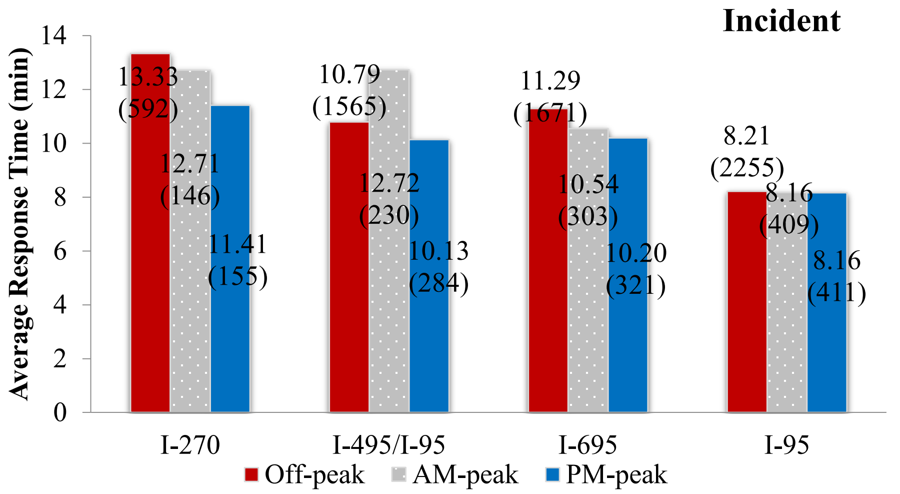


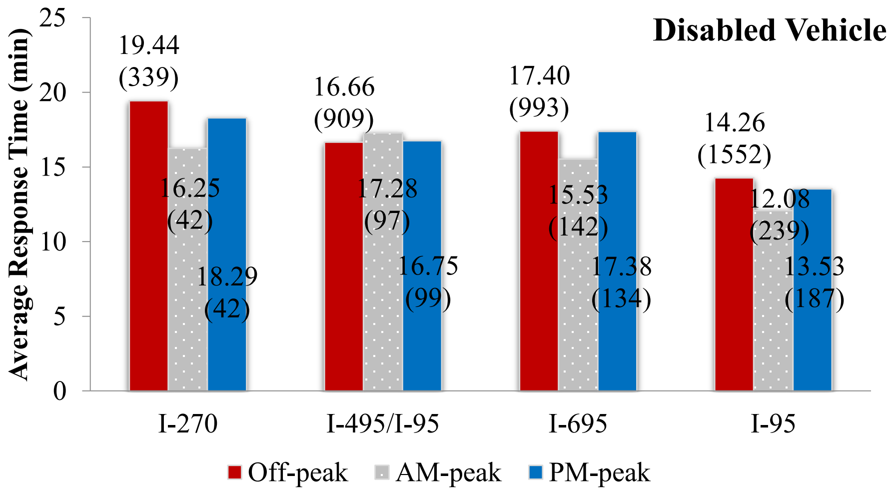


Note: Off-peak Hours include night times.

Figure 5.1 Distributions of Average Response Times by Time of Day in 2015 and 2014

Figure 5.1 compares response times by time of day in 2015 and 2014. During peak hours, the average response times to incidents in 2015 were shorter than those of 2014. In 2015, the response times to incidents and disabled vehicles during peak hours were shorter than those during off-peak hours.



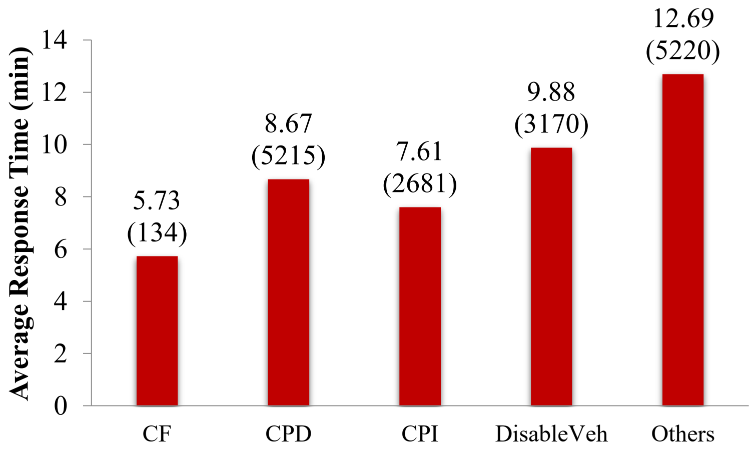


Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. Numbers in each parenthesis show frequencies.

Figure 5.2 Distributions of Average Response Times for Roads by Time of Day in 2015

Figure 5.2 shows the average response times by different times of day through the major roads. During the p.m. peak period, the incidents on I-270 experienced the longer durations than any other major road, while during the a.m. peak period, the incidents on I-495/I-95 and I –270 suffered longest times. A similar pattern also revealed in the average response time for disabled vehicles in 2015, where I-270 and I-95 experienced the longest and shortest duration, respectively.

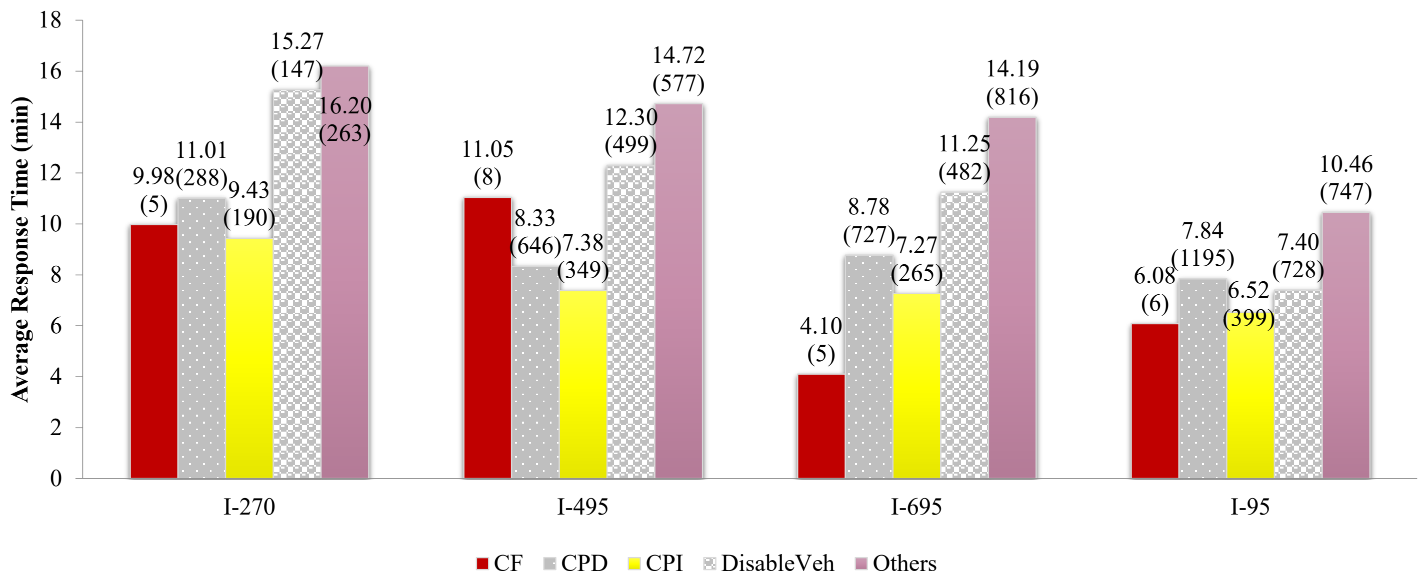
5.2 DISTRIBUTION OF AVERAGE RESPONSE TIMES BY INCIDENT NATURE



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 represent collision-fatality, collision-property damage, and collision-personal injury, respectively.

Figure 5.3 Average Response Time by Incident Nature in 2015

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.

Figure 5.4 Average Response Time for Roads by Incident Nature in 2015

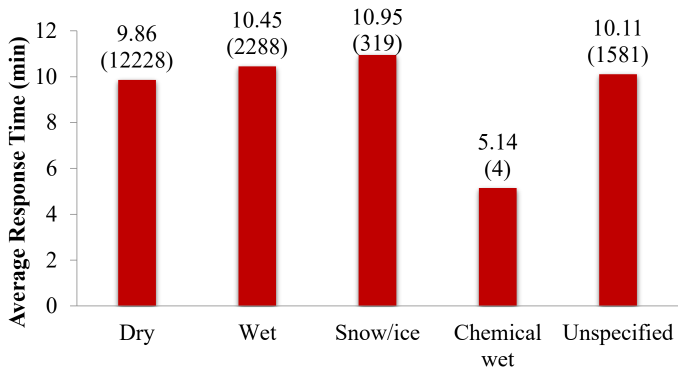
A similar pattern of decreased response times as the incident becomes severe appears on four major corridors as shown in Figure 5.4.

DISTRIBUTION OF AVERAGE RESPONSE TIMES BY VARIOUS FACTORS

5.3

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 slower on wet and snow/ ice pavements, whereas they tend to be faster on chemically wet 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 2015

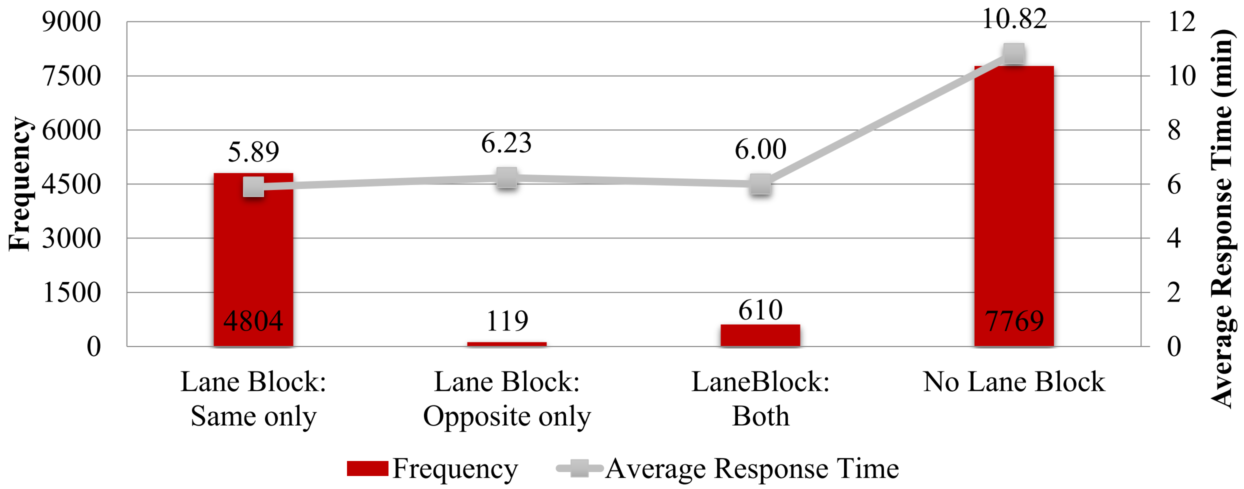


Figure 5.6 Average Response Time by Lane Blockage in 2015

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 5.3 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.

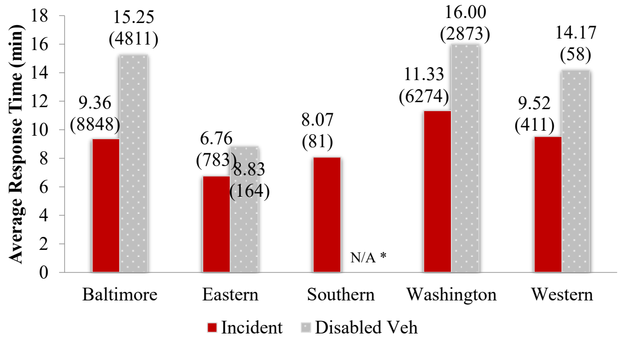
5.3 DISTRIBUTION OF AVERAGE RESPONSE TIMES BY VARIOUS FACTORS

It is noticeable that incidents involved with heavy vehicles such as vans, UVs, pick-up trucks, single-unit trucks, or tractor-trailers, generally experienced a longer response time, 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 2015

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 and Southern Maryland, than in 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 would be quicker than those for disabled vehicles 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.*
3. *Frequency of disabled vehicles in Southern MD is only one with the response time of 34.68 min.*

Figure 5.8 Average Response Time by Region in 2015

CHAPTER 6

ANALYSIS OF INCIDENT DURATIONS

6

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 statistical results from the incident duration data; this analysis provides some critical insights into the characteristics of incident duration under various conditions. In this analysis, the distributions of average incident duration are classified 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.

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 2015, about 41 percent of incidents without collisions were caused by Disabled Vehicles. A similar pattern was also observed in 2014, when about 42 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.

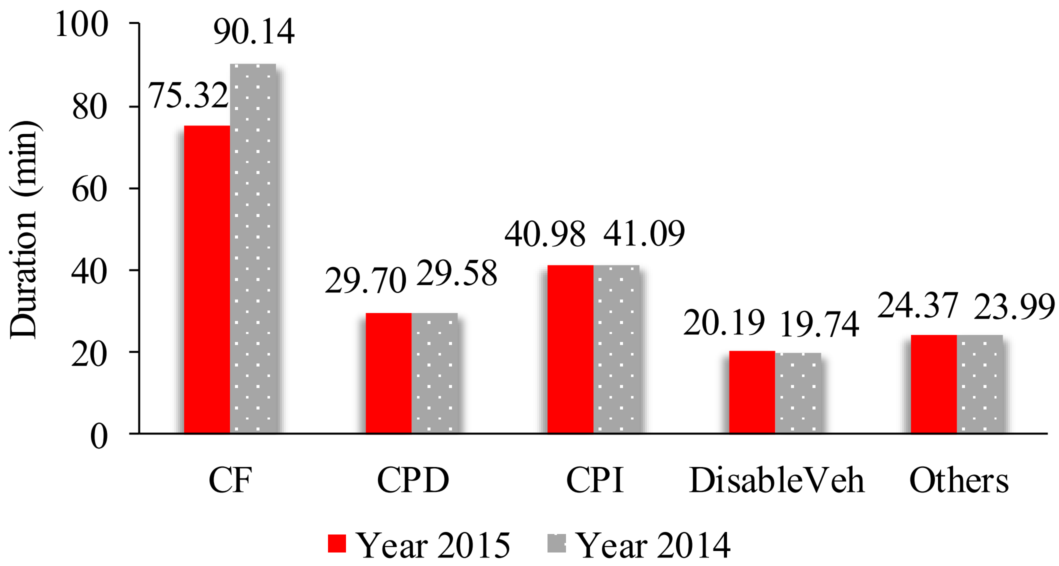
Table 6.1 Categories of Incident Nature

<table>
<tr><td rowspan="10">Incidents</td><td rowspan="3">With collision</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 (CP)</td></tr>
<tr><td rowspan="7">Without collision</td><td colspan="2">Disabled Vehicles</td></tr>
<tr><td rowspan="6">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>
<tr><td>Weather closure, etc.</td></tr>
</table>

DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY NATURE

6.1

Figure 6.1 summarizes the average incident duration for each type in year 2015. 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.

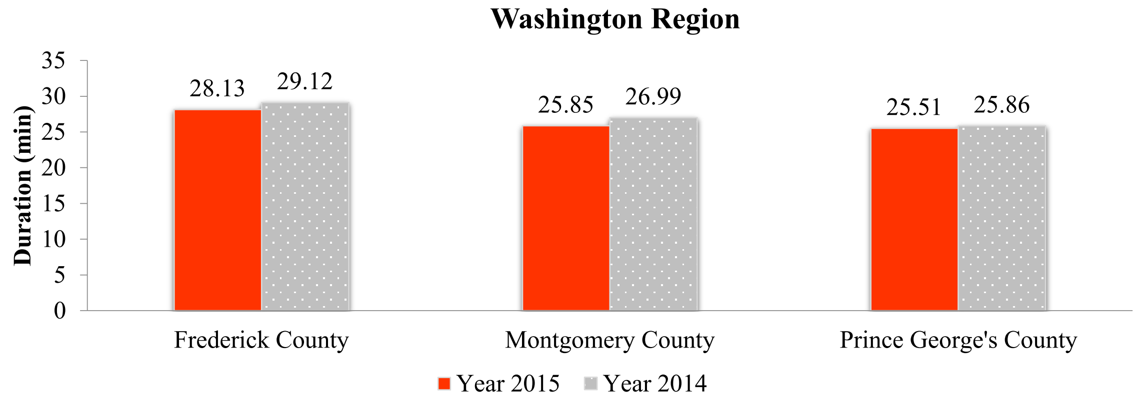


Note: 1. Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis
2. CF, CPD, and CPI represent collision-fatality, collision-property damage, and collision-personal injury, respectively.

Figure 6.1 Distribution of Average Incident Duration by Nature in 2015 and 2014

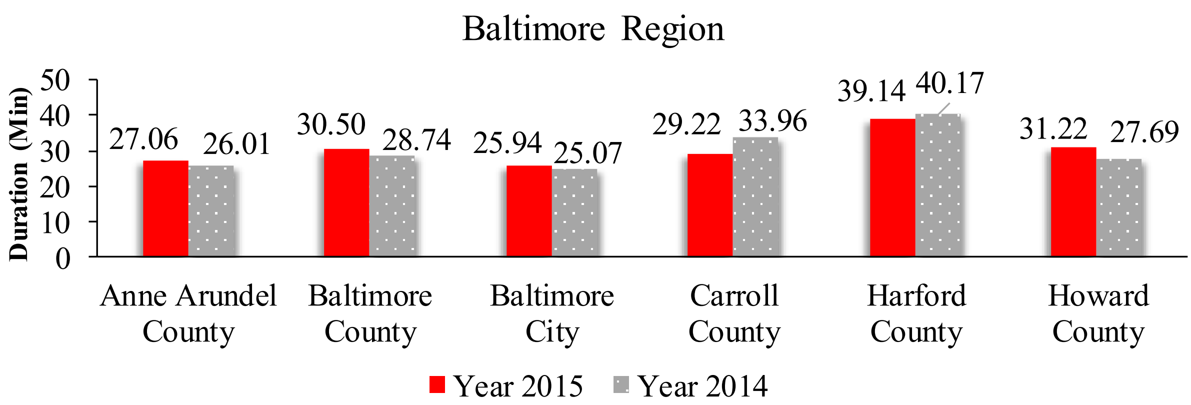
6.2 DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY COUNTY AND REGION

The distribution of incident durations also varies between counties and regions. Figures 6.2 to 6.5 illustrate incident durations by county in regions in 2014 and 2015. In the Washington region, the area around Washington D.C. (i.e., Montgomery and P.G. Counties) experienced a much shorter incident duration, as shown in Figure 6.2. Figure 6.3 shows that the incidents especially around Harford Counties had longer durations than incidents occurring in 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 2015 and 2014



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

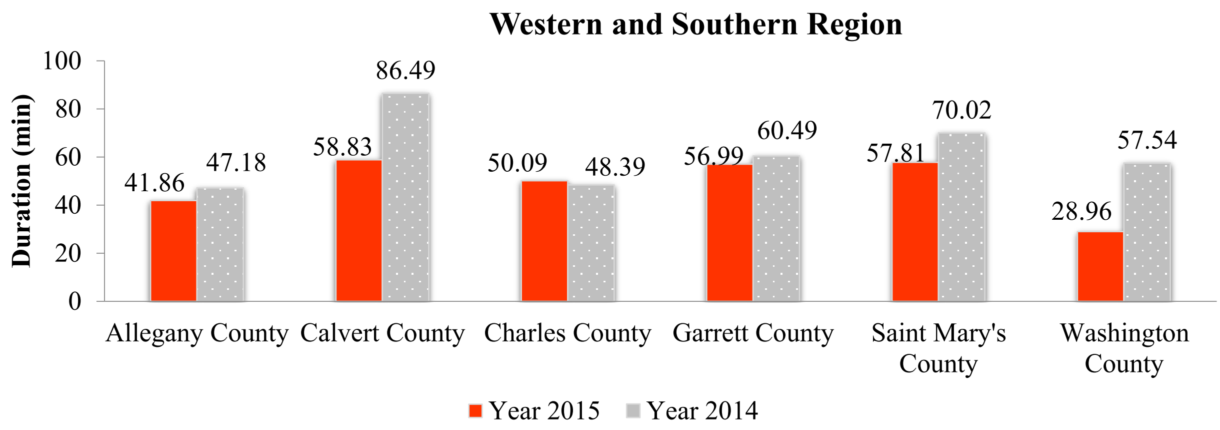
Figure 6.3 Distribution of Average Incident Duration by County in Baltimore Region in 2015 and 2014

DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY COUNTY AND REGION

6.2

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 close to one hour. Washington County had the shortest average incident duration in western and southern Maryland in the year 2015.

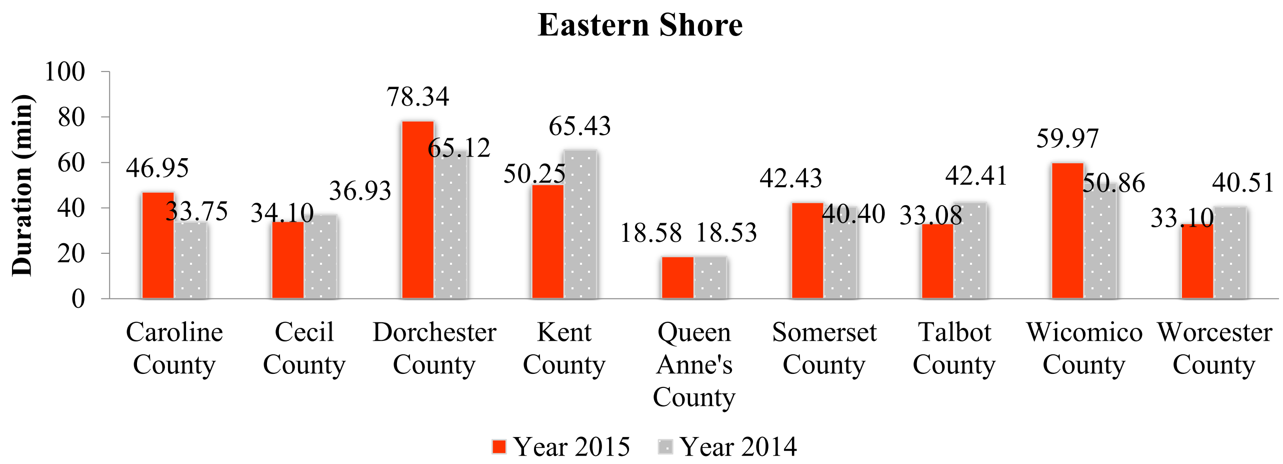
Similarly, the incidents occurred in Queen Anne's County on the Eastern Shore (Figure 6.5) are likely to result in shorter durations than those in any other areas of Eastern Shore. On the other hand, incidents occurred in Dorchester County on the Eastern Shore took about an average clearance duration of 78.34 minutes on.



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 2015 and 2014

Table 6.2 summarizes the average response times, clearance times and incident durations by region. One can easily notice that incidents occurred in the Southern area took longer to be responded and cleared than in any other regions. On the other hand, the Washington region took shorter time to clear the detected incidents, even though the average response time was relatively longer than those in the other areas in Maryland in 2015.



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 2015 and 2014

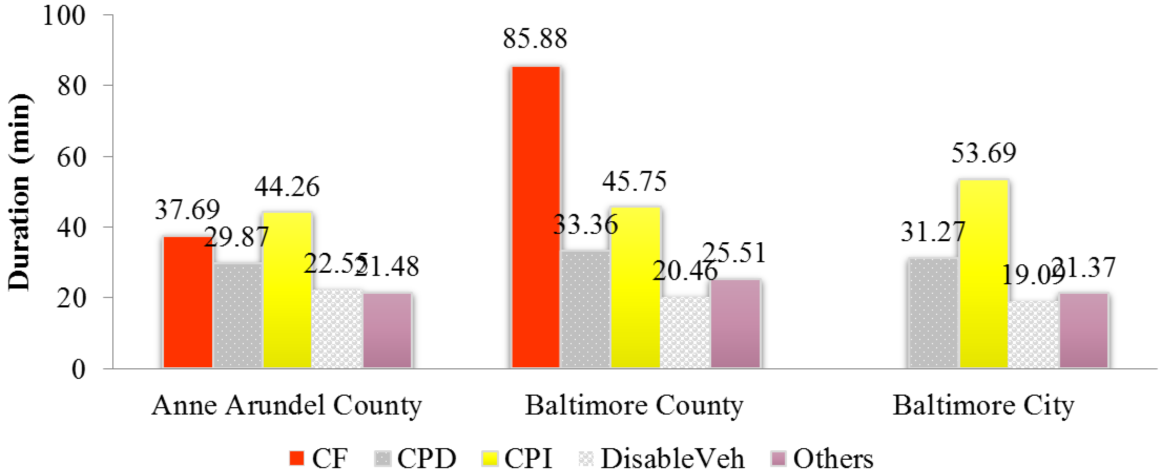
Table 6.2 Summary of Incident Duration Components by Region

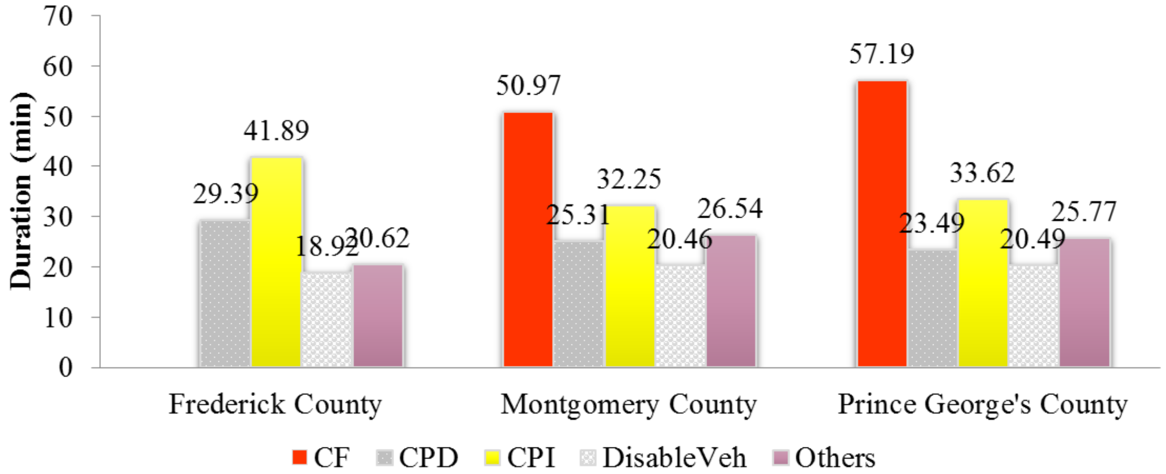
Region	Sample Frequency*	Avg. Response Time (min)	Avg. Clearance Time (min)	Avg. Incident Duration (min)
Baltimore	12,604	6.84	22.33	29.17
Eastern	1,112	5.45	22.23	27.68
Others	30	7.05	42.44	49.49
Southern	84	10.05	42.65	52.70
Washington	9,701	7.90	18.45	26.35
Western	647	6.63	25.80	32.43

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

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 Anne Arundel County was shorter than in any other area. On the other hand, CF-related incidents in Baltimore County 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.





**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

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 2015 are slightly different, the average clearance time for weekends was approximately 1.1 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

	Year	Sample* Frequency	Avg. Response Time (min)	Avg. Clearance Time (min)	Avg. Incident Duration (min)
Weekdays	2015	18,970	7.18	20.42	27.60
	2014	18,337	7.23	20.45	27.68
Weekends	2015	5,208	7.32	22.91	30.23
	2014	3,819	6.61	23.34	29.94

**Note: 1. Incident records with the complete information 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

	Year	Sample* Frequency	Avg. Response Time (min)	Avg. Clearance Time (min)	Avg. Incident Duration (min)
Off-Peak	2015	17,381	7.24	21.55	28.78
	2014	15,611	7.15	21.48	28.63
Peak*	2015	6,797	7.14	19.44	26.58
	2014	6,545	7.06	19.66	26.72

**Note: 1. Incident records with the complete information 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.

DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY CHART INVOLVEMENT, PAVEMENT CONDITION, HEAVY VEHICLE INVOLVEMENT, AND ROAD

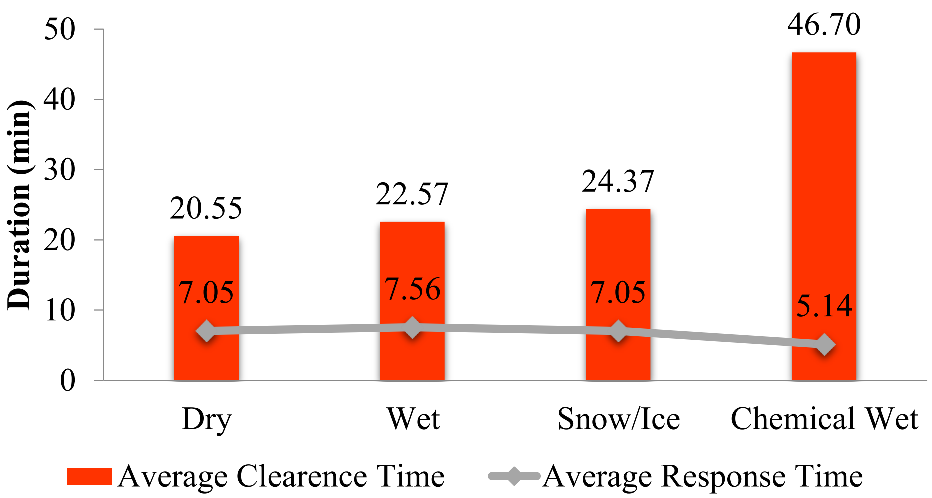
Whether or not CHART responded to an incident is another significant factor affecting the distribution of incident durations. When CHART was involved in the incident recovery task, the incident duration was likely to be reduced. This observation indicates that CHART played an efficient role in shortening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

Table 6.5 Distribution of Average Incident Duration without and with CHART

	Year	Sample* Frequency	Avg. Response Time (mins)	Avg. Clearance Time (mins)	Avg. Incident Duration (mins)
w/o CHART	2015	3,102	6.25	27.57	33.83
	2014	2,421	7.36	27.73	35.08
w/ CHART	2015	21,000	7.35	20.02	27.37
	2014	19,727	7.10	20.12	27.21

** Incident records with the complete information for duration computation.*

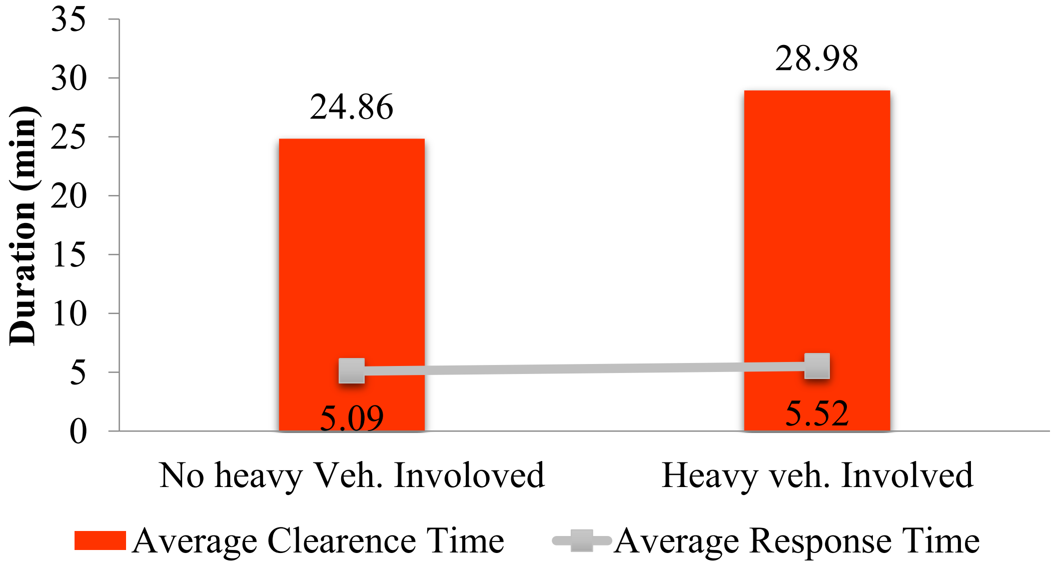
The response time and clearance time of incidents could vary with the pavement conditions. Figure 6.7 shows that the condition of chemically wet pavement such as an oil spill may result in a faster response, but a longer clearance time, than any other conditions. Wet and Snow/ice pavement conditions seem to cause a longer clearance time than those on the dry condition.



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

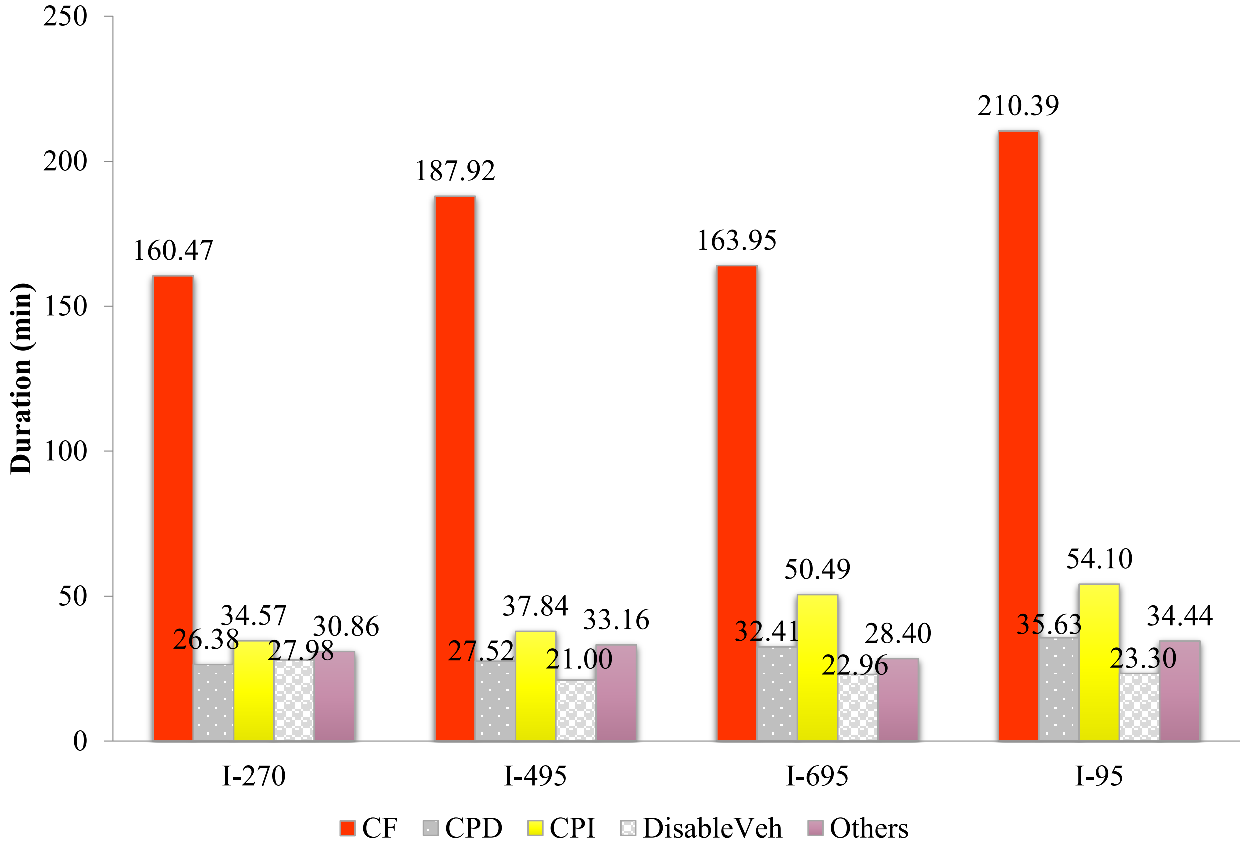
Figure 6.8 illustrates how a heavy vehicle influences the incident durations. In 2015, the response and clearance times for incidents involved with a heavy vehicle were likely to be longer than those without a heavy vehicle due to their incident severity.



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-95 seemed to exhibit the longest average duration (i.e., 210 minutes).



* *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

7

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 into 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

Since the inception of CHART, 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 flows, 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 2015 and Year 2014 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.

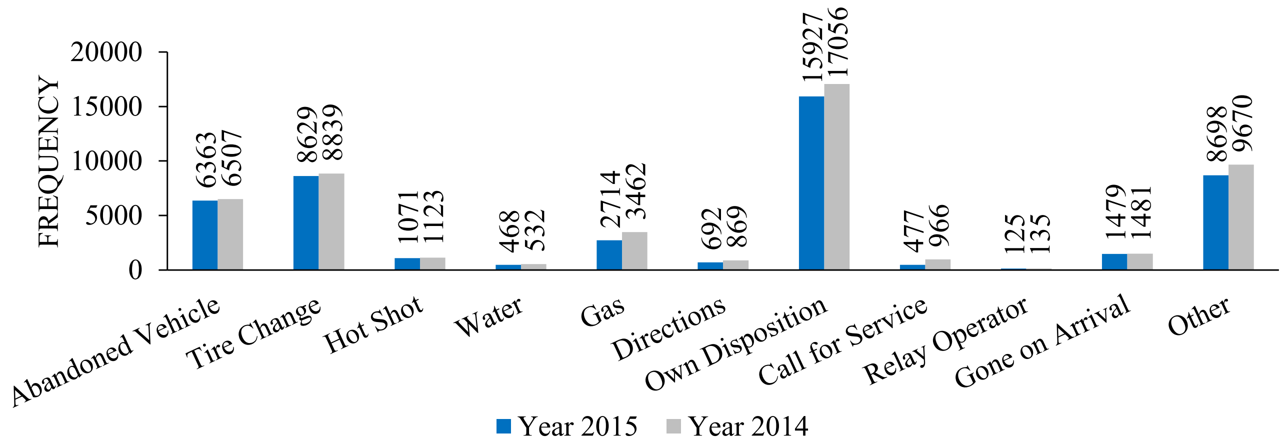


Figure 7.1 Classification of Driver Assistance Requests by Nature in 2015 and 2014

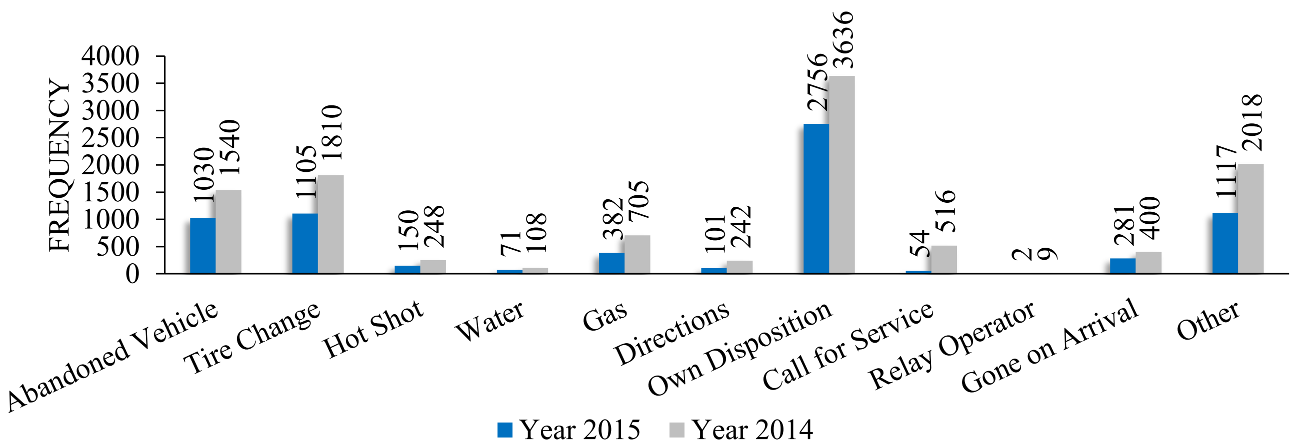


Figure 7.2 Classification of Driver Assistance Requests by Nature for TOC 3

ASSISTANCE TO DRIVERS

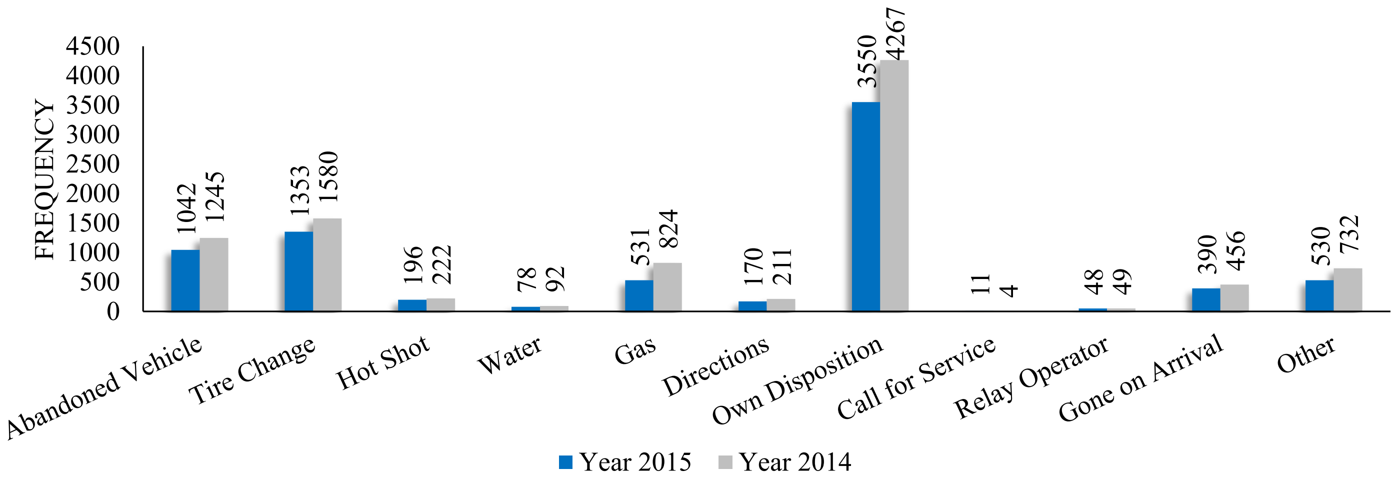


Figure 7.3 Classification of Driver Assistance Requests by Nature for TOC 4

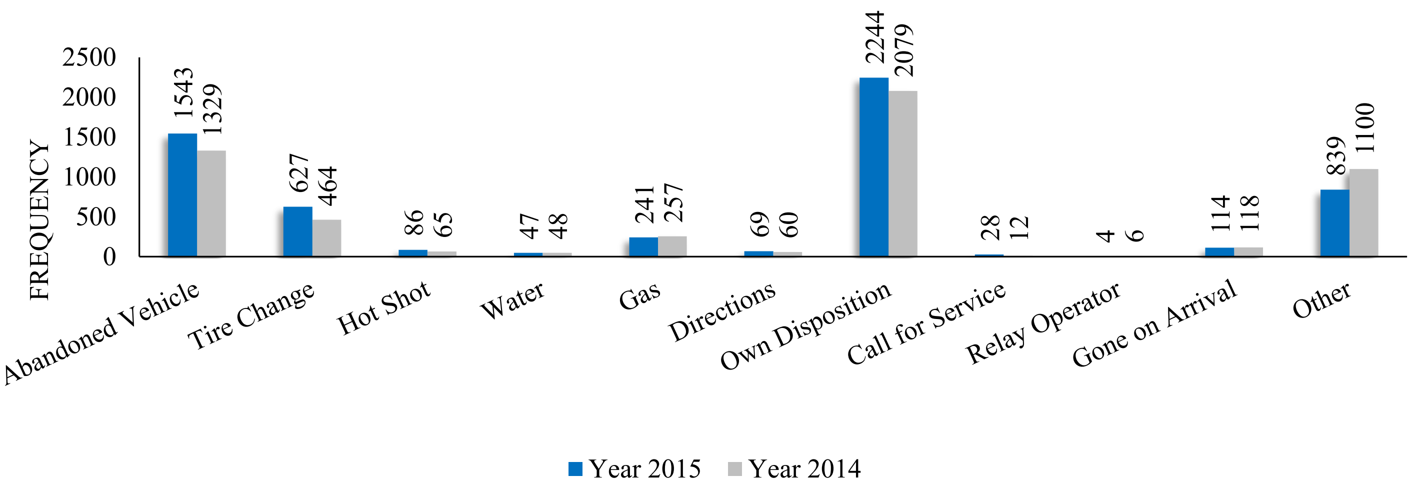


Figure 7.4 Classification of Driver Assistance Requests by Nature for TOC 7

These types of driver assistance in 2015 include flat tires, shortages of gas, or mechanical problems. Out of the 46,643 assistance requests, 11,343 assists were related to "out of gas" or "tire changes,", less than the number in 2014 (12,301 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 results of previous studies, this study has adopted the following definitions 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, and occur within half an hour from the onset of a primary incident.

Figure 7.5 shows the distribution of incidents classified as secondary incidents with the above definition, using the accident database of the MSP for the year 2015. Notably, 1,079 secondary incidents occurred in 2015. A linear relation exists 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: 1,079
- Estimated number of secondary incidents without CHART, which reduced incident duration by 29.05 percent, calculated as: 1,079/(1-0.2905) = 1,521 incidents
- The number of potentially reduced incidents due to CHART/MSHA operations: 1,521-1,079 = 442 secondary incidents.

Note that the 442 secondary incidents may have further prolonged the primary incident duration, increasing congestion, fuel consumption, and travel times. These benefits are not computed in this report due to data limitations.

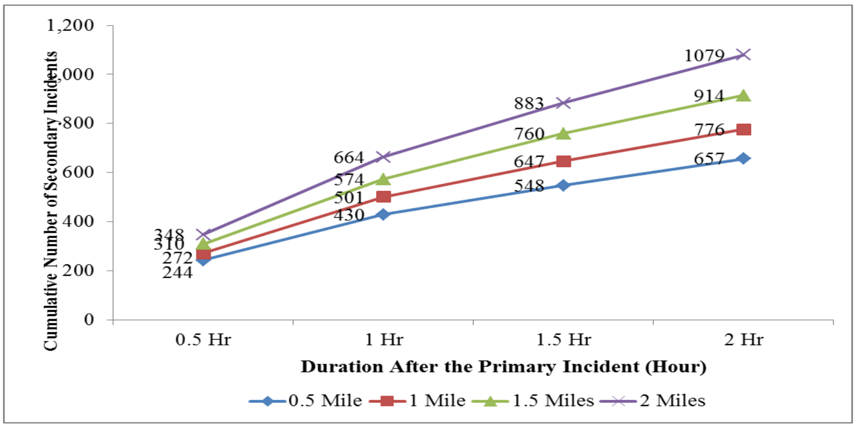


Figure 7.5 Distributions of Reported Secondary Incidents

ESTIMATED BENEFITS DUE TO EFFICIENT REMOVAL OF STATIONARY VEHICLES

7.3

It is noticeable that drivers are often 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, a 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 with respect to the reduction in potential incidents 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 to have negligible correlations with the lane-changing maneuvers and accidents. A detailed description of the estimation methodology can be found in the previous CHART performance evaluation reports.

Table 7.1 Reduction in 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. of Potential Incidents Reduced	2015	185	213	45	161	60	34	24	75	797
	2014	203	231	48	149	72	44	30	71	848
	2013	126	183	36	87	43	29	11	67	582
	2012	90	140	27	54	39	13	8	58	429
	2011	86	174	33	68	38	22	7	54	482

**Note: The analysis has excluded the outlier data (i.e. used data meeting mean ± 2 standard)*

7.4 DIRECT BENEFITS TO HIGHWAY USERS

The benefits obtained as a result of reduced delays and fuel consumption are summarized in Table 7.2, where the monetized benefit conversion from delay reduction was based on the unit rates from the U.S Census Bureau (2013) and the Energy Information Administration (2015). Figure 7.6 also shows the difference in benefits between 2014 and 2015.

The evaluation for 2015 has adopted delay reduction for cars and trucks to convert the delays to fuel consumption. Please refer to Note 3 under Table 7.2 for details.

The estimated reductions in vehicle emissions for HC, CO, and NO were based on the total reduction with the parameters provided by MDOT. Since CO_2 is recognized as a primary factor for global warming, we also included its estimated reduction, based on the factor from the Energy Information Administration. Using the cost parameters shown in Table 7.2 (DeCorla-Souza, 1998), the reduction in emissions resulted in a total savings of 44.72 million dollars. Thus, CHART operations in Year 2015 generated a total savings of 1,356.42 million dollars.

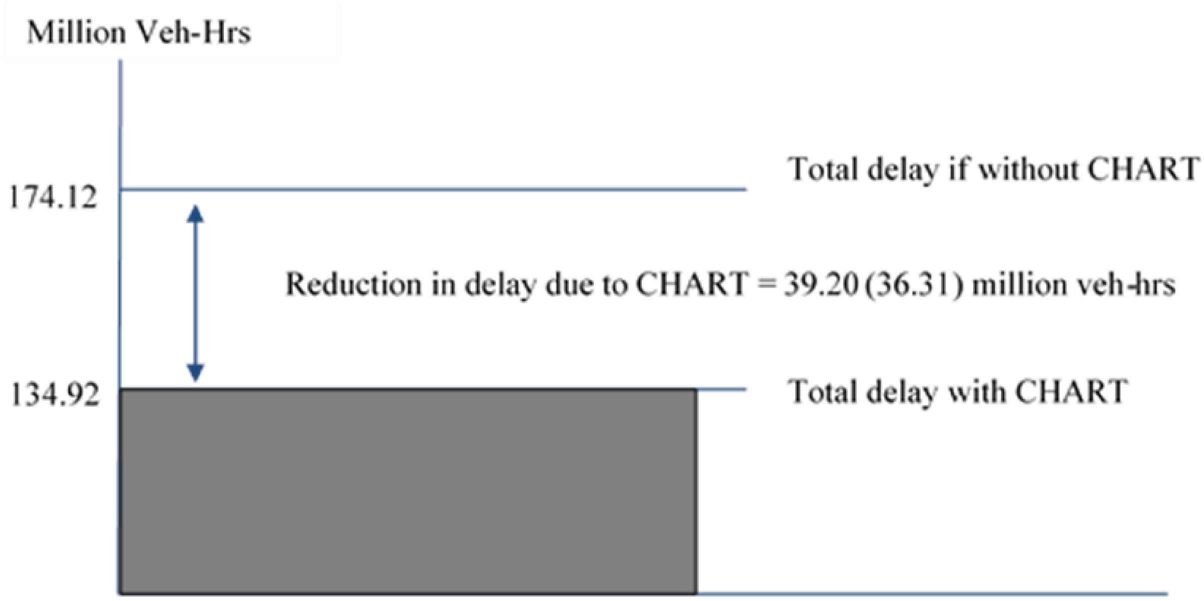
Table 7.2 Total Direct Benefits to Highway Users in 2015

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	**Truck**	1.66 (1.59)	Driver *\$20.43/hour (20.20)* [1]	33.93 (32.19)
			Cargo \$45.40/hour	75.42 (72.37)
	Car	37.54 (34.71)	*\$31.54/hour (31.54)* [2]	1,183.81 (1,094.71)
Fuel Consumption (M gallon)		7.27 [4] (6.77)	Gasoline *\$2.51/gal (3.44)* [3]	18.54 (23.83)
			Diesel *\$2.71/gal (3.83)* [3]	
Emissions	**HC (ton)**	512.45 (474.64)	\$6,700/ton	44.72 (41.43)
	CO (ton)	5,755.68 (5,330.96)	\$6,360/ton	
	NO (ton)	245.43 (227.32)	\$12,875/ton	
	CO_2 (metric ton)	66,307.85 (61,817.23)	\$23/metric ton [5]	
Total		**\$1,356.42 (1,264.53)**		

<Note>
** The number in each parenthesis is the estimate in year 2014*
** Italic unit rates indicate changes in 2015, and the number in the parenthesis is the unit rate for the 2014 analysis*
** All values are rounded to the nearest hundredth in this table only for the presentation purpose, since actual values need more spaces to be presented. For example, the benefit from truck drivers = 2,311,857.08… veh-hr * \$19.285/hr = \$ 44,584,163.74…*

<Source>

1. *The truck driver's unit cost is based on the information from the Bureau of Labor Statistics in year 2015, the US DOT in year 2000, and FHWA's Highway Economic Requirements System (HERS, a benefit/cost system for highways).*
2. *The car driver's unit cost is based on household income by the U.S. Census Bureau (2013).*
3. *The gasoline and diesel unit costs are from the Energy Information Administration in year 2015.*
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 CO2/gallon of gasoline and 22.38 lbs CO2/gallon of diesel from the Energy Information Administration and \$23/metric ton of CO2 from CBO (Congressional Budget Office)'s cost estimate for S. 2191, America's Climate Security Act of 2007. e.g. 4.73 (million gallon) * 19.56 (lbs CO_2/gallon) / 2204 (lbs/metric ton) * 23(\$/metric ton)*



** Note: The number in the parenthesis shows the reduction in 2014.*

Figure 7.6 Reduction in Delay due to CHART in Year 2015

The total benefits increased from 1,264.53 million dollars in 2014 to 1,356.42 million dollars in 2015, and the possible contributing factors are listed below:

- The total number of eligible incidents for the benefit estimate increased by about 10 percent from year 2014 to year 2015 as shown in Table 7.7.
- The performance efficiency ratio, reflecting the difference between the incident duration with CHART and those without CHART, decreased from 33 percent in 2014 to 29 percent in 2015 as shown in Table 7.8.
- Table 7.9 shows that the adjusted AADT with peak hour factors in 2015 for major roads in Maryland, compared with 2014, generally increased by 3.23 percent.
- The truck percentage in 2015 decreased on all major roads, as shown in Table 7.10.

Table 7.7 Total Number of Incidents Eligible for the Benefit Estimate

	2014	2015	Δ('14 ~ '15) (%)
No. of Incidents	27,014	29,827	10.41

Note: 1. They only include the incidents causing main lanes blockage. To estimate benefits, the incidents causing only shoulder lanes blockage are excluded.
2. The percentage change in No. of Incidents (X) from Year 2014 to Year 2015 is calculated as follows:

$$\Delta \mathbf{X}(\%) = \frac{X_{2015} - X_{2014}}{X_{2014}} \times 100$$

Table 7.8 Comparison of Incident Duration Reduction between 2014 and 2015

	With CHART (mins)	Without CHART (mins)	Difference (mins)	Ratio in Difference
2014	23.32	34.82	11.50	33.03%
2015	23.54	33.18	9.64	29.05%
Δ('14 ~ '15)	0.94%	-4.71%	-16.17%	-

Note: The percentage change in incident duration (X) from Year 2014 to Year 2015 is calculated as follows:

$$\Delta \mathbf{X}(\%) = \frac{X_{2015} - X_{2014}}{X_{2014}} \times 100$$

7.4 DIRECT BENEFITS TO HIGHWAY USERS

Table 7.9 Changes in AADTs for Major Roads from 2014 to 2015

	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	**2014**	11,677	7,979	7,164	10,680	4,343	1,891	4,203	2,936	3,181	54,054
	2015	12,051	8,217	7,176	11,085	4,499	2,344	4,348	2,909	3,171	55,800
Δ('14~ '15) (%)		3.20	2.98	0.17	3.79	3.59	23.96	3.45	-0.92	-0.31	3.23

Note: The percentage change in the adjusted AADT(X) from Year 2014 to Year 2015 is calculated as follows:

$$\Delta \mathbf{X}(\%) = \frac{X_{2015} - X_{2014}}{X_{2014}} \times 100$$

Table 7.10 Changes in Truck Percentage for Major Roads from 2014 to 2015

	Year	I-495	I-95	I-270	I-695	MD 295	US 50	US 1	I-83	I-70	Average
Truck Percentage (%)	**2014**	10.69	14.78	8.15	9.97	3.53	9.03	5.26	9.03	11.68	9.12
	2015	9.24	13.86	7.90	9.96	3.30	9.32	5.21	9.24	12.17	8.91
Δ('14 ~ '15) (%)		-13.53	-6.21	-3.02	-0.06	-6.47	3.17	-1.04	2.29	4.23	-2.33

Note: The percentage change in the truck percentage from Year 2014 to Year 2015 is calculated as follows:

$$\Delta \mathbf{X}(\%) = \frac{X_{2015} - X_{2014}}{X_{2014}} \times 100$$

7.4 DIRECT BENEFITS TO HIGHWAY USERS

In addition to the above benefit analysis, a reduction in emissions due to reduced travel time in the Baltimore and Washington regions has also been computed. The results are summarized in Tables 7.11(a) and 7.11(b), where the daily delay reductions for the Washington region in 2015 were 1,599 hours/day and 45,253 hours/day for trucks and cars, respectively, compared with the 1,615 hours/day for trucks and 44,214 hours/day for cars in 2014. The delay reduction for trucks in the Baltimore region decreased from 4,516 hours/day in 2014 to 4,790 hours/day in 2015, and increased from 89,296 hours/day in 2014 to 99,125 hours/day in 2015 for passenger cars. The overall reductions in emissions (i.e., by cars and trucks) for the entire region were $172,017/day and $159,360/day for the years 2015 and 2014, respectively.

Table 7.11(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	
		2015	2014	2015	2014	2015	2014
Annual Delay Reduction	hour	1,661,143	1,594,083	415,805	419,899	1,245,338	1,174,184
Daily Delay Reduction	hour	6,389	6,131	1,599	1,615	4,790	4,516
Emission Reduction							
HC reduction	ton/day	0.084	0.080	0.036	0.034	0.048	0.046
	$/day	559.61	537.02	238.83	228.67	320.78	308.35
CO reduction	ton/day	0.938	0.900	0.400	0.383	0.538	0.517
	$/day	5,966.35	5,725.49	2,546.34	2,438.00	3,420.01	3,287.49
NO reduction	ton/day	0.040	0.038	0.017	0.016	0.023	0.022
	$/day	515.02	494.23	219.80	210.45	295.22	283.78
CO2 reduction	metric ton/day	55.14	52.92	23.53	22.53	31.61	30.38
	$/day	1,268.32	1,217.12	541.30	518.27	727.02	698.85
Total	$/day	8,309.30	7,973.85	3,546.27	3,395.39	4,763.02	4,578.46

Table 7.11(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	
		2015	2014	2015	2014	2015	2014
Annual Delay Reduction	hour	37,538,200	34,712,700	11,765,730	11,495,722	25,772,471	23,216,978
Daily Delay Reduction	hour	144,378	133,510	45,253	44,214	99,125	89,296
Emission Reduction							
HC reduction	ton/day	1.887	1.745	0.806	0.743	1.082	1.002
	$/day	12,645.91	11,694.05	5,397.07	4,979.51	7,248.84	6,714.55
CO reduction	ton/day	21.199	19.603	9.047	8.347	12.152	11.256
	$/day	134,826.41	124,678.03	57,541.74	53,089.83	77,284.67	71,588.19
NO reduction	ton/day	0.904	0.836	0.386	0.356	0.518	0.480
	$/day	11,638.34	10,762.32	4,967.06	4,582.76	6,671.28	6,179.56
CO2 reduction	metric ton/day	199.89	184.84	85.31	78.71	114.58	106.13
	$/day	4,597.37	4,251.33	1,962.09	1,810.28	2,635.29	2,441.05
Total	$/day	163,708.04	151,385.73	69,867.96	64,462.39	93,840.08	86,923.34

Since each key factor has a different degree of exponential impact on the resulting benefit change, Table 7.12 has further illustrated the results of sensitivity analysis with respect to each key contributor..

Table 7.12 Sensitivity Analysis of key factors contributing to the Benefits (Unit: M dollar)

Benefit of the Previous Year (2014)			**1,264.53**
Key Factor		**Δ ('14 - '15)[1]**	**Benefit difference[2]**
Sensitivity Analysis	**Adjusted AADT**	▲ 3.23 %	1,392.73(▲10.14%)
	Number of incidents	▲ 10.41 %	1,396.23(▲10.41%)
	Incident duration difference between w/ and w/o CHART	▼ 16.17 %	1,112.40(▼12.03%)
	Truck percentage	▼ 2.33 %	1.262.34(▼ 0.17%)
	Monetary unit value of time	▲ 0.57 %	1,258.35 (▼0.49%)
	Monetary unit of gas price	▼ 28.15 %	
Benefit of the Current Year (2015)			**1,356.42 (▲7.27%)**

Note:
1. *This field is showing the difference in percentage between 2014 and 2015 .*
2. *The number in each parenthesis shows the percentage of the benefit change from year 2014.*

Note that the sensitivity results shown in Table 7.12 were obtained with the following steps:

- Identifying key factors contributing to the total CHART benefits, which are: traffic volume, the number of incidents resulting in lane blockage, incident duration with and without CHART involvements, truck percentage, value of time, and gas price;
- Computing the marginal impacts of the selected factor, using its 2015 value, but setting all other factors identical to those in 2014; and
- Following the same procedures to analyze the sensitivity of the total 2015 benefits with respect to each key factor.

Notably, an increase of 3.23 percent in the AADT adjusted with the peak hour factor results in 10.14 percent benefit increase. Also, the number of incidents increased by 10.41 percent in 2014 resulted in the 10.41 percent benefit increase. The difference between incident duration with CHART and those without CHART decreased by 16.17 percent in 2014, and it yields a reduction of 12.03 percent in the total benefit. The decrease of 2.33 percent in truck percentage results in 0.17 percent reduction in benefits. Since the unit rate of gas price is much lower than the unit rate of time value, the total benefits decrease only by 0.49 percent despite the significant decrease in gas price (28.15 percent) and the slight increase in the value of time (0.57 percent).

CHAPTER 8
CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

8.2 Recommendations and Further Development

8

8.1 Conclusions

Building on the previous research experience, this study has conducted a rigorous evaluation of CHART's performance in 2015 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.

8.1 CONCLUSIONS

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 2015 was 11.70 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 2015 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.

RECOMMENDATIONS AND FURTHER DEVELOPMENT

8.2

The main recommendations, based on the performance of CHART in 2015, are listed below:

- Increase the resources for CHART to sustain the high quality incident response operation, including more staffs and hardware supports.
- Provide practical training to staffs in the control center responsible for recording incident related information to ensure the data quality.
- Develop and update a strategy to allocate CHART's resources between different response centers, based on their respective performance and efficiency so that they can effectively contend with the ever-increasing congestion and accompanying incidents both in urban and suburban areas.
- 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 data quality evaluation report available to the centers' operators for their continuous improvement of data recording and documentation.
- Implement training sessions to educate/re-educate operators on the importance of high-quality data, and discuss how to effectively record critical performance-related information.
- Improve the data structure used in the CHART-II system for recording incident locations to eliminate the current laborious and complex procedures.
- Document and re-investigate the database structure on a regular basis to improve the efficiency and quality of collected data.
- Document possible explanations for extremely short or long response and/or clearance times so that the results of performance analysis can be more reliable.
- 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.

APPENDIX A – ADDITIONAL ANALYSIS TO INCIDENTS /DISABLED VEHICLES

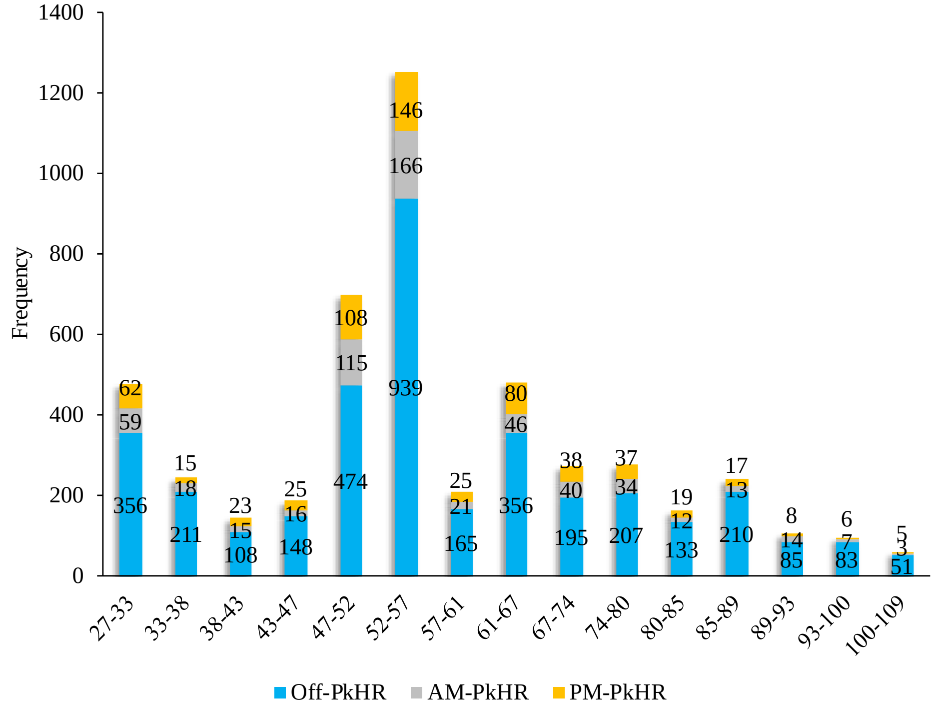


Figure A.1 Distribution of Incidents by Time of Day on I-95 in Year 2015

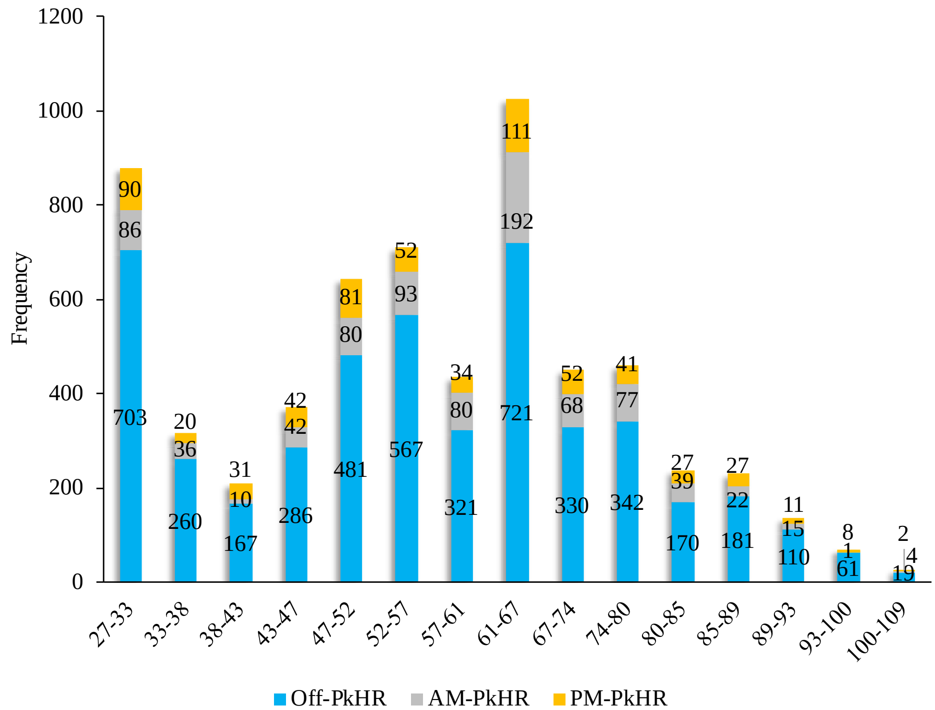


Figure A.2 Distribution of Disabled Vehicles by Time of Day on I-95 in Year 2015

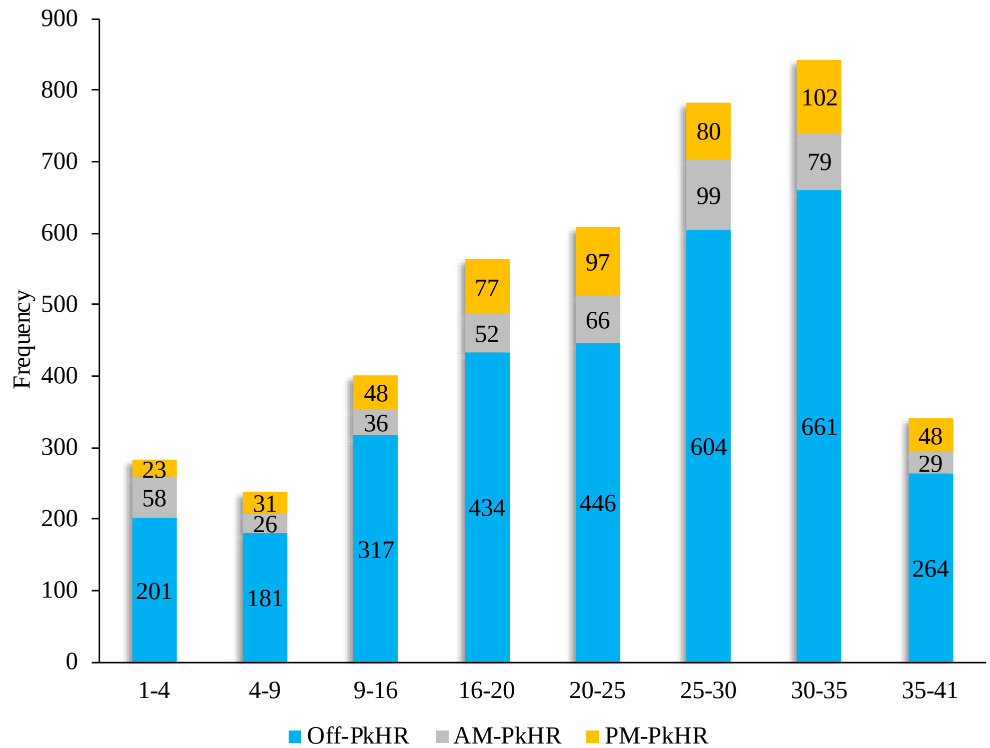


Figure A.3 Distribution of Incidents by Time of Day on I-495 in Year 2015

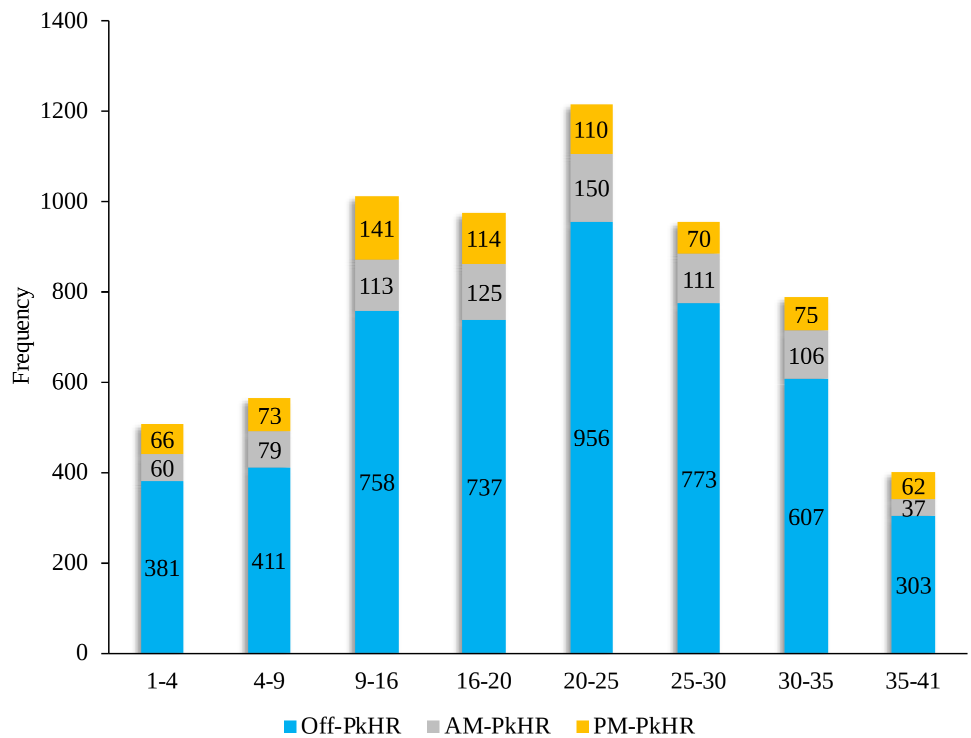


Figure A.4 Distribution of Disabled Vehicles by Time of Day on I-495 in Year 2015

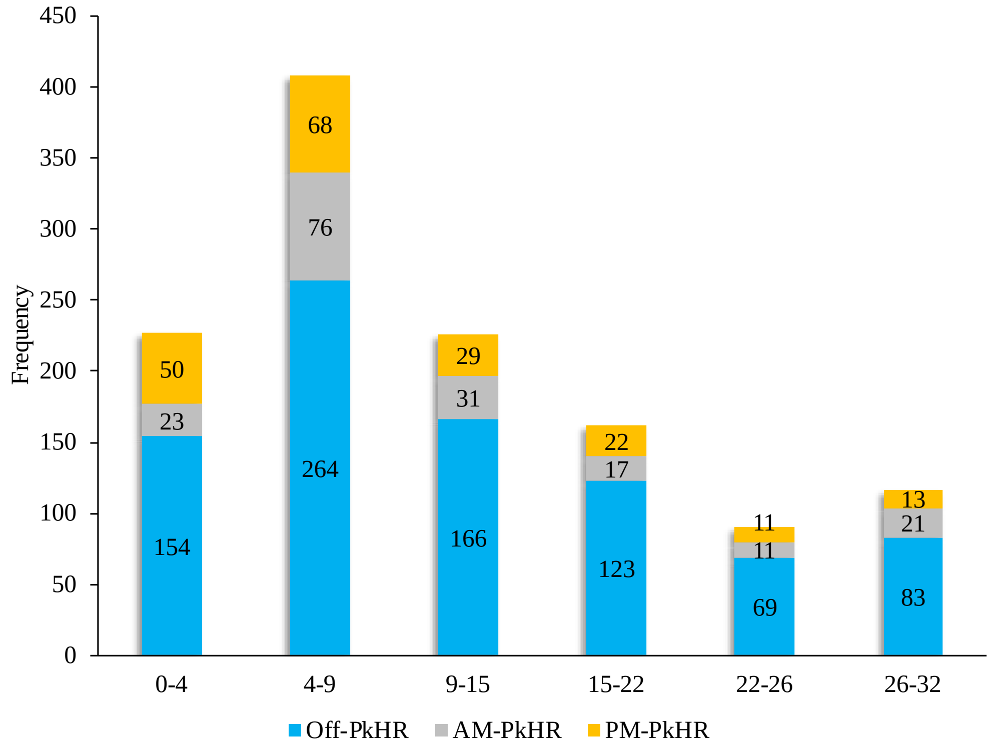


Figure A.5 Distribution of Incidents by Time of Day on I-270 in Year 2015

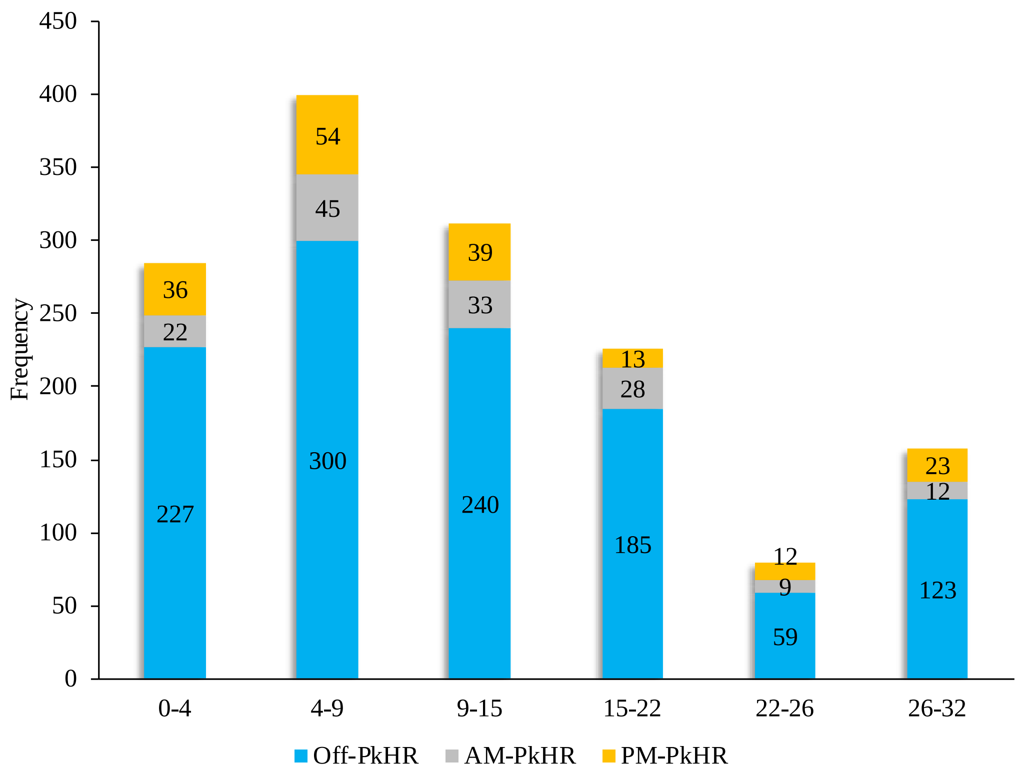


Figure A.6 Distribution of Disabled Vehicles by Time of Day on I-270 in Year 2015

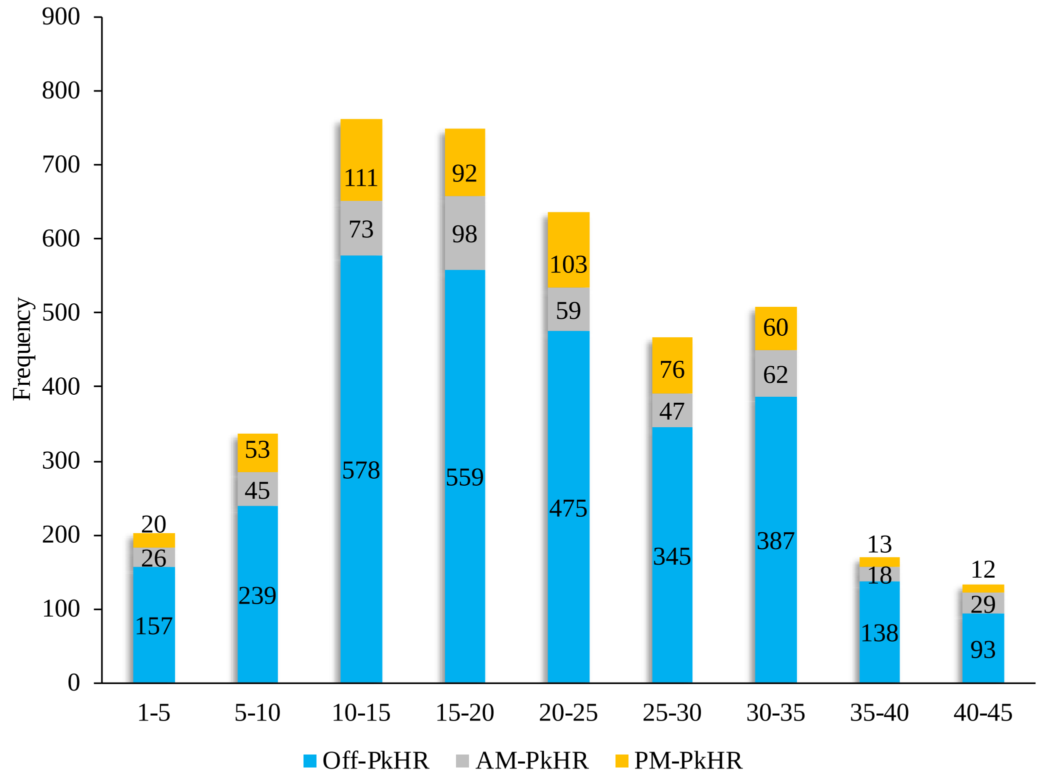


Figure A.7 Distribution of Incidents by Time of Day on I-695 in Year 2015

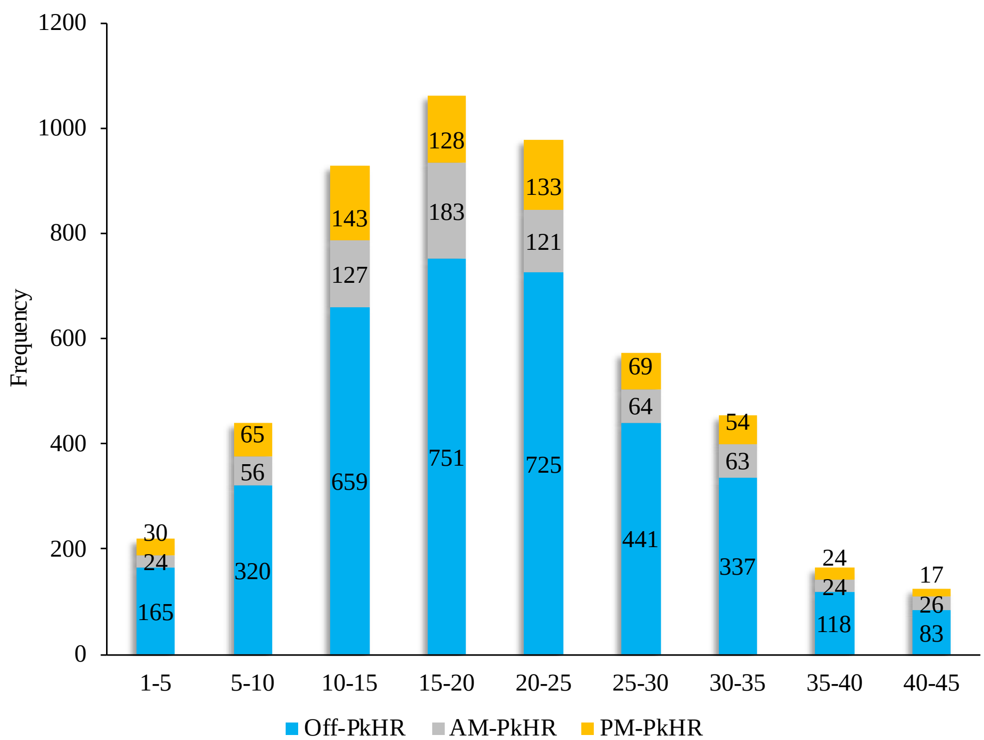


Figure A.8 Distribution of Disabled Vehicles by Time of Day on I-695 in Year 2015

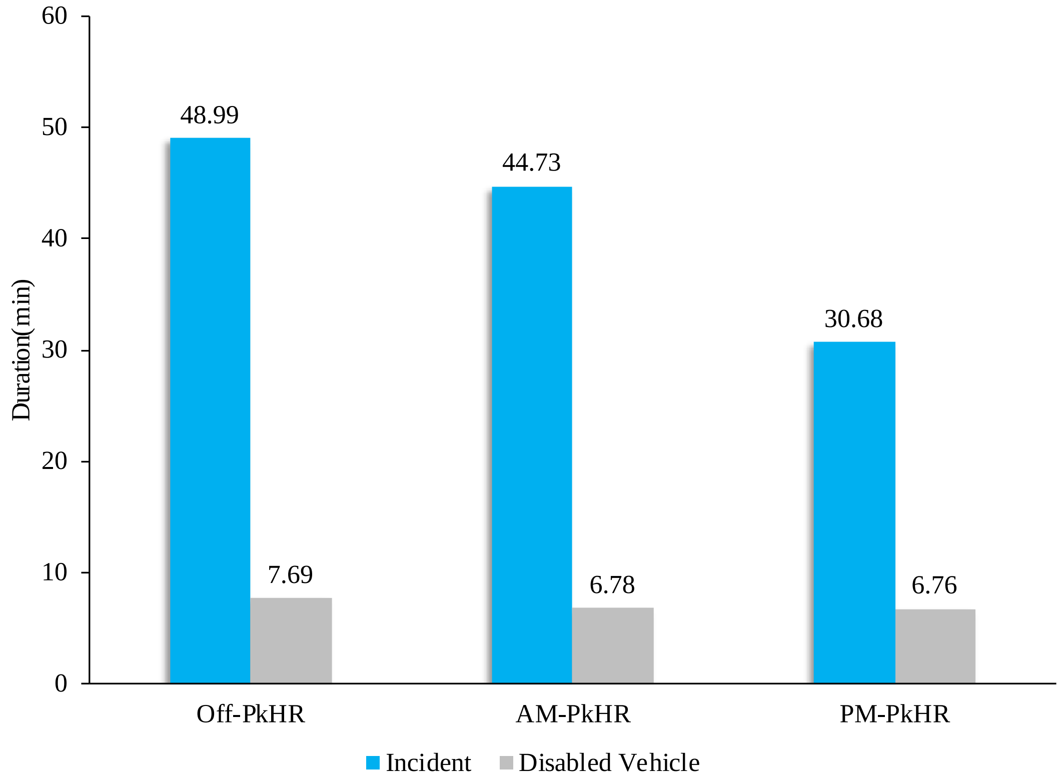


Figure A.9 Distribution of Clearance Time by Time of Day in Year 2015

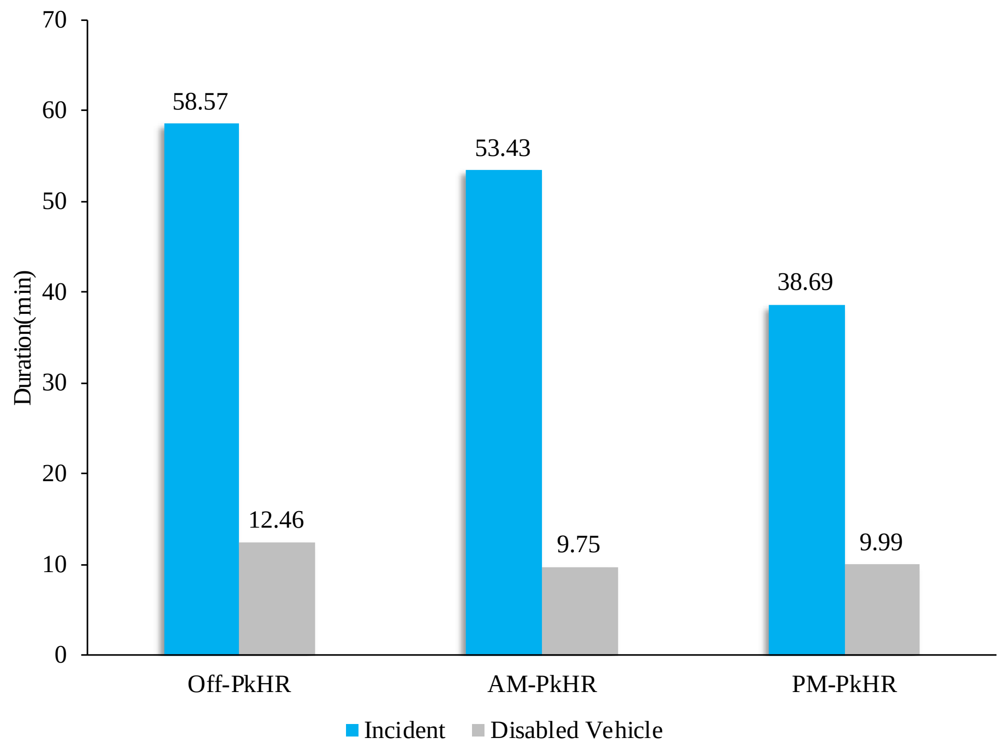


Figure A.10 Distribution of Incident Duration by Time of Day in Year 2015

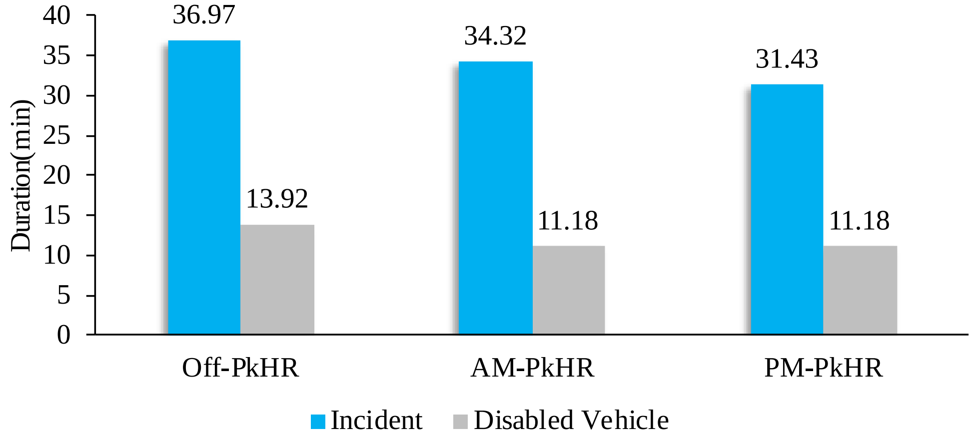


Figure A.11 Distribution of Incident Duration by Time of Day on I-95 in Year 2015

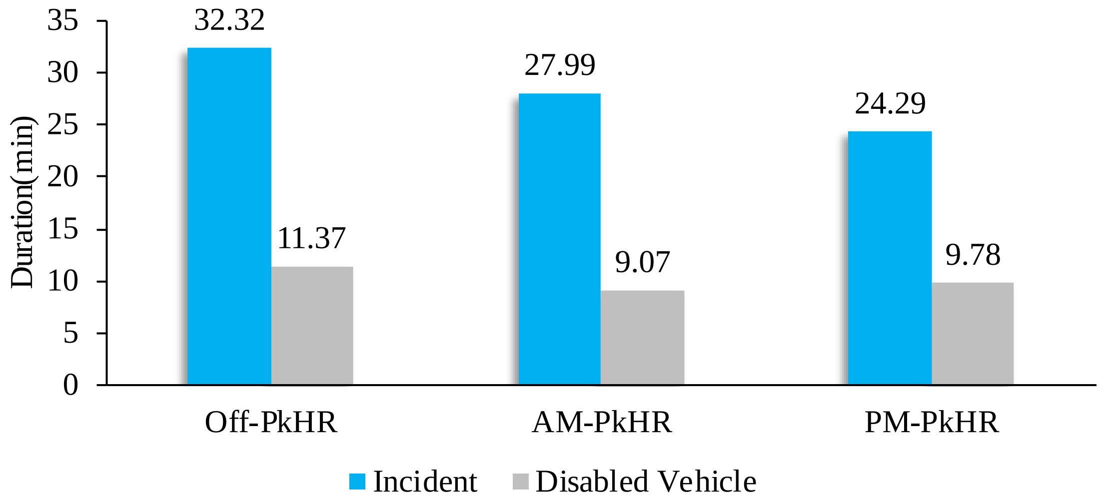


Figure A.12 Distribution of Incident Duration by Time of Day on I-495 in Year 2015

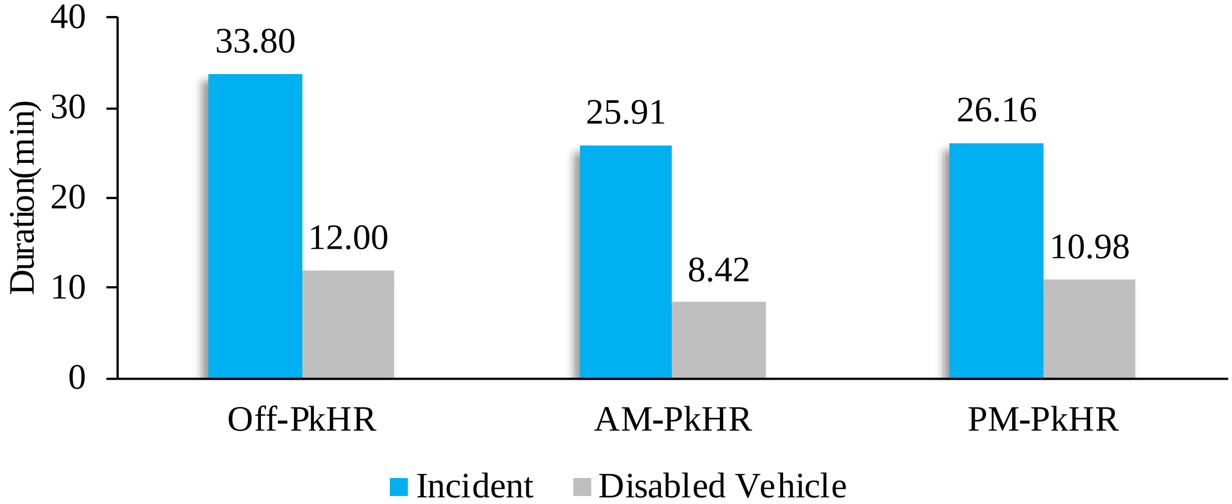


Figure A.13 Distribution of Incident Duration by Time of Day on I-270 in Year 2015

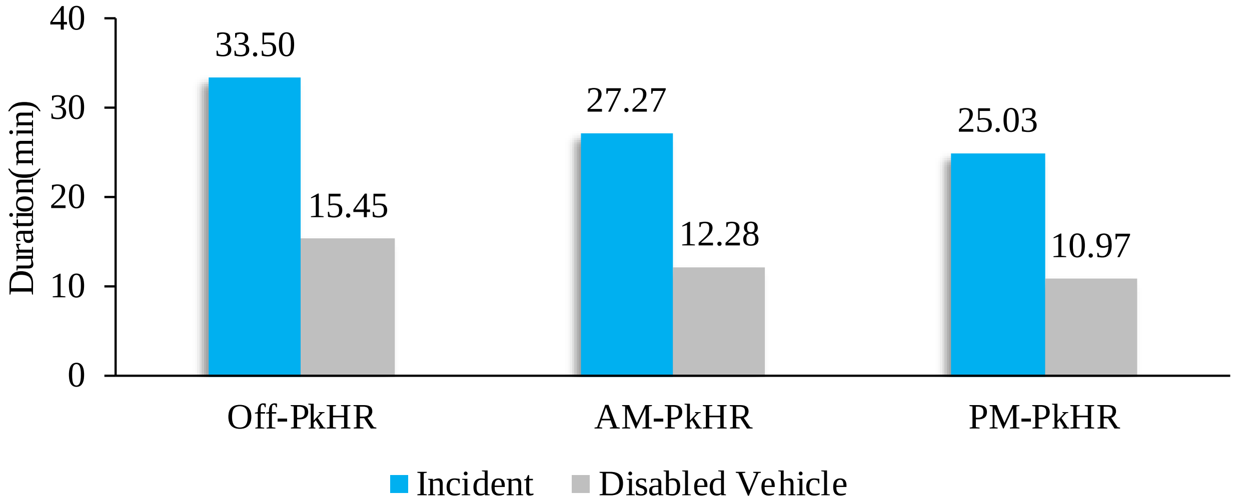


Figure A.14 Distribution of Incident Duration by Time of Day on I-695 in Year 2015

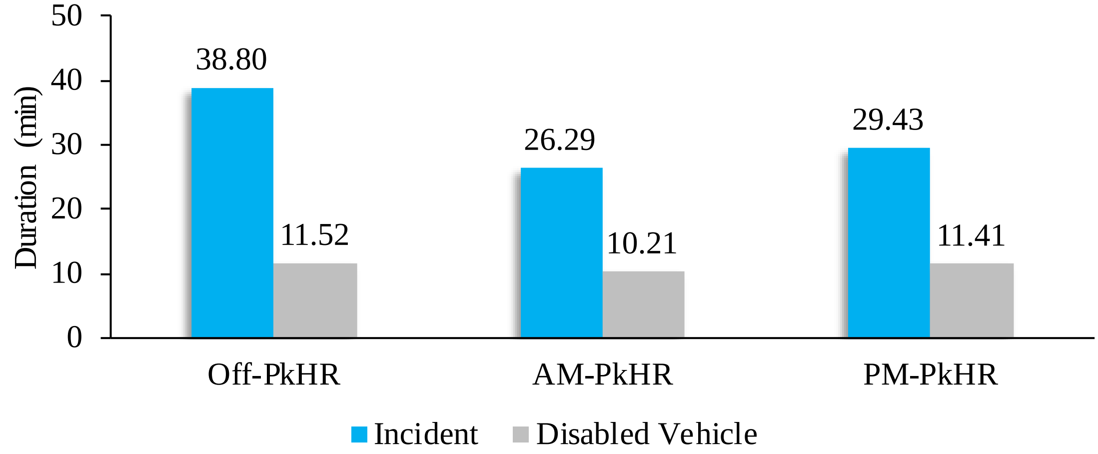


Figure A.15 Distribution of Incident Duration by Time of Day on I/MD-295 in Year 2015

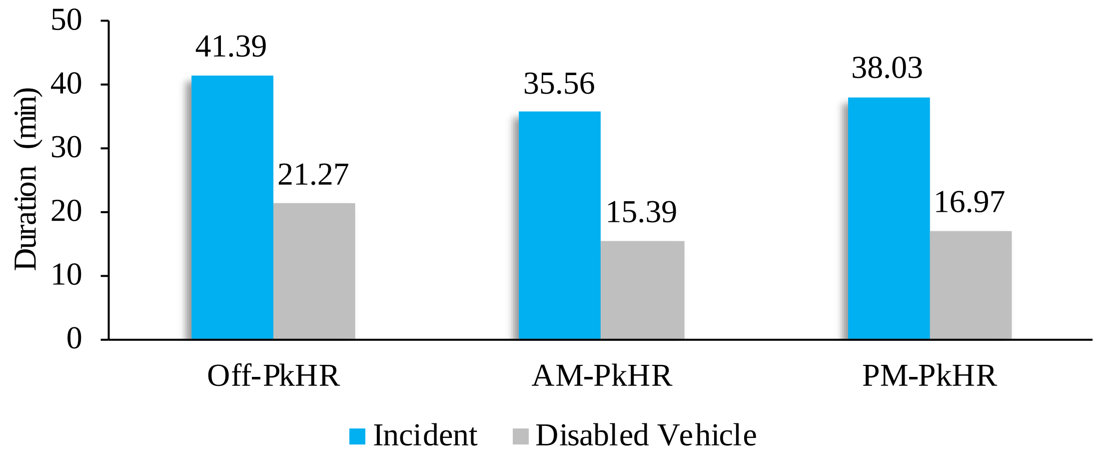
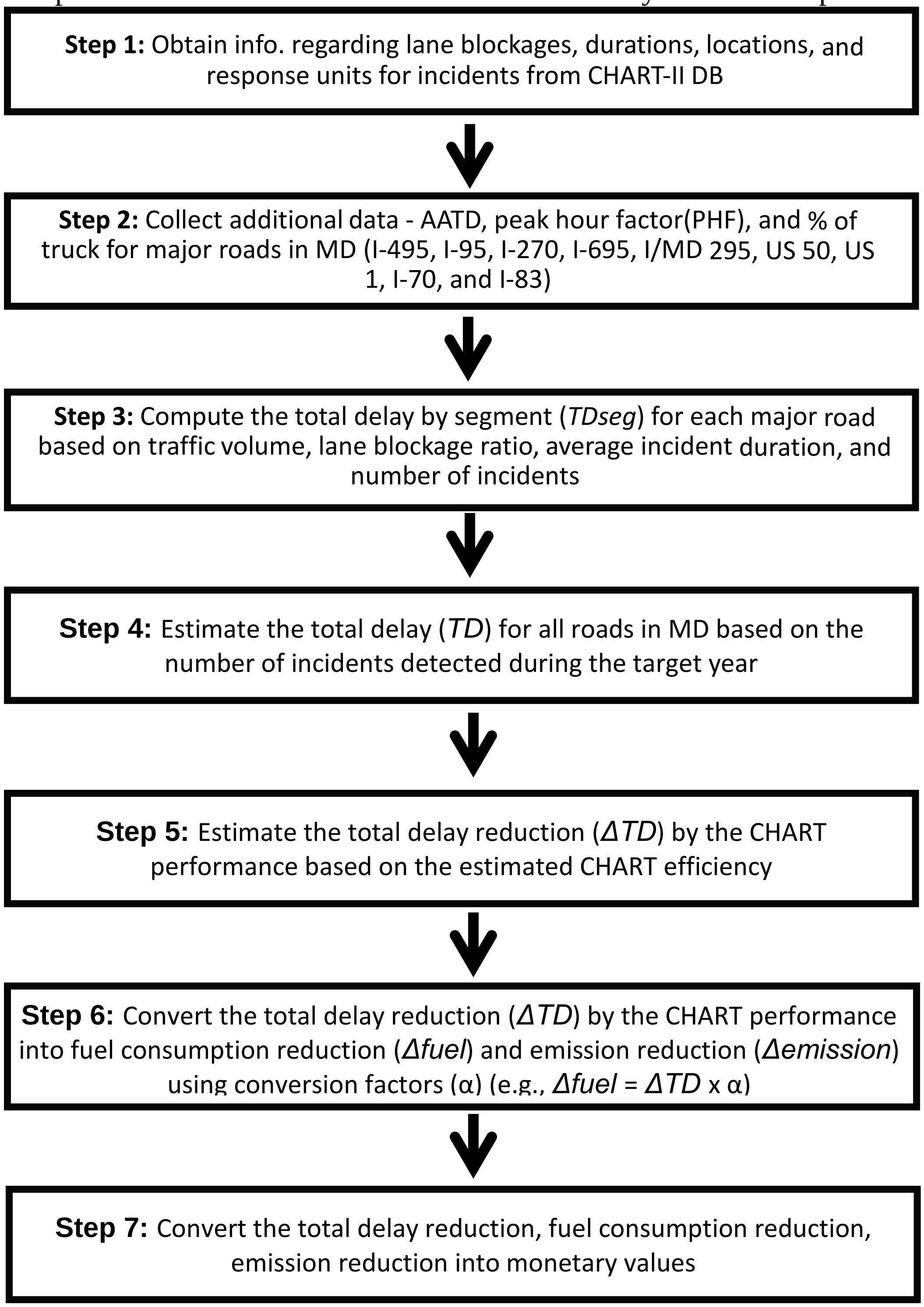


Figure A.16 Distribution of Incident Duration by Time of Day on I-83 in Year 2015

APPENDIX B - Benefit Estimation Procedure and Sensitivity Analysis

➢ The procedure to estimate the total benefit induced by the CHART performance



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