Year 2020

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Performance Evaluation and Benefit Analysis For CHART

– Coordinated Highways Action Response Team –

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MARYLAND DEPARTMENT OF TRANSPORTATION
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Performance Evaluation of CHART

The Real-Time Incident Management System (Year 2020)

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EXECUTIVE SUMMARY

Objectives

This report presents the performance evaluation study of the Coordinated Highways Action Response Team (CHART) for 2020, including its operational efficiency and resulting benefits. The research team at the Department of Civil Engineering at the University of Maryland, College Park (UM), has conducted the annual CHART performance analysis over the past twenty-three years for the Maryland Department of Transportation State Highway Administration (MDOT SHA).

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 a 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 2020 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 MDOT SHA, 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 because of the Statewide Operations Center's (SOC) opening 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, UM (Chang and Point-Du- Jour, 1998) was contracted to work jointly with MDOT SHA staff to collect, and subsequently, research items 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 collected all previous performance records for a scrupulous evaluation.

The 1997 CHART performance evaluation had the advantage of possessing 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 increased considerably since 1999. These results reflect the need to keep an extensive operational record in order to justify CHART's 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 34,590 in 2020.

Table E.1 shows the total number of emergency response operations assiduously documented from 2016 to 2020.

Table E.1 Summary of the Total Number of Emergency Responses from 2016 to 2020

	2016	2017	2018	2019	2020	Δ (2020-2019)
Incidents Only	37,566 (30,314)	37,100 (30,335)	41,247 (34,692)	38,383 (31,750)	34,590 (26,702)	-9.88% (-15.90%)
Total *	81,853 (72,362)	81,299 (72,381)	88,138 (79,956)	79,506 (71,233)	70,115 (60,665)	-11.81% (-14.84%)

**Note: 1. Total includes incidents and disabled vehicles (i.e., assists to drivers).*

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

It should be noted that CHART has responded to fewer incidents this year than in the past four years. This may be due to a decrease in networkwide incidents.

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. Assessing the quality of available data and using only reliable data in the benefit analysis is imperative. Therefore, since 1999, the performance evaluation reports have included data quality analysis, ensuring continued advancement in the quality of incident- related data so as to reliably estimate all potential benefits of CHART operations.

Since February 2001, all incidents requesting emergency assistance have been recorded in the CHART-II information system, regardless of CHART's involvement. 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 with the exception of incident-location-related information, which remains documented in a text format that cannot be processed automatically with a data analysis program.

Distribution of Incidents/Disabled Vehicles

The evaluation methodology was created to use all available data sets possessing 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 2020 incident data results indicate that there were 3,221 incidents resulting in a one-lane blockage, 8,205 incidents causing two-lane closures, and 5,111 incidents blocking three or more lanes. In addition, either disabled vehicles or minor incidents caused a total of 41,409 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

	2016	2017	2018	2019	2020	Δ (2020-2019)
Shoulder[2]	50,519	51,115	54,630	48,485	41,409	-14.59%
1 lane	3,962	3,727	3,948	3,480	3,221	-7.44%
2 lanes[3]	8,746	8,383	9,589	8,823	8,205	-7.00%
3 lanes[3]	3,042	2,859	3,086	2,965	2,780	-6.24%
≥ 4 lanes[3]	2,327	2,114	2,458	2,301	2,331	**1.30%**

**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., two-lane blockage can either be two travel lanes or one travel lane and one shoulder blockage)

Most of these incidents/disabled vehicles were distributed along six major commuting corridors: I-495/95, which experienced a total of 10,339 incidents/disabled vehicles in 2020; and I-695, I-95, US-50, I/MD-295, and I-270, which experienced 8,025, 12,937, 6,942, 2,694, and 4,058 incidents/disabled vehicles, respectively. CHART managed an average of 35 emergency requests per day on I-95 alone, and 28, 22, 18, 7, and 11 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 2016 and 2020 is shown in Table E.3:

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

	2016	2017	2018	2019	2020	Δ (2020 - 2019)
I-495/95	12,168	12,570	11,807	10,589	10,339	-2.36%
I-695	11,029	12,249	11,752	10,705	8,025	-25.04%
I-95	12,751	11,259	15,619	14,729	12,937	-12.17%
US-50	8,077	8,053	7,940	7,208	6,492	-9.93%
I/MD-295	4,217	3,459	3,578	3,152	2,694	-14.53%
I-270	5,087	4,998	5,086	4,892	4,058	-17.05%

** This analysis is based on incidents and disabled vehicles having the information of their event locations recorded in the database.*

Freeway segments experiencing most incidents and disabled vehicle assists during the AM and PM peak hours in 2020 are shown in Table E.4. The highest frequency of incidents occurred on the I-95 southbound segment between Exits 56 and 57, and the I-95 northbound segment between Exits 55 and 56 in AM and PM peaks, respectively. The northbound segment on I-95 between Exits 67 and 74 ranked the first with the respect to the number of disabled vehicle requests in 2020 in both AM and PM peak hours.

Table E.4 Top 10 Freeway Segments with the Most Incidents/Disabled Vehicles in 2020

	Incidents				Disabled vehicles			
	AM Peak		PM Peak		AM Peak		PM Peak	
1	I-95 S	Exit 56&57	I-95 N	Exit 55&56	I-95 N	Exit 67&74	I-95 N	Exit 67&74
2	I-695 IL	Exit 43&44	I-95 N	Exit 67&74	I-95 S	Exit 67&74	I-95 N	Exit 61&62
3	I-95 N	Exit 55&56	I-95 S	Exit 56&57	I-495 IL	Exit 13&15	US 50 W	Exit 16&21
4	I-495 OL	Exit 27&28	I-695 IL	Exit 11&12	I-495 IL	Exit 7&9	I-95 S	Exit 67&74
5	I-95 S	Exit 67&74	I-695 IL	Exit 43&44	I-495 OL	Exit 27&28	I-495 OL	Exit 9&11
6	I-95 S	Exit 93&100	I-95 N	Exit 64&67	I-495 IL	Exit 9&11	I-695 IL	Exit 17&18
7	I-95 N	Exit 89&93	I-95 N	Exit 74&77	US 50 W	Exit 32&37	I-695 OL	Exit 17&18
8	I-95 S	Exit 58&59	I-95 S	Exit 49&50	I-95 S	Exit 56&57	I-95 N	Exit 55&56
9	I-495 OL	Exit 29&30	I-495 IL	Exit 33&34	I-495 IL	Exit 22&23	US 50 E	Exit 16&21
10	I-95 N	Exit 100&109	I-95 S	Exit 67&74	I-495 OL	Exit 30&31	I-495 IL	Exit 33&34

** This analysis is based on incidents and disabled vehicles having the information of their event locations recorded in the database.*

It should be mentioned that most incidents/disabled vehicles on major commuting freeways did not block traffic for more than one hour. For instance, about 73% of incidents/disabled vehicles had durations shorter than 30 minutes in 2020. This observation can be attributed to the nature of the incidents and, more probably, to the efficient response of CHART. The distributions of incidents/disabled vehicle duration from 2016 to 2020 are summarized in Table E.5:

Table E.5 Distribution* of Incidents/Disabled Vehicle Duration from 2016 to 2020

Duration(Hrs)	2016	2017	2018	2019	2020
D < 0.5	75%	76%	74%	73%	73%
0.5 ≤ D < 1	14%	14%	15%	16%	15%
1 ≤ D < 2	6%	6%	6%	7%	7%
2 ≤ D	5%	4%	5%	5%	5%

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

In brief, it is apparent that the highway networks served by CHART are 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 major commuting highway corridors like 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. MDOT SHA 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.6 shows the average response times of 12.17, 12.98, 11.42, 14.32, and 9.03 minutes for TOC-3, TOC-4, TOC-7, SOC and AOC, respectively, in 2020. This table also shows that TOC-3 and TOC-4 provided more prompt response services in 2020 than in 2019. In addition, TOC-4 and TOC-7 demonstrated faster responses during their operational hours than non-operational hours. Note that incidents/disabled vehicles included in this analysis were responded to by various units, including CHART and non-CHART agencies:

Table E.6 Evolution of Response Times* by Center from 2016 to 2020

Response Time (mins)	2016	2017	2018	2019	2020		
					During OH	After OH	Overall
TOC-3	13.05	12.33	13.00	12.99	12.18 (4,734)	10.31 (32)	12.17 (4,766)
TOC-4	12.49	13.17	14.01	13.40	12.97 (4,916)	14.39 (39)	12.98 (4,955)
TOC-7	10.88	10.24	11.46	11.38	11.39 (2,635)	13.18 (48)	11.42 (2,683)
ESTO	7.89	6.95	7.12	6.84	N/A	N/A	N/A
SOC	13.65	13.34	13.78	13.93	14.32 (4,684)	N/A	14.32 (4,684)
AOC	7.23	7.66	8.74	8.99	9.03 (8,066)	N/A	9.03 (8,066)
OTHER	5.24	6.84	8.91	11.68	N/A	2.53 (1)	2.53 (1)
Weighted Average	**11.69**	**11.44**	**11.99**	**11.88**	**11.64 (25,035)**	**12.72 (120)**	**11.64 (25,155)**

** Note: 1. This analysis is based on the data of incidents and disabled vehicles (i.e., assists to drivers) that have indicated the responsible operation center and response times.*

2. This analysis includes those sample data that 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 police, private towing companies, etc.

4. OH stands for Operational Hours: TOCs operate 5 a.m. – 9 p.m. Monday through Friday. TOC-3 and TOC-4 began operating seven days a week (5 a.m. - 9 p.m.) as of August 30th, 2017. SOC and AOC operate on a 24 hour/seven-day-a-week basis.

5. The number in each parenthesis indicates the available samples with acceptable quality for analysis.

6. ESTO's response records are absorbed by SOC as of Oct 6th, 2019.

Table E.7 shows that incidents receive more prompt response times than disabled vehicles during both operational and non-operational hours.

Table E.7 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	12.40 (3,256)	12.70 (1,487)	12.28 (25)	4.93 (6)	12.40 (3,281)	12.67 (1,493)	12.48 (4,774)
TOC-4	12.91 (3,569)	16.63 (1,414)	14.01 (36)	17.96 (7)	12.92 (3,605)	16.64 (1,421)	13.97 (5,026)
TOC-7	11.69 (2,028)	12.48 (593)	12.19 (38)	16.68 (12)	11.69 (2,066)	12.56 (605)	11.89 (2,671)
SOC	14.64 (3,020)	19.11 (1,337)	N/A	N/A	14.64 (3,020)	19.11 (1,337)	16.01 (4,357)
AOC	7.24 (5,371)	12.04 (2,387)	N/A	N/A	7.24 (5,371)	12.04 (2,387)	8.71 (7,758)
OTHER	N/A	N/A	2.99 (2)	N/A	2.99 (2)	N/A	2.99 (2)
Weighted Average	**11.21 (17,244)**	**14.42 (7,218)**	**12.68 (101)**	**14.22 (25)**	**11.22 (17,345)**	**14.42 (7,243)**	**12.16 (24,588)**

** Note: 1. This analysis is based on the dataset of incidents and disabled vehicles (assistance to drivers) that have indicated responsible operation center and response times.*

2. This analysis includes those sample data that have CHART response times between 1 minute and 60 minutes.

3. Events included in this analysis were responded by CHART.

4. OH stands for Operational Hours: TOCs operate 5 a.m. – 9 p.m. Monday through Friday. TOC-3 and TOC-4 began operating seven days a week (5 a.m. - 9 p.m.) as of August 30, 2017. SOC and AOC operate on a 24 hour/seven-day-a-week basis.

5. The number in each parenthesis indicates the data availability.

The 2020 data also 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.

Analysis of Incident Durations

To better understand the contributions of the incident management program, the study compared the average duration of incidents responded by CHART and those managed by other agencies. For example, the difference in average response times for one-lane-blockage incidents with and without CHART involvement is about 12.37 minutes.

The duration of incidents managed by CHART response units averaged 25.35 minutes, shorter than the average duration of 37.02 minutes for incidents managed by other agencies. On average, CHART operations in 2020 reduced the average incident duration by about 31.5%.

Performance improvement of CHART operations from years 2016 to 2020 is summarized in Table E.8:

Table E.8 Comparison of Average Incident Duration* with and without CHART Response

Year	With CHART (mins)	Without CHART (mins)
2016	24.06	35.52
2017	24.01	34.88
2018	25.42	33.08
2019	25.75	33.91
2020	25.35	37.02

** Note: 1. This analysis is based on incident records which have included the information of event duration, lane blockage, and response units.*

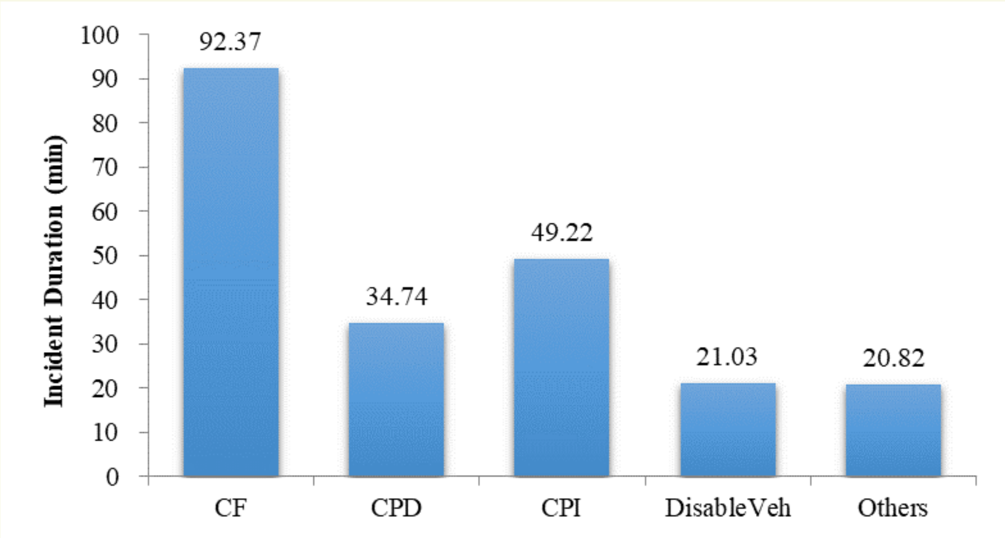
2. This analysis includes those sample events which have incident durations between 1 minute and 120 minutes.

3. The numbers are the weighted average of incidents with different lane blockages, including shoulder only blockage.

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 insight 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 92 minutes, while incidents with property damage (CPD) and personal injuries (CPI) lasted, on average, 35 and 49 minutes, respectively (see Figure E.1). The average duration of disabled vehicle incidents was 21 minutes, similar to those classified as “Others” (e.g., debris, vehicles on fire, police activities, etc.).



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

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

Figure E.1 Distribution of Average Incident Duration by Nature in 2020

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 2020, CHART responded to a total of 34,590 lane blockage incidents and assisted 35,525 highway drivers who may otherwise have caused incidents or rubbernecking delays to highway traffic. In addition, the efficient removal of stationary vehicles and large debris from travel lanes by CHART patrol units may have prevented 800 potential lane-changing-related collisions in 2020, 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. 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 2020 several primary factors, such as AADT and the number of incident responses, have noticeably decreased compared with 2019 because of the COVID-19 pandemic, while other factors such as truck percentage and incident duration difference with and without CHART have increased. The reduction in delay due to CHART's services in 2020 (23.52 million vehicle hours) decreased by 28% in comparison with the performance in 2019 (32.58 million vehicle-hours). Such reduction consequently results in a decrease of the total benefits by approximately 22%, from \$1,393.38 M to \$1,080.83 M. A comparison of the direct benefits from reduced delay times, fuel consumption, and emissions from 2016 to 2020 is summarized in Table E.9:

Table E.9 Comparison of Direct Benefits from 2016 to 2020

	Total Direct Benefits (million)[1,2,3,4]	# of Incidents Eligible for the Benefit Estimate[5]
2016	$1,511.97	31,172
2017	$1,465.62	29,986
2018	$1,311.89	33,243
2019	$1.393.38	30,793
2020	$1,080.83	28,513

** 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 consumption, 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).

Most benefits were produced by delay reductions due to CHART's efficient incident response and management, especially along the major corridors that are the primary contributors to traffic congestion in Maryland. The estimated delay reduction due to CHART's services on I-95, I-495, I-270, I-695, I-70, and I-83 are 4.61, 3.29, 1.04, 3.46, 1.50, and 0.45 million vehicle-hours, respectively, in 2020. Such direct benefits for each major road in 2020 are summarized in Table E.10:

Table E.10 Direct Benefits for Major Roads in 2020 due to CHART Operations

Roads	Total Direct Benefits (million)[1,2,3]	# of Incidents Eligible for the Benefit Estimate
I-95	$219.43	4,976
I-495/95	$154.22	3,310
I-270	$47.62	975
I-695	$159.13	3,297
I-70	$70.56	1,404
I-83	$21.00	662
Others	$408.87	13,889
Total	$1,080.83	28,513

** 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 in car/truck delay times, fuel consumption, and emissions due to the CHART effective operations.

3. *The direct benefits vary with some key factors, including traffic and heavy vehicle volumes, the number of lane blockages, the number of incidents responded, and incident durations.*

4.*The direct benefits are estimated only based on the incidents causing travel lane closure(s).*

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

- The total number of eligible incidents for the benefit estimate decreased by about 7.40% from 2019 to 2020, as shown in Table E.11.
- The ratio reflecting the difference between incident duration with CHART and those without CHART increased from 22.49% in 2019 to 28.41% in 2020, as shown in Table E.12.
- Table E.13 shows that the adjusted AADT with peak hour factors in 2020 for major roads in Maryland compared with 2019 generally decreased by 18.30%.
- As shown in Table E.14, truck percentage on major corridors in 2020 increased by 26.49%.

Table E.11 The Total Number of Incidents Eligible for the Benefit Estimate

	2019	2020	Δ('19 ~ '20)
No. of Incidents	30,793	28,513	***-7.40%***

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 2019 to 2020 is calculated as follows: $\Delta\mathbf{X}(\%) = \frac{X_{2020}-X_{2019}}{X_{2019}} \times 100$

Table E.12 Incident Duration Reduction in 2019 and 2020

	With CHART(mins) (A)	Without CHART(mins) (B)	Difference(mins) (B-A)	Ratio in Difference ((B-A)/B)
2019	27.67	35.70	8.03	***22.49%***
2020	27.06	37.80	10.74	***28.41%***
Δ('19 ~ '20) *	-2.20%	0.25%	33.73%	***26.30%***

Note: 1. The analysis is based on incidents that have main lanes blockage.
2.The percentage change in incident duration (X) from 2019 to 2020 is calculated as follows: $\Delta\mathbf{X}(\%) = \frac{X_{2020}-X_{2019}}{X_{2019}} \times 100$

Table E.13 The Adjusted AADT (with Peak Hour Factor) for Major Roads from 2019 to 2020

	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	**2019**	12,967	8,614	7,444	11,336	4,369	2,499	4,807	2,866	3,489	***58,391***
	2020	10,502	6,827	6,127	9,316	3,600	2,082	4,115	2,293	2,843	***47,706***
Δ('19 ~ '20) (%)*		-19%	-21%	-18%	-18%	-18%	-17%	-14%	-20%	-19%	***-18.30%***

Note: The percentage change in the adjusted AADT(X) from 2019 to 2020 is calculated as follows: $\Delta\mathbf{X}(\%) = \frac{X_{2020}-X_{2019}}{X_{2019}} \times 100$

Table E.14 Truck Percentage for Major Roads from 2019 to 2020

	Year	I-495	I-95	I-270	I-695	MD 295	US 50	US 1	I-83	I-70	Average
Truck %	**2019**	7.12	12.46	5.25	6.63	2.56	9.06	4.08	7.03	8.24	***6.94***
	2020	9.08	15.62	6.96	8.32	3.03	9.82	4.85	10.54	10.73	***8.77***
Δ('19 ~ '20)(%)*		27.5%	25.4%	32.5%	25.6%	18.4%	8.4%	18.9%	49.9%	30.2%	***26.49%***

Note: The percentage change in the truck percentage from 2019 to 2020 is calculated as follows: $\Delta\mathbf{X}(\%) = \frac{X_{2020}-X_{2019}}{X_{2019}} \times 100$

The following procedures are used for performing the below 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 2020 value, but setting all other factors identical to those in 2019; and
- following the same procedures to analyze the sensitivity of the total 2020 benefits with respect to each key factor.

The results of sensitivity analysis for each factor are shown in the Table E.15. The decrease in the average adjusted AADT by 18.30% in 2020 contributed to a decrease of 43.98% in the total benefit while the 26.49% increase in truck percentage resulted in an increase of 0.83% in the benefit. The number of eligible incidents decreased by 7.40% in 2020, resulting in the benefit decrease of 5.17%. Note that the increasing ratio of the performance difference between incident durations with CHART and those without CHART by 26.30% resulted in a 26.30% increase in the total benefit. The total benefits increase by 6.69% was due solely to the increase of 6.49% in drivers' income (i.e., a proxy for time value).

Table E.15 Sensitivity Analysis of Key Factors Contributing to the Benefits (Unit: M dollar)

Benefit of the Previous Year (2019)			**1,393.38**
Key Factor		**Δ ('19 - '20)**	**Estimated Benefit**
Sensitivity Analysis	**Adjusted AADT**	▼18.30%	780.55 (▼43.98%)
	Number of incidents	▼7.40%	1,321.41 (▼5.17%)
	Incident duration difference between w/ and w/o CHART	▲26.30%	1,759.79 (▲26.30%)
	Truck percentage	▲26.49%	1,404.98 (▲0.83%)
	Monetary unit of gas price	▼16.12%	1,390.64 (▼0.20%)
	Monetary unit value of time	▲6.49%	1,486.62 (▲6.69%)
Benefit of the Current Year (2020)			**1,080.83** (▼22.43%)

** The number in each parenthesis shows the percentage of benefit change from year 2019.*

Conclusions and Recommendations

Grounded on the lessons from the earlier studies, this study has conducted a rigorous evaluation of CHART's performance in 2020 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 2020 was 11.64 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 2020, are listed below:

- Increase the resources for CHART to sustain the high-quality incident response operation, including more staff and hardware supports.
- Provide constant training to staff in the control center responsible for recording incident-related information to ensure 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 for such roadways in the annual CHART review.
- Make CHART's data quality evaluation report available to the centers' operators for their 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 need of employing 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.
- Extend the CHART analysis model to investigate the relationship between the incident duration and the probability of incurring secondaries incidents.
- Incorporate the delay and fuel consumption benefits from the reduced potential secondary incidents in the CHART benefit evaluation.

Summary of Key Findings from the 2020 CHART Performance Evaluation

- Both the number of statewide emergency responses and CHART responses decreased significantly (about 11.81% and 14.84%) from 2019 to 2020, due likely to the impact of the COVID-19 pandemic. CHART responded to 14.84% less events in 2020 than in 2019.
- The average response time was shorter in 2020 compared to that in 2019, especially for TOC-3 and TOC-4.
- In 2020, the average incident duration with CHART was 25.35 minutes, shorter than the average of 37.02 minutes for those incidents responded by other agencies. The reduction in the average incident duration is about 32%. The average incident duration with CHART of 25.35 minutes was shorter than that in 2019 (i.e., 25.75 minutes).
- Despite the reduction of about 15% in shoulder lane blockages in 2020, those incidents blocking multiple travels lanes exhibited less significant decrease even under the substantially lower traffic volumes due to the COVID-19 pandemic. In fact, 2020 records show a slight increase in incidents blocking 4+ lanes, compared to 2019.
- Among major corridors, I-695 experienced the most significant reduction in its incidents/disabled vehicles frequency in 2020, compared to 2019 (about 25%); the total incidents/disabled vehicles frequency on I-495/I-95 is at the same level as in 2019.
- The total benefit of CHART operation decreased by 22.43%, mainly due to the significant reduction (18.30%) of adjusted AADT in 2020.

The aforementioned changes, along with other factors, collectively contributed to the direct benefits by CHART's performance in 2020.

CHAPTER 1

INTRODUCTION

1 Introduction

CHART (Coordinated Highways Action Response Team)

is the highway incident management system of the Maryland Department of Transportation State Highway Administration **(MDOT SHA).** 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 MDOT SHA 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.

1.1 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 34,590 reports in 2020. A summary of total emergency response operations documented from 2016 to 2020 is presented in Table 1.1.

Table 1.1 Total Number of Emergency Response Operations

Records	2016	2017	2018	2019	2020
Incidents*	37,566 (30,314)	37,100 (30,335)	41,247 (34,692)	38,383 (31,750)	34,590 (26,702)
Disabled Vehicles	44,287 (42,048)	44,199 (42,046)	46,891 (45,264)	41,123 (39,483)	35,525 (33,963)
Total	81,853 (72,362)	81,299 (72,381)	88,138 (79,956)	79,506 (71,233)	70,115 (60,665)

**Note: 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. Numbers in each parenthesis show the incidents and assists by CHART.

INTRODUCTION

1.1

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 MDOT SHA programs from the general public and state policy-makers 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 2019 and 2020, 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/MDOT SHA operations, as well as the reduction in potential accidents due to efficient removal of stationary vehicles in travel lanes by the CHART/MDOT SHA response team.

1.1 INTRODUCTION

The subsequent chapters are structured as follows:

Chapter 2 assesses the quality of data available for the 2020 CHART performance evaluation. This includes the total available incident reports, the percentage of missing data for each critical performance parameter, and a comparison of 2020 data quality with that of 2019.

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.

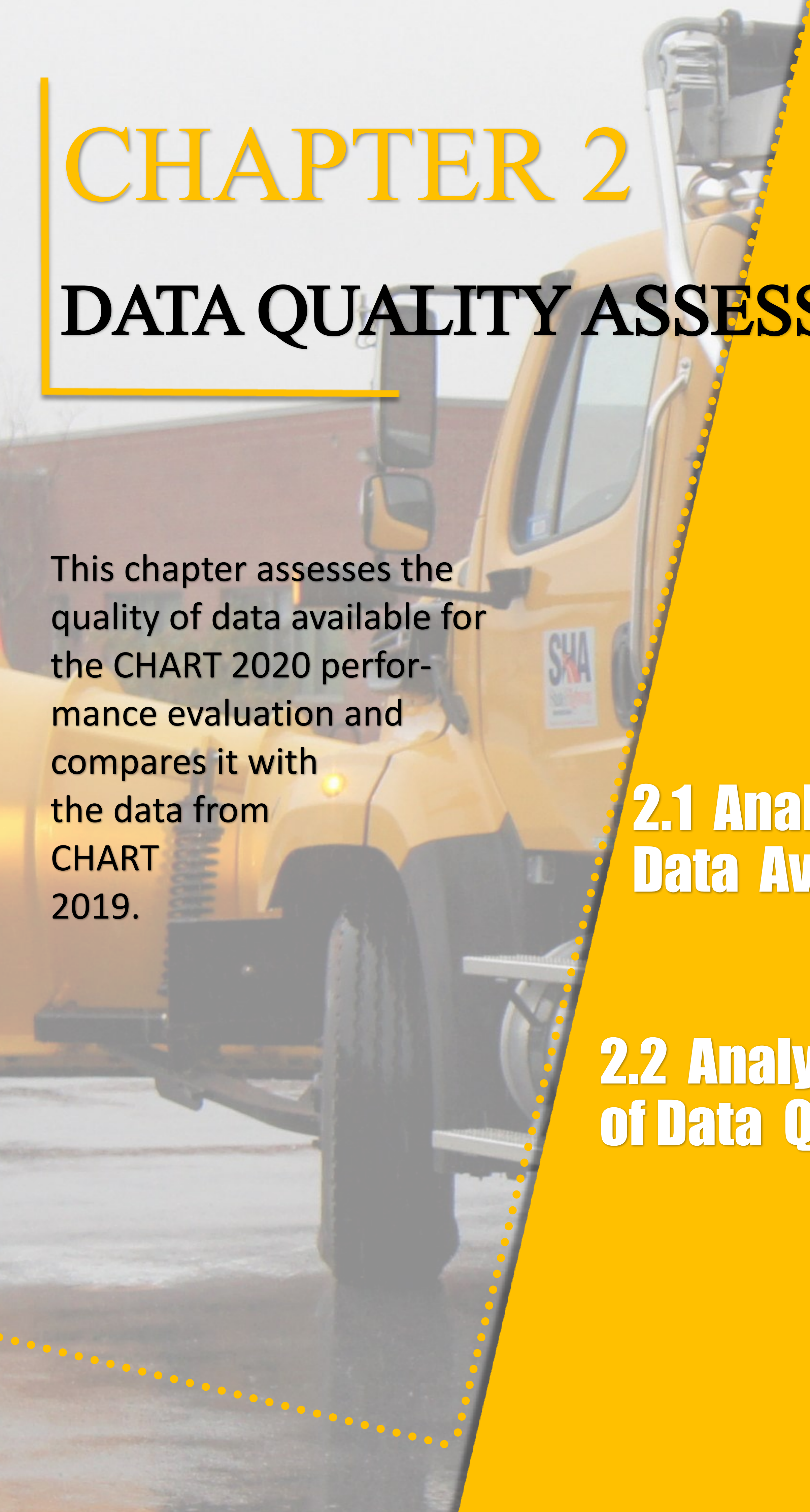
INTRODUCTION 1.1

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 2020 performance evaluation and compares it with the data from CHART 2019.

2.1 Analysis of Data Availability

2.2 Analysis of Data Quality

2

2.1 Analysis of Data Availability

In 2020, CHART recorded a total of 70,115 emergency response cases. These are categorized into two groups: incidents and disabled vehicles. A summary of the total available incident reports for the years 2018, 2019 and 2020 is shown in Table 2.1.

Table 2.1 Comparison of Available Data for 2018, 2019, and 2020

Available Records		2018		2019		2020	
		Records	Ratios (%)	Records	Ratios (%)	Records	Ratios (%)
CHART II Database	Disabled Vehicles	46,891	53.2	41,123	51.7	35,525	50.7
	Incidents	41,247	46.8	38,383	48.3	34,590	49.3
Total		88,138	100	79,506	100	70,115	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 2019 and 2020.

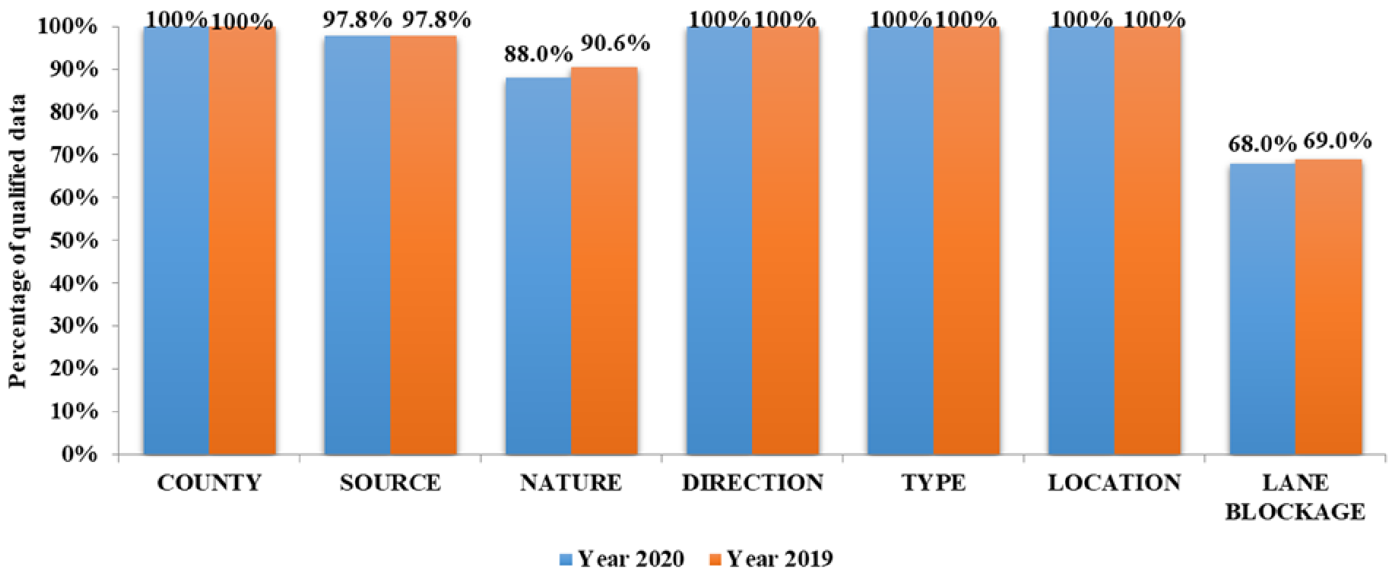


Figure 2.1 Summary of Data Quality for Critical Indicators

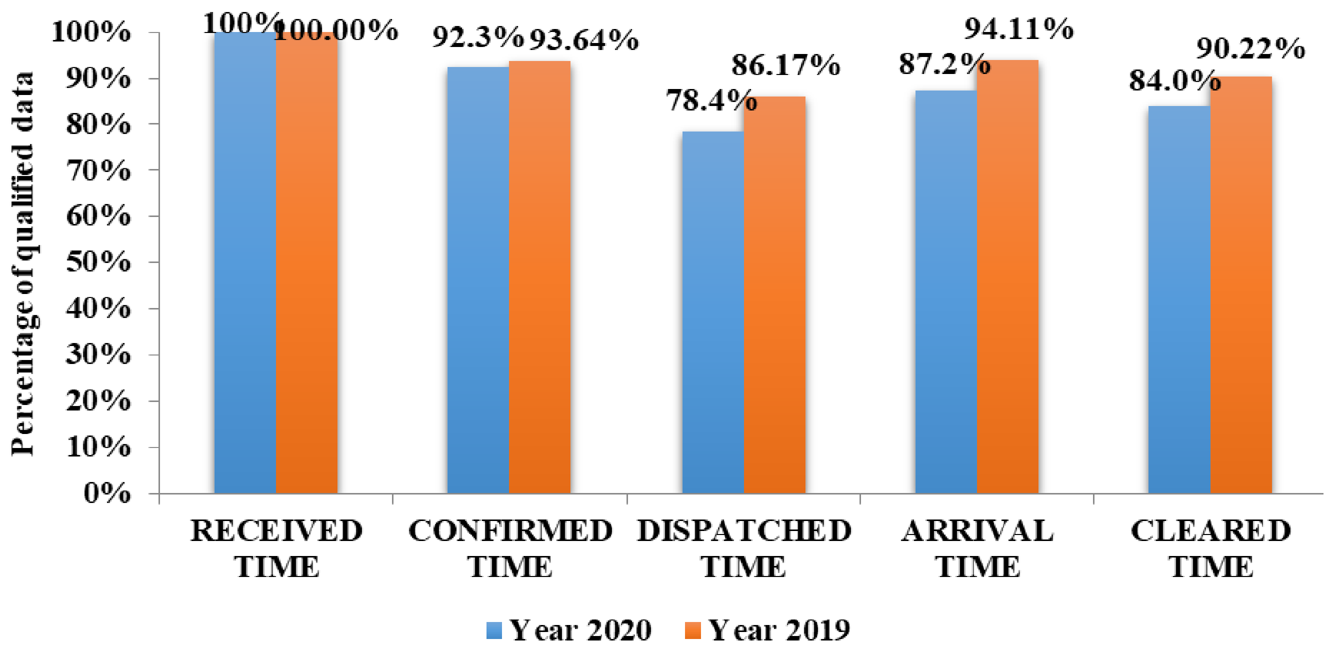


Figure 2.2 Summary of Data Quality for Time Indicators

ANALYSIS OF DATA QUALITY

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 88.0 percent of emergency responses reported in 2020 recorded the nature of incidents/disabled vehicles. Note that the location nature of disabled vehicles has been included in the CHART II database since January 2019.

Detection Sources

As Figure 2.1 shows, about 97.8 percent of all emergency responses recorded in 2020 contained the source of detection, which is almost the same as the previous year's data. In 2020, about 95.9 percent of incidents reported and 99.7 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 2020 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 to around 90 percent 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 2020 is summarized in Table 2.2. Overall, CHART responded to a total of 34,590 incidents in 2020. Over the same period, the response team also attended to 35,525 disabled vehicle requests.

Table 2.2 Emergency Assistance Reported in 2020

Operation Center	TOC3	TOC4	SOC	TOC7	AOC	OTHER	TOTAL
Disabled Vehicles	8,867 (5,092)	6,958 (10,707)	5,847 (10,038)	6,491 (5,897)	7,356 (8,740)	6 (649)	35,525 (41,123)
Incidents	6,243 (4,284)	6,356 (7,771)	8,863 (11,346)	3,977 (4,439)	9,146 (10,216)	5 (327)	34,590 (38,383)
Total	15,110 (9,376)	13,314 (18,478)	14,710 (21,384)	10,468 (10,336)	16,502 (18,956)	11 (976)	70,115 (79,506)

Note: numbers in each parenthesis are the corresponding data from 2019

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

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 2020. Note that about 99.99 percent of data have some information related to the locations (road names and exit numbers) and about 60 percent of them can be used to clearly identify the event sites. For the remaining 40 percent of incidents/disabled vehicles, the location information is either unclear or not specified, and therefore cannot be used for reliable performance analysis.

Table 2.3 Data Quality Analysis with Respect to Road and Location

Data Quality	Incident	Disabled Vehicles	Total
Road	99.18%	99.41%	99.30%
Location	99.99%	99.99%	99.99%
Valid Data for Road & Location	56.29%	63.62%	60.00%

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 2020 shows that up to 67.97 percent of emergency response reports involved lane/shoulder blockage. This value is lower than 69.05 percent in 2019.

In summary, in 2020, 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 80 percent) of incidents/disabled vehicles in 2020 occurred on weekdays. Thus, more resources and personnel are required on weekdays than on weekends to manage the incidents/disabled vehicles more effectively. Note that the percentage of weekend responses by TOC3 and AOC slightly decreased while other centers did not experience any significant change in the distribution of incidents/disabled vehicles by day.

Table 3.1 Distribution of Incidents/Disabled Vehicles by Day

Center	TOC3		TOC4		ESTO		TOC7	
Year	2020	2019	2020	2019	2020	2019	2020	2019
Weekdays	86%	88%	85%	85%	N/A	31%	98%	98%
Weekends	14%	12%	15%	15%	N/A	69%	2%	2%

Center	SOC		AOC		Other		Total	
Year	2020	2019	2020	2019	2020	2019	2020	2019
Weekdays	63%	63%	76%	77%	0%	34%	80%	79%
Weekends	37%	37%	24%	23%	100%	66%	20%	21%

Notes: "Others" includes RAVENS TOC.
In 2020, ESTO and REDSKIN TOC were closed.

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 27 percent of incidents/disabled vehicles reported in 2020 occurred during peak hours, which is slightly lower than the one in 2019.

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

Center	TOC3		TOC4		ESTO		TOC7	
Year	2020	2019	2020	2019	2020	2019	2020	2019
Peak**	33%	35%	32%	38%	N/A	15%	36%	39%
Off-Peak	67%	65%	68%	62%	N/A	85%	64%	61%

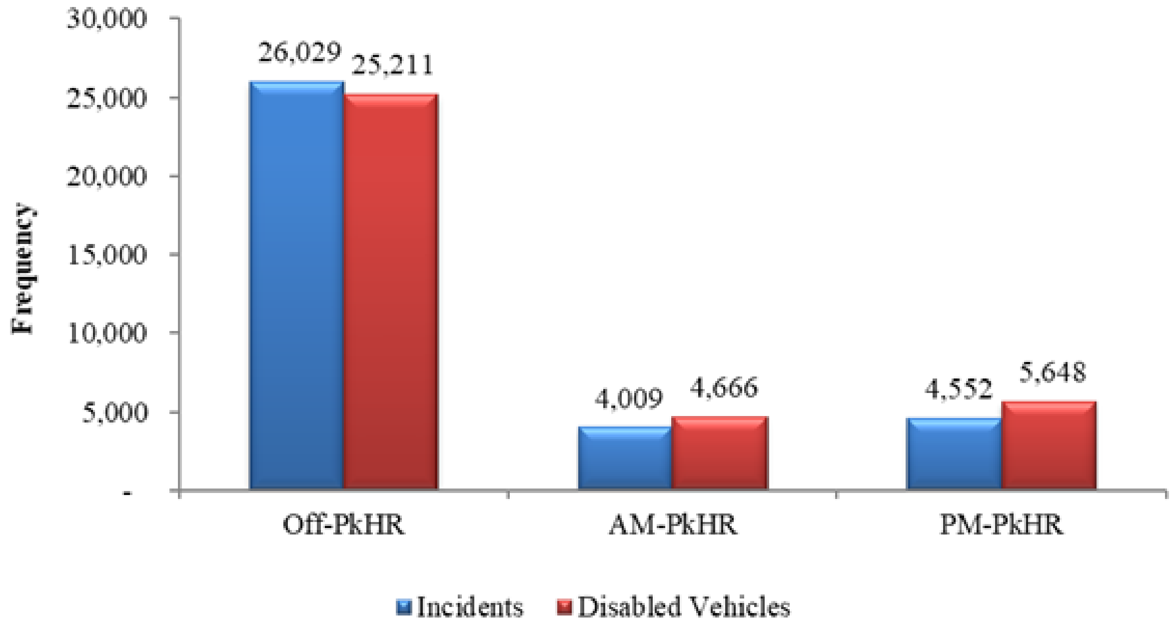
Center	SOC		AOC		Other*		Total	
Year	2020	2019	2020	2019	2020	2019	2020	2019
Peak**	12%	17%	25%	26%	0%	9%	27%	29%
Off-Peak	88%	83%	75%	74%	100%	91%	73%	71%

Notes: "Others" includes RAVENS TOC.
In 2020, ESTO and REDSKIN TOC were closed.
Peak hours: 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.

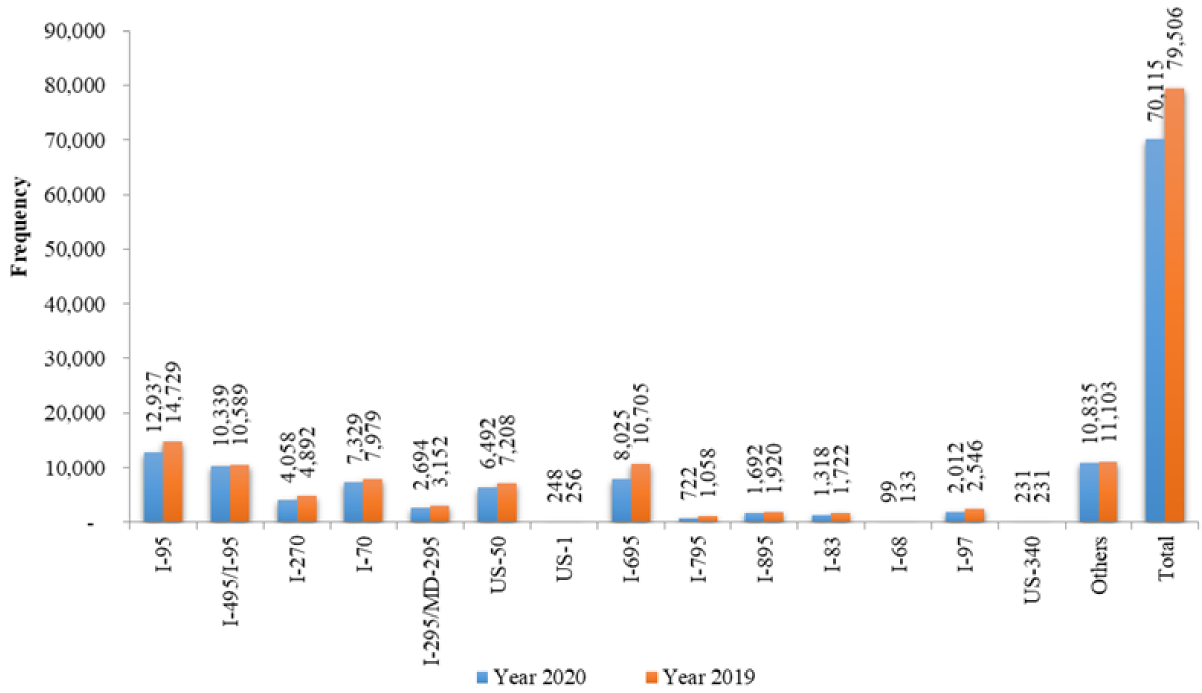


** Off-PkHR, AM-PkHR, and PM-PkHR stand for Off-Peak hours, AM-Peak hours, and PM-Peak hours, respectively.*

Figure 3.1 Distributions of Incidents/Disabled Vehicles by Time of Day in 2020

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

Figure 3.2 compares the frequency distribution among roads between 2020 and 2019, and Figure 3.3 depicts the frequency distribution of incidents and disabled vehicles for 2020.



** "Total" includes incomplete data for road name and direction.*

Figure 3.2 Distributions of Incidents/Disabled Vehicles by Road in 2020 and 2019

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

3.2

Based on the statistics shown below, the roadways with high incident frequencies for 2020 were I-95 (from the Delaware border to the Capital Beltway), I-495/95 (Capital Beltway), I-695 (Baltimore Beltway), I-70, US-50 and I-270. I-95 experienced a total of 12,937 incidents/disabled vehicles in 2020, while I-695 had 8,025 incidents/disabled vehicles within the same period. I-495/95, US-50, I-70 and I-270 had 10,339, 6,492 7,329, and 4,058 incidents/disabled vehicles, respectively. Also, notice that the CHART-II database includes 1,084 incidents/disabled vehicles detected by CHART with incomplete information for road names in 2020.

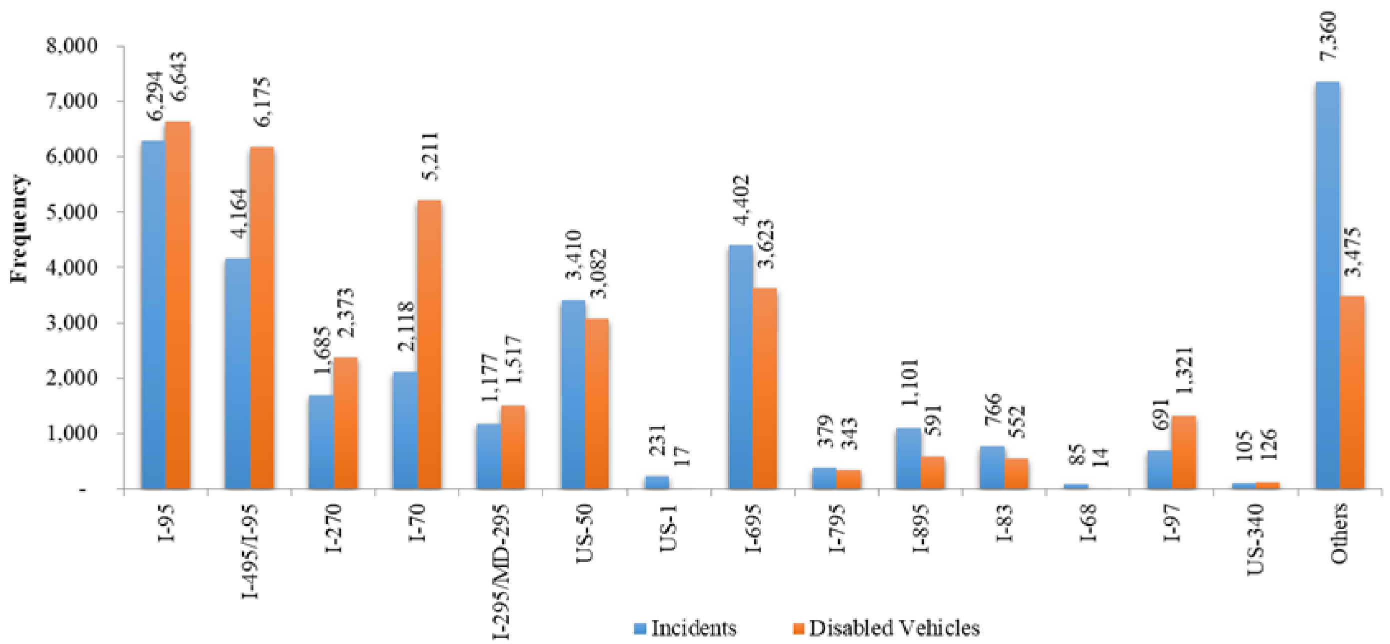


Figure 3.3 Distributions of Incidents/Disabled Vehicles by Road in 2020

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, more incidents occurred during p.m. peak hours than a.m. peak hours on all major roads.

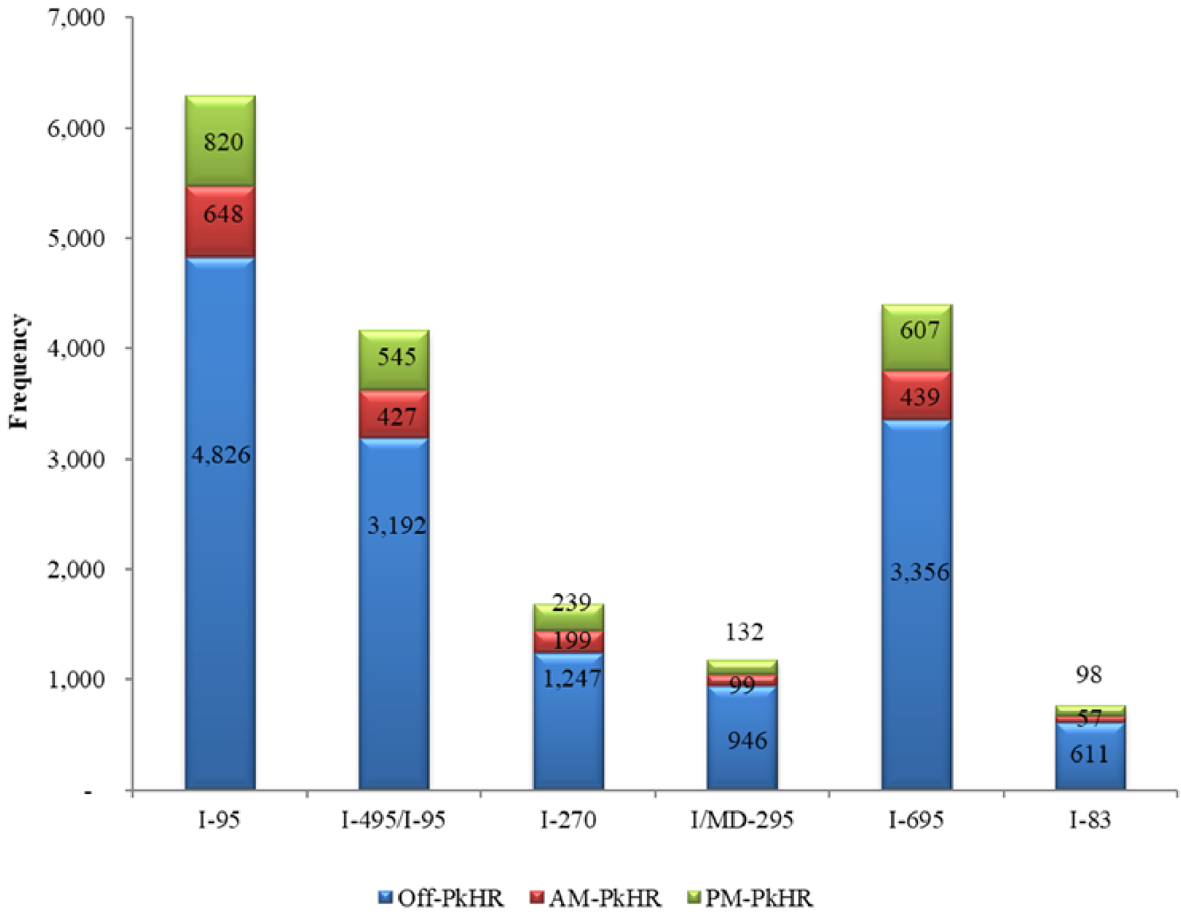


Figure 3.4 Distributions of Incidents by Time of Day on Major Roads in 2020

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 .

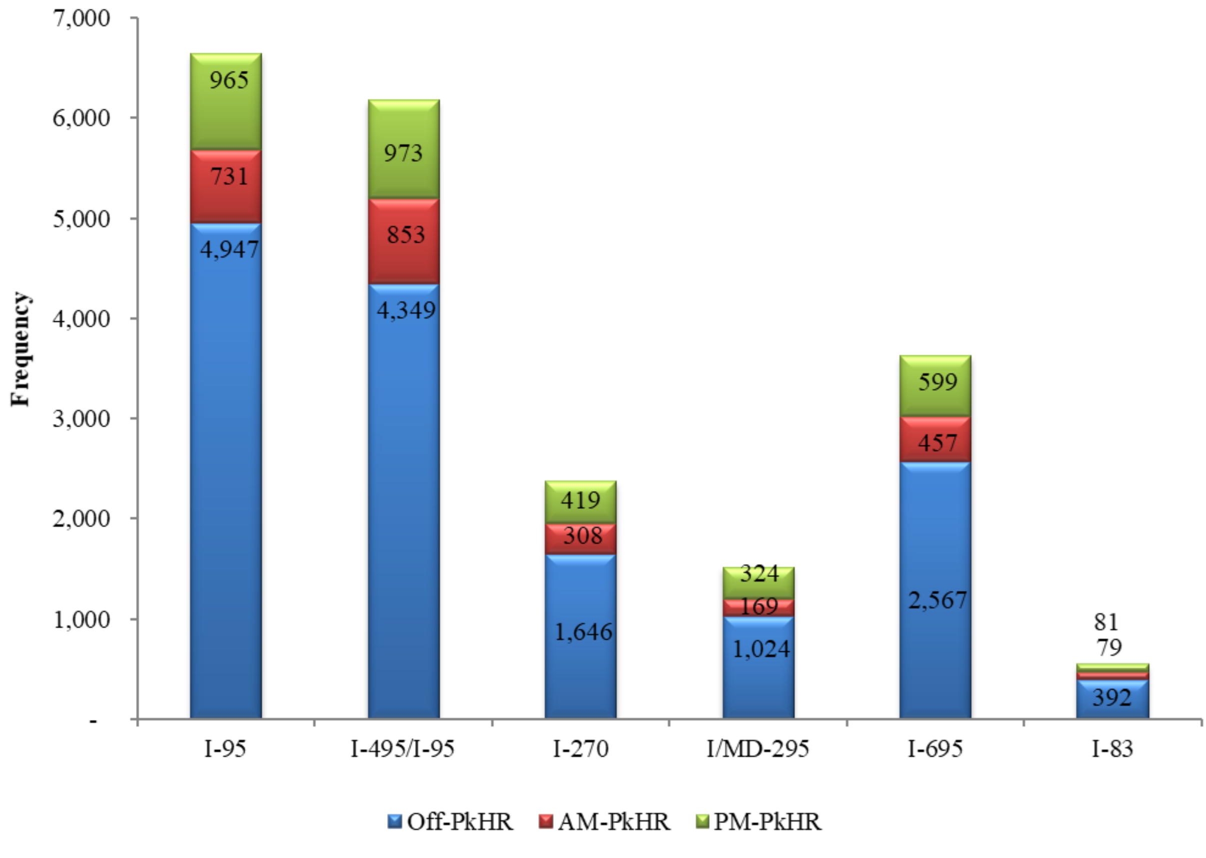


Figure 3.5 Distributions of Disabled Vehicles by Time of Day on Major Roads in 2020

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

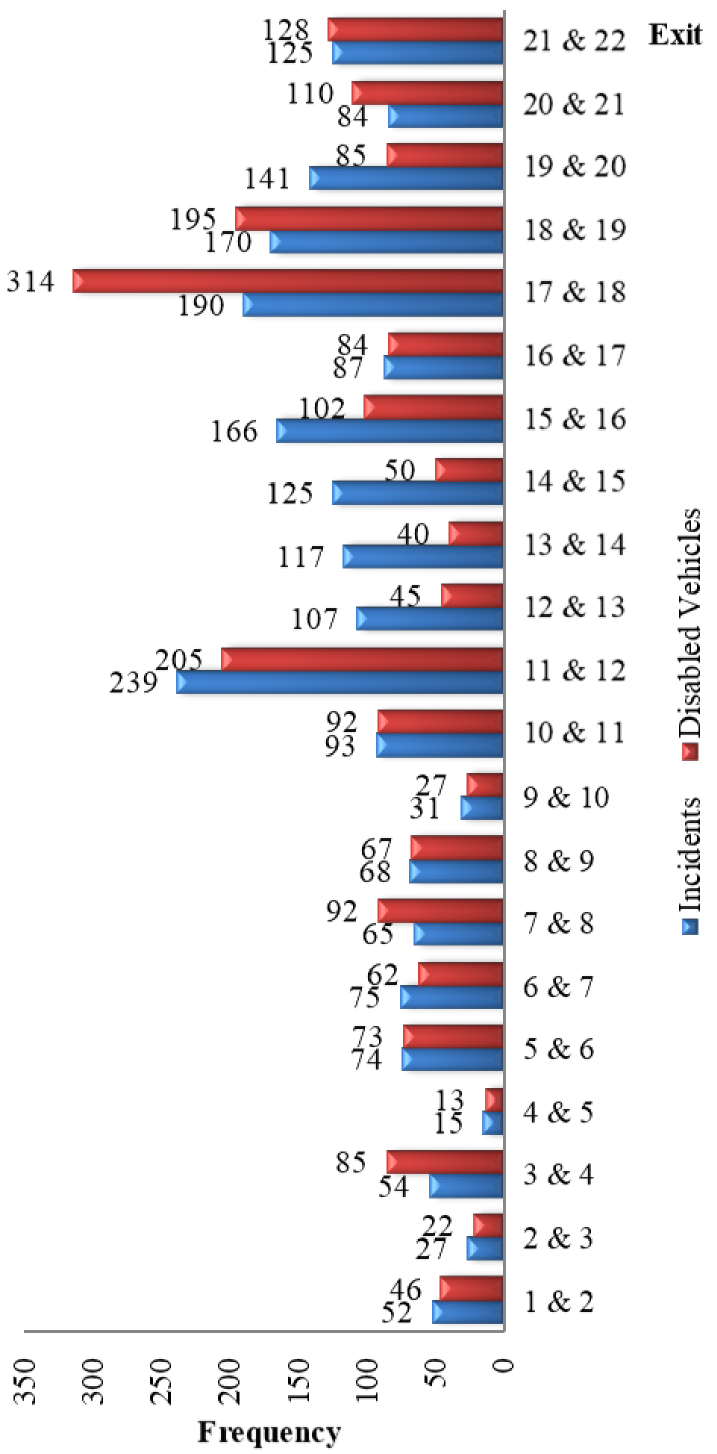


Figure 3.6 Distributions of Incidents/Disabled Vehicles by Location on I-695

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

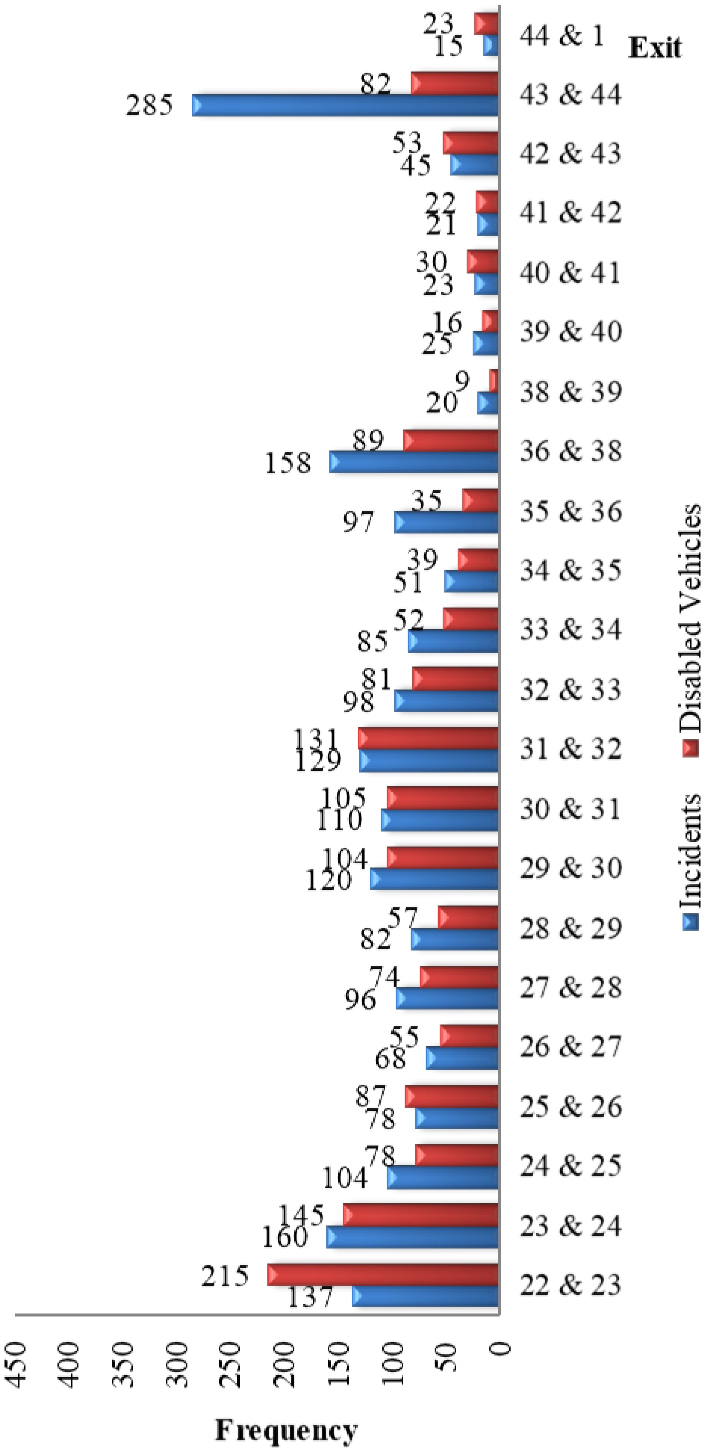


Figure 3.6 Distributions of Incidents/Disabled Vehicles by Location on I-695 (cont.)

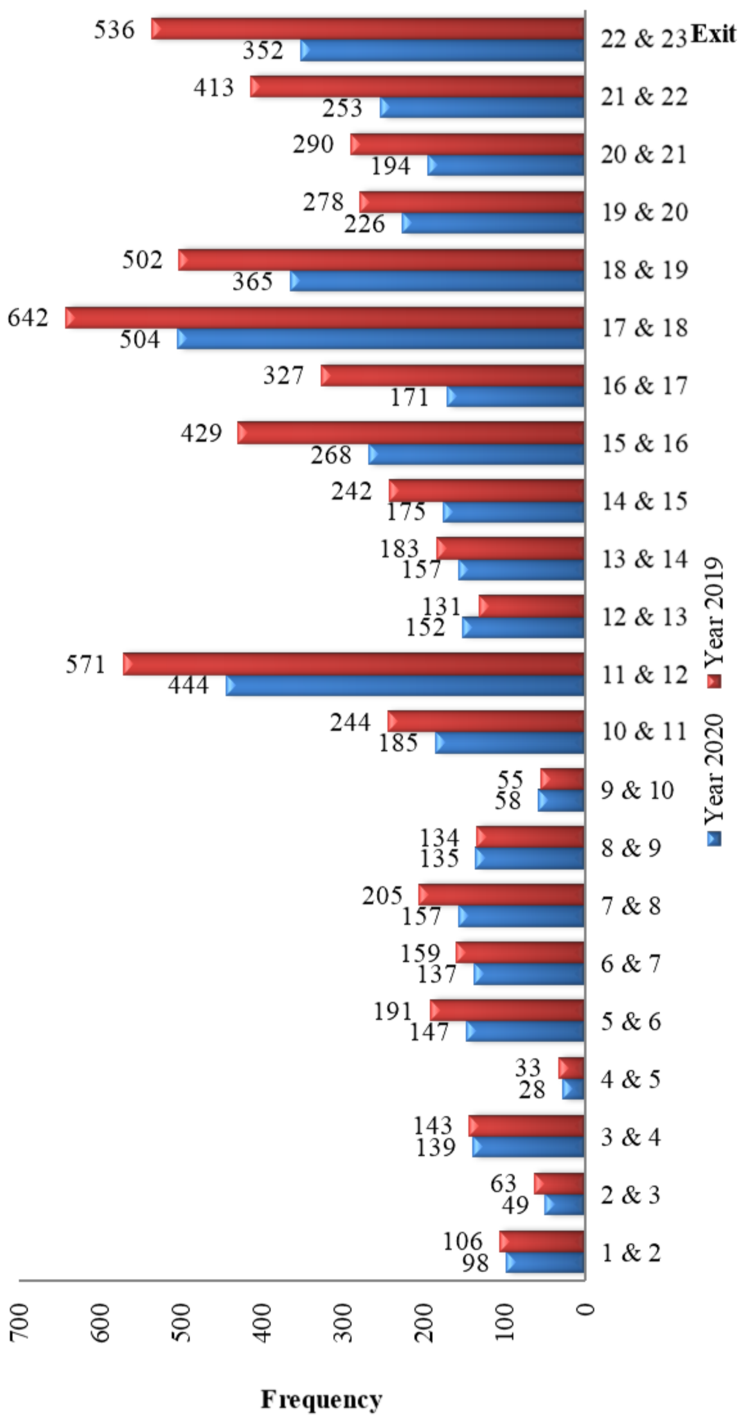


Figure 3.7 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-695

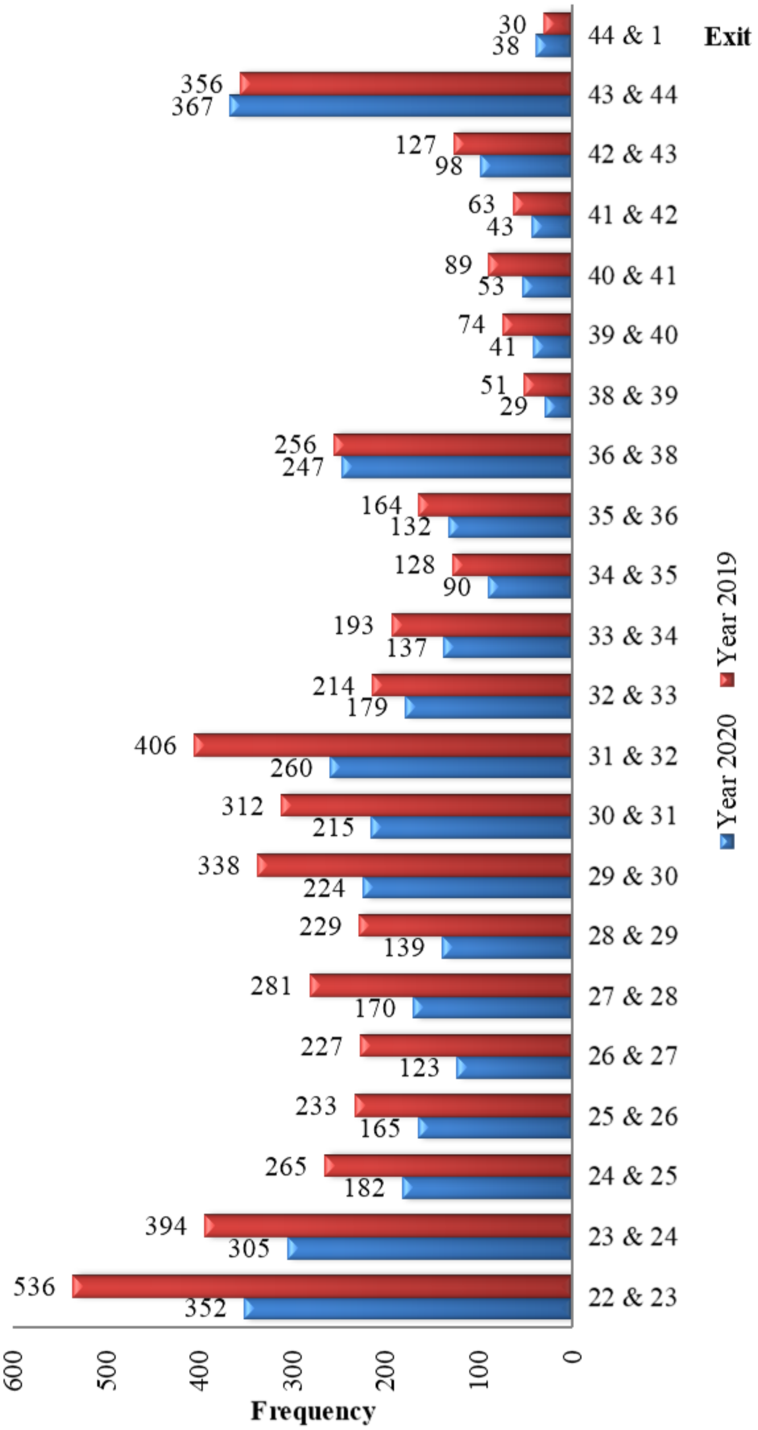


Figure 3.7 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-695 (Cont.)

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 2020, while Figure 3.7 compares these values with the results in 2019. The high-incident segments are from Exits 43 to 44, Exits 11 to 12, and Exit 17 to 18 (285, 239 and 190, respectively). The two high frequencies of disabled vehicles (314 and 215 cases) were recorded on the segments between Exits 17 and 18 and Exits 22 and 23, which are close to the I-70 and I-83 interchanges, respectively.

The subsequent figures present the comparison between 2020 and 2019 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 (267 cases) occurred between Exits 31 and 33 of I-495. The location with the highest frequency of disabled vehicles (380 cases) occurred between Exits 4 and 7. A comparison with the data in 2019 is illustrated in Figure 3.9.

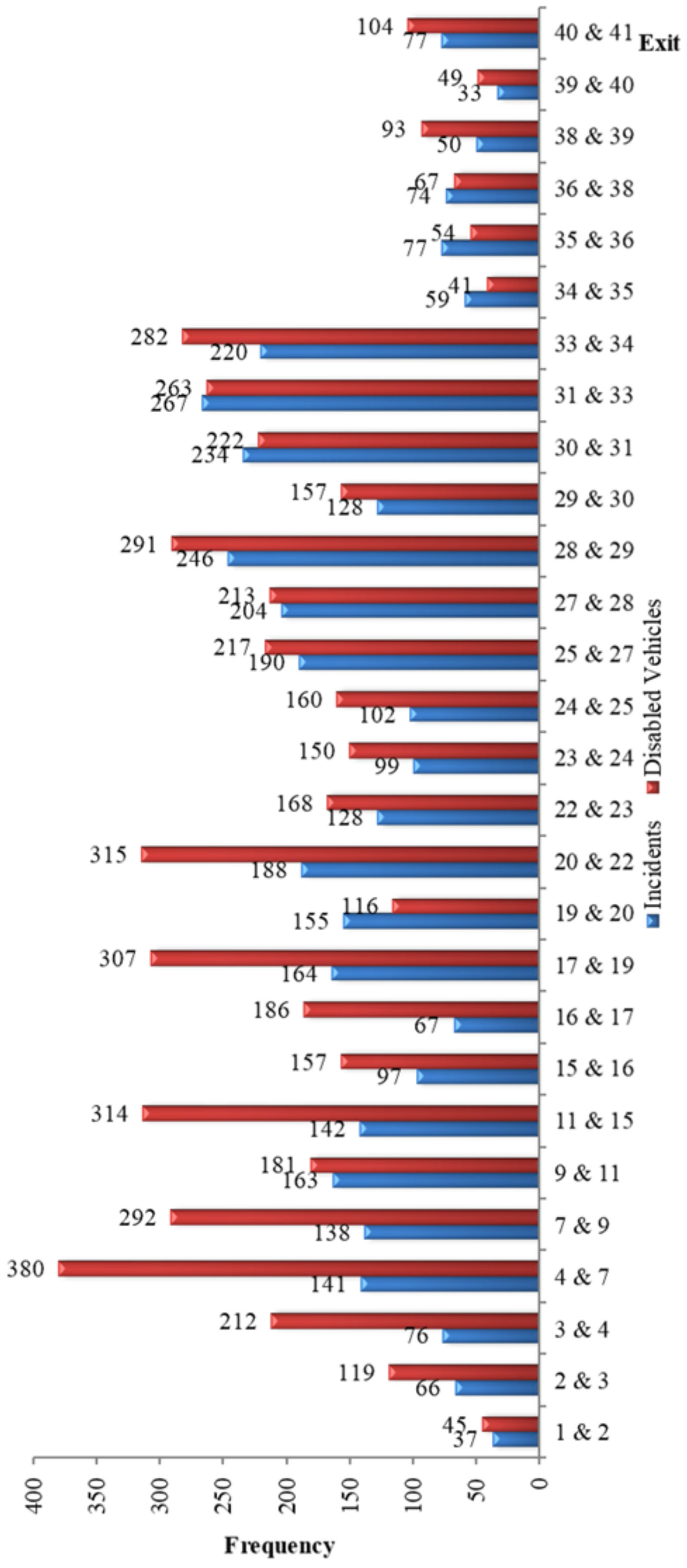


Figure 3.8 Distributions of Incidents/Disabled Vehicles by Location on I-495/I-95

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

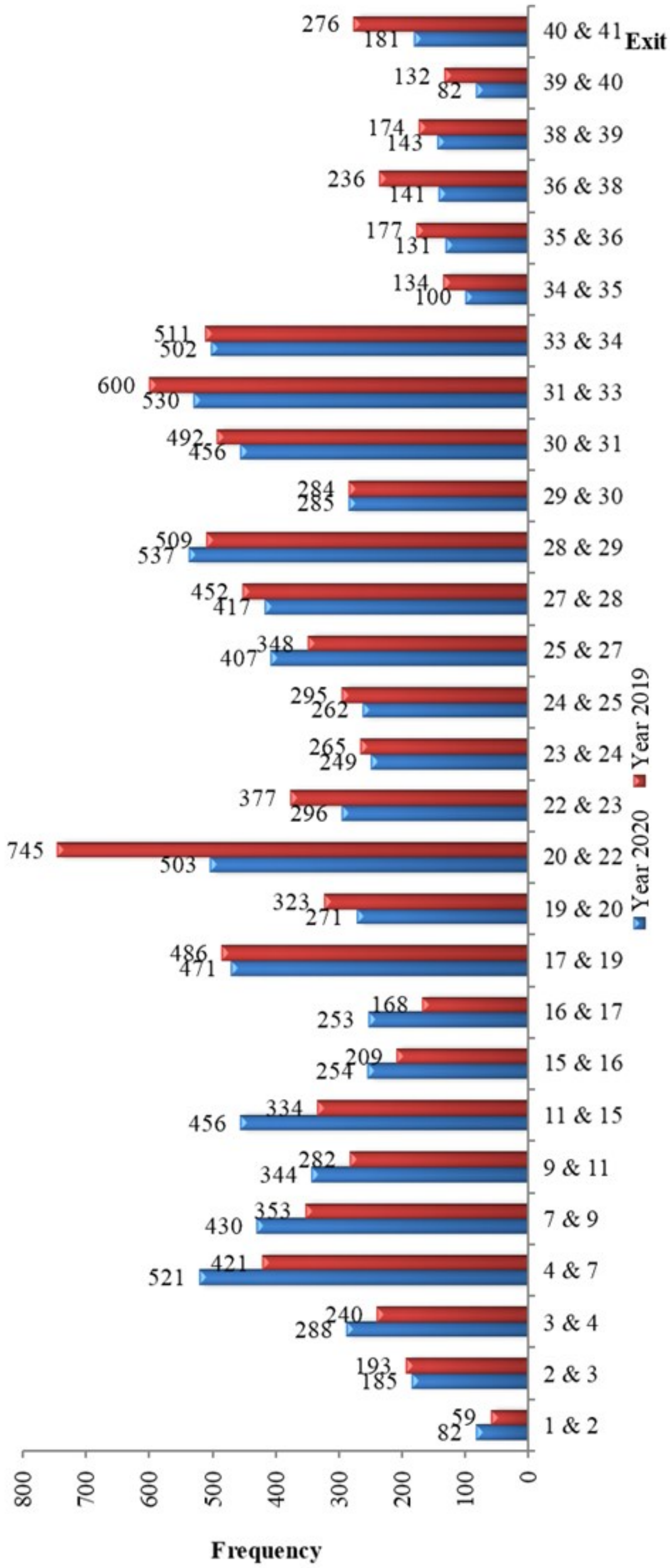


Figure 3.9 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-495/I-95

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

3.2

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 2020 and 2019. As shown in Figure 3.10, the highest number of incidents occurred at the segment between Exits 56 and 57 (549 cases). The segments between Exits 67 and 74 experienced a high number of disabled vehicles (716 cases).

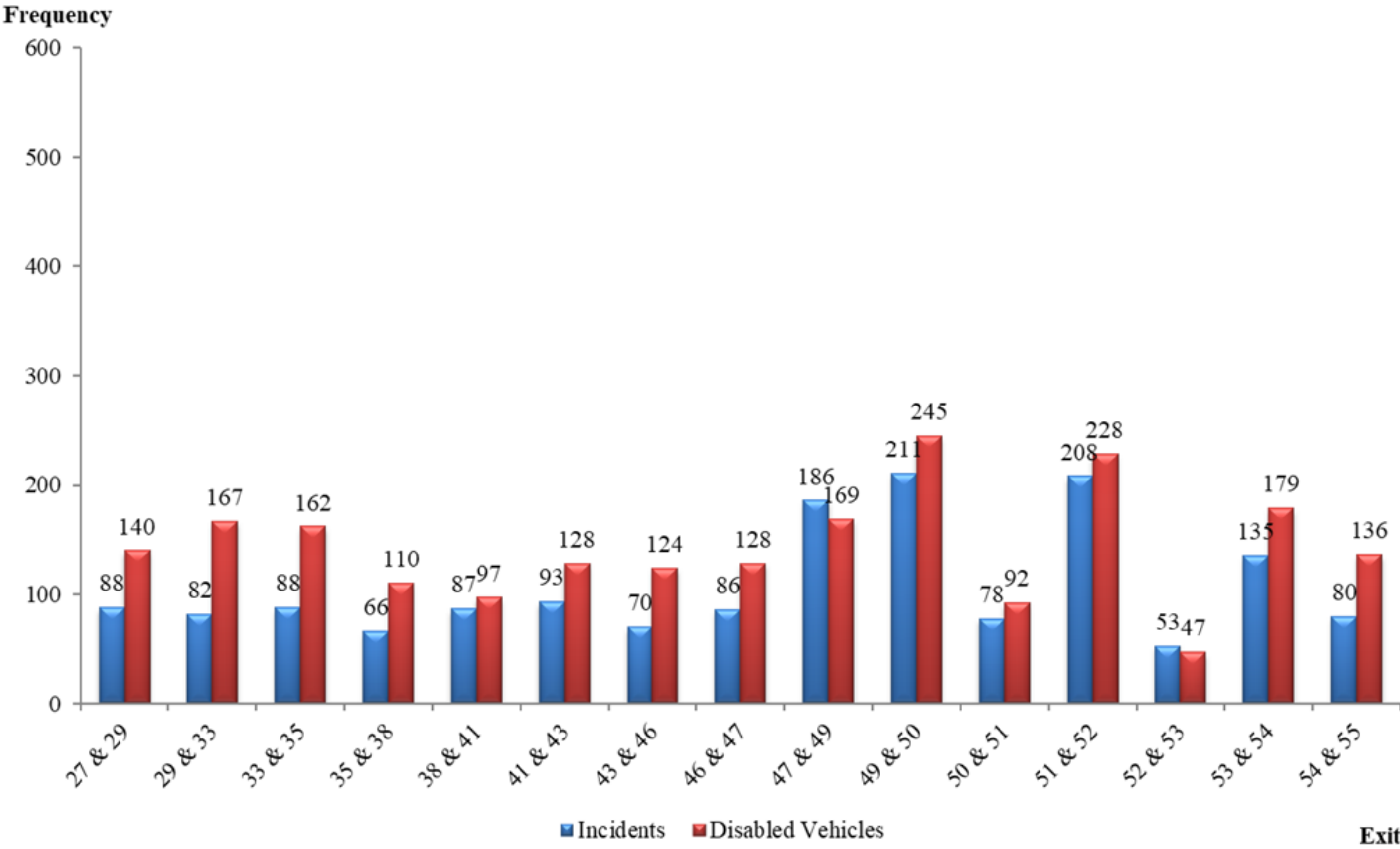


Figure 3.10 Distributions of Incidents/Disabled Vehicles by Location on I-95

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

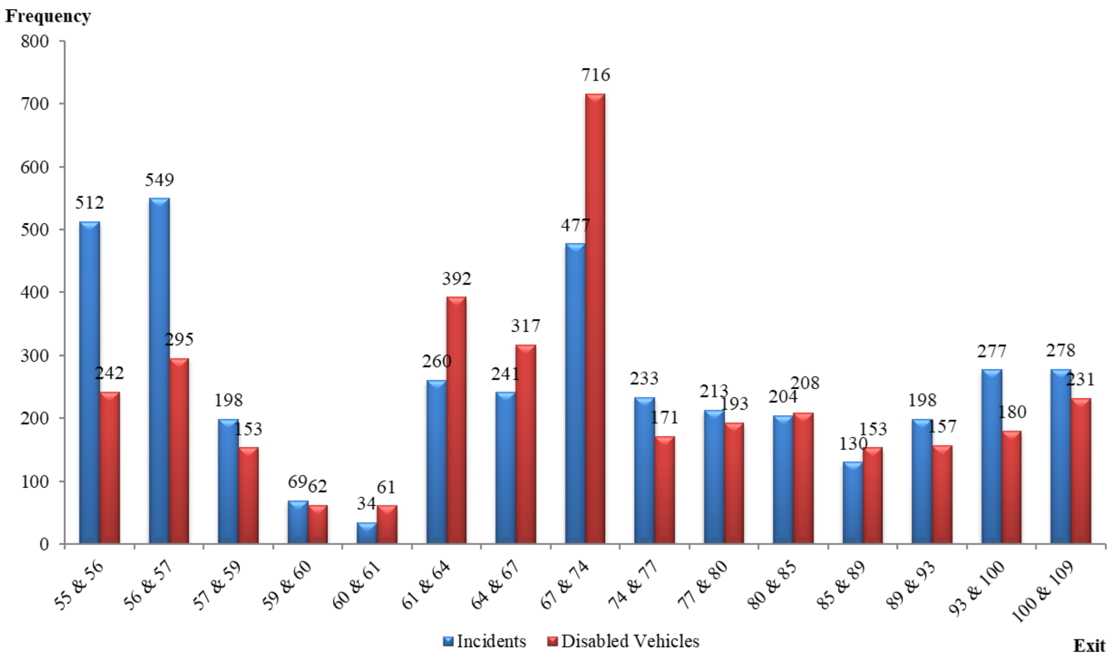


Figure 3.10 Distributions of Incidents/Disabled Vehicles by Location on I-95 (cont.)

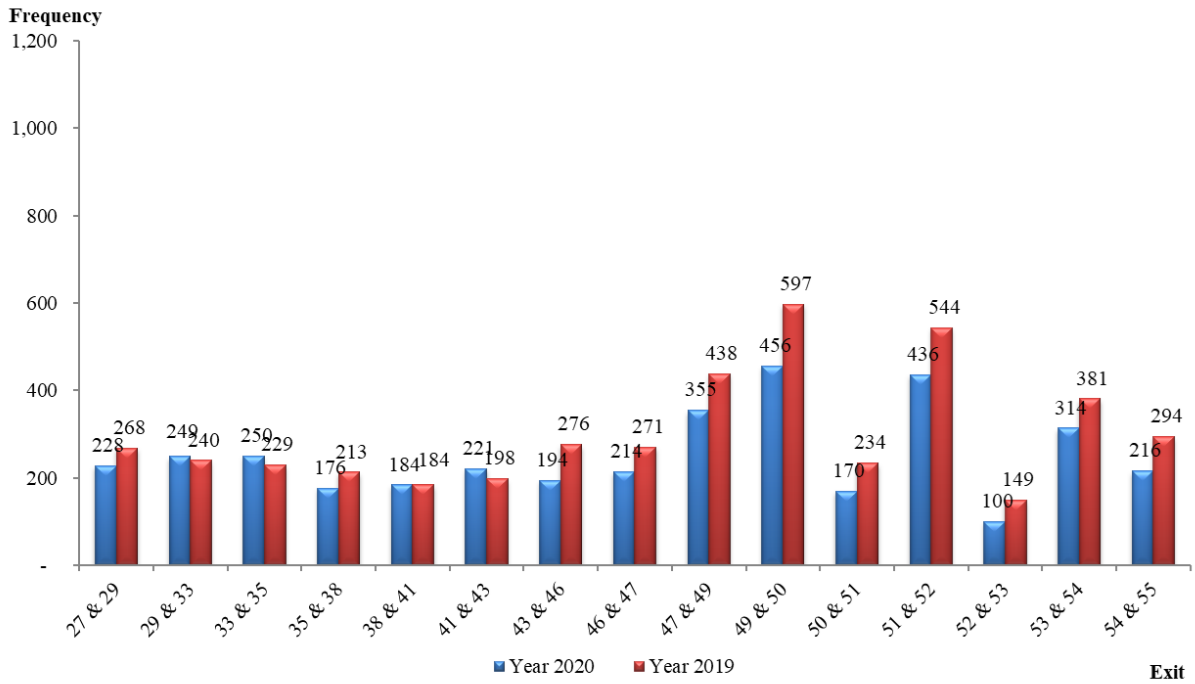


Figure 3.11 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-95

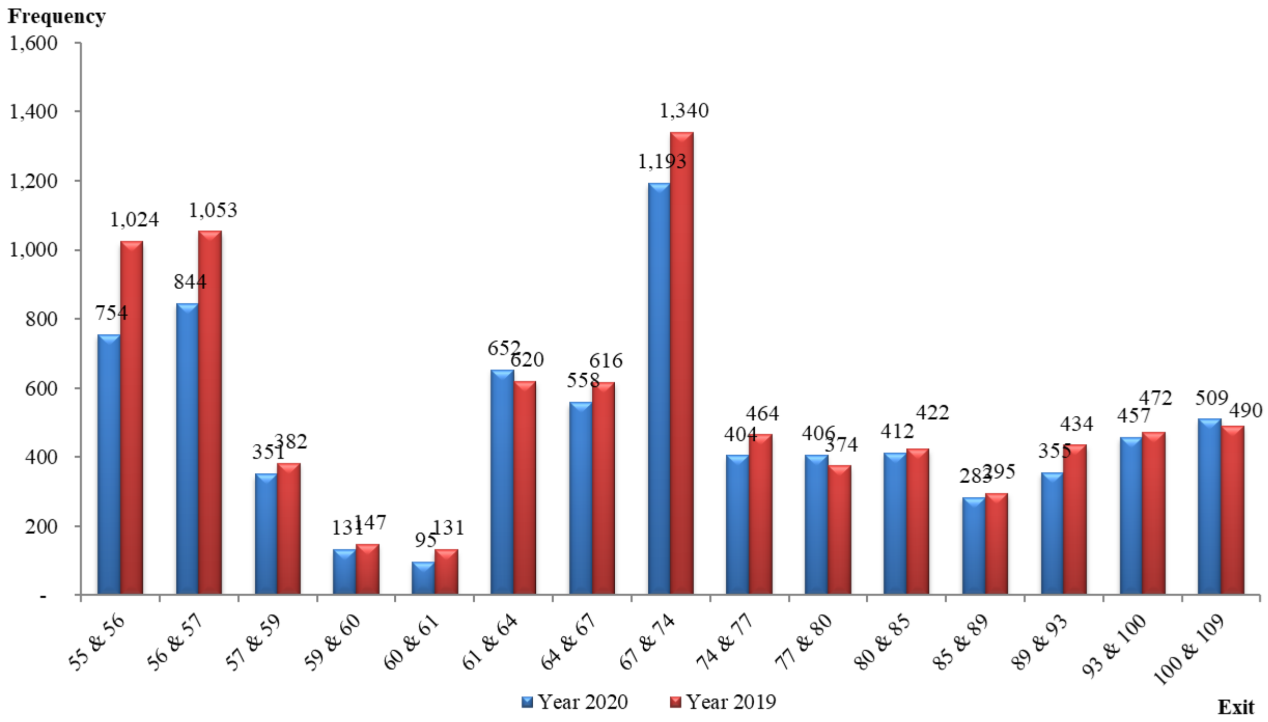


Figure 3.11 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-95 (cont.)

In 2020, the incidents and disabled vehicles recorded for the I-95 segment between Exits 67 and 74 received the maximum number of responses, with a total frequency of 1,193 revealing the same patterns as in 2019 (1,340 cases, ranked the 1st). The segments on I-95 between Exits 56 and 57 sustained the second largest number of incidents/disabled vehicles requests (844) in 2020. Most I-95 segments, especially those between Exits 43 and 61, and Exits 64 and 77, were reported to experience fewer requests of responding to incident/disabled vehicles than in 2019.

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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 2020. The segment between Exits 6 and 8 on I-270 experienced the highest numbers of incidents (136) and the segment between Exits 26 and 31 experienced the highest number of disabled vehicles (223).

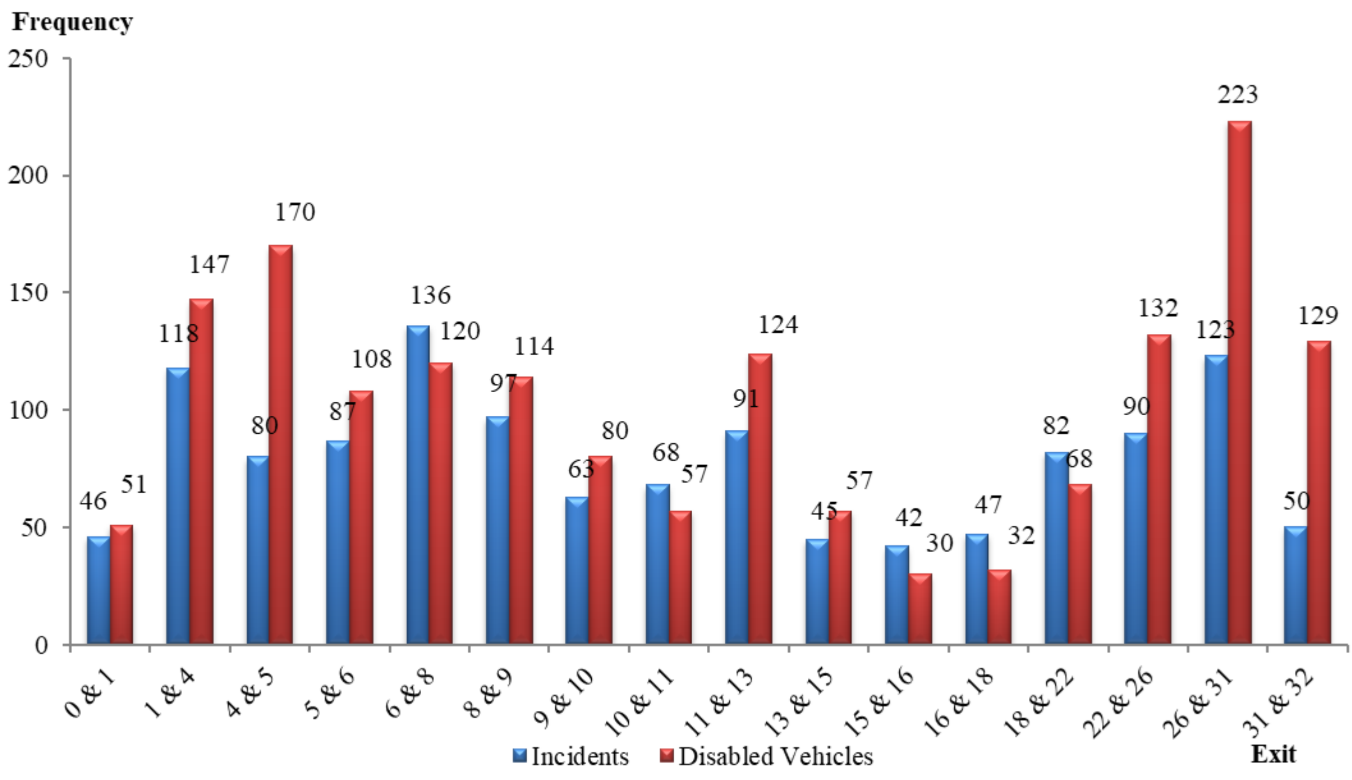


Figure 3.12 Distributions of Incidents/Disabled Vehicles by Location on I-270

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

Figure 3.13 shows a comparison between 2020 and 2019 data; all I-270 segments from Exit 1 to Exit 22 show fewer incident/disabled vehicles requests than those observed in 2019, while segments from Exit 22 to Exit 31 show higher response frequencies than 2019.

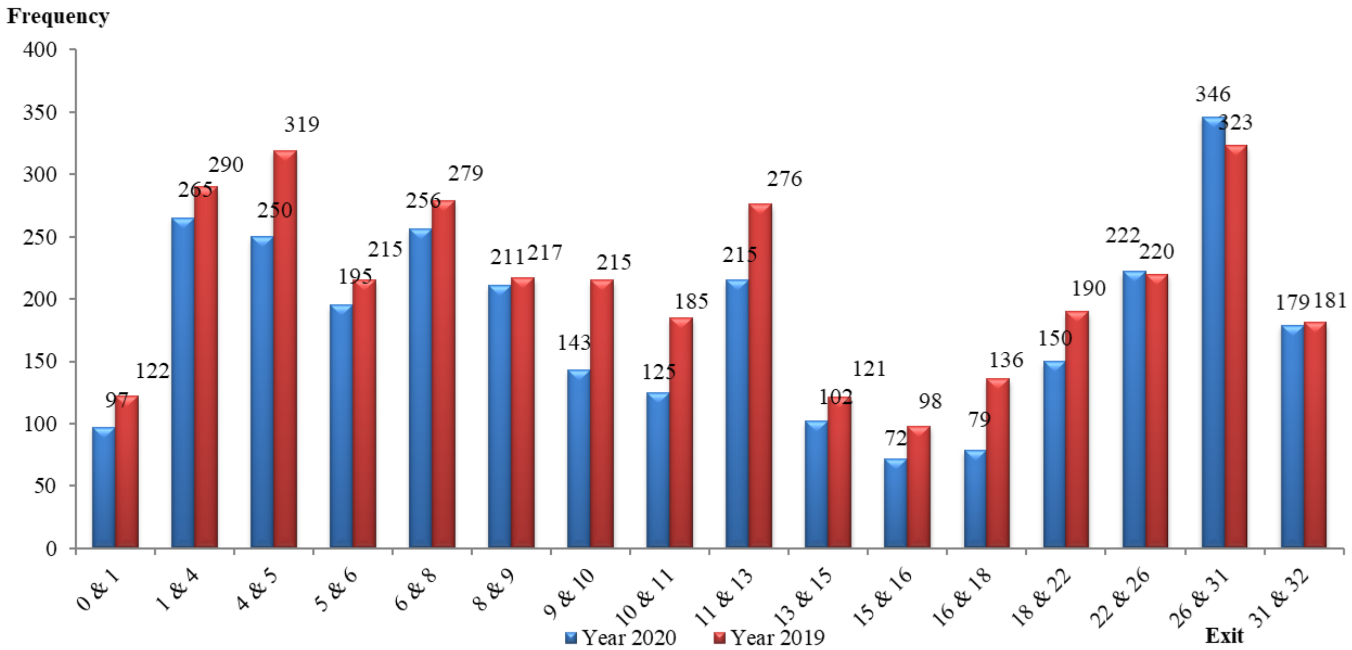
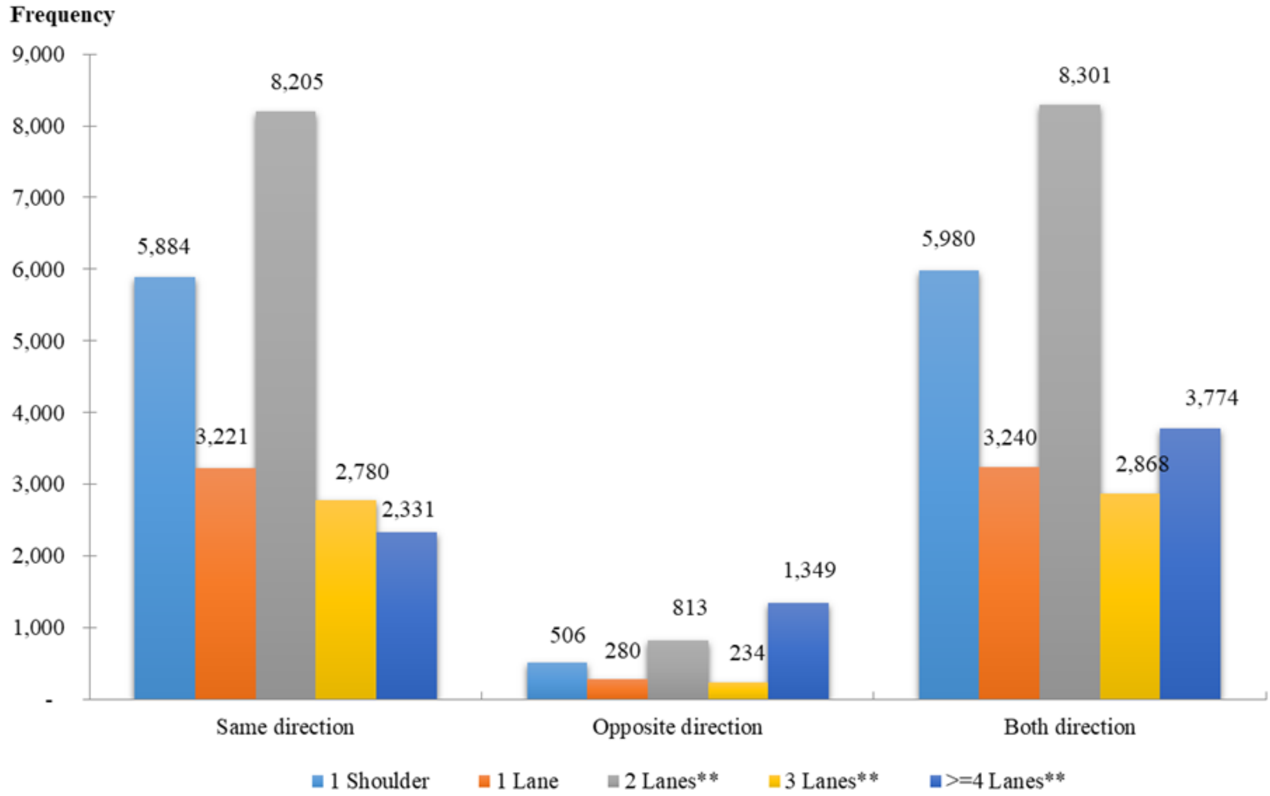


Figure 3.13 Comparisons of Incidents/Disabled Vehicles by Location on I-270

3.3 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY LANE BLOCKAGE TYPE

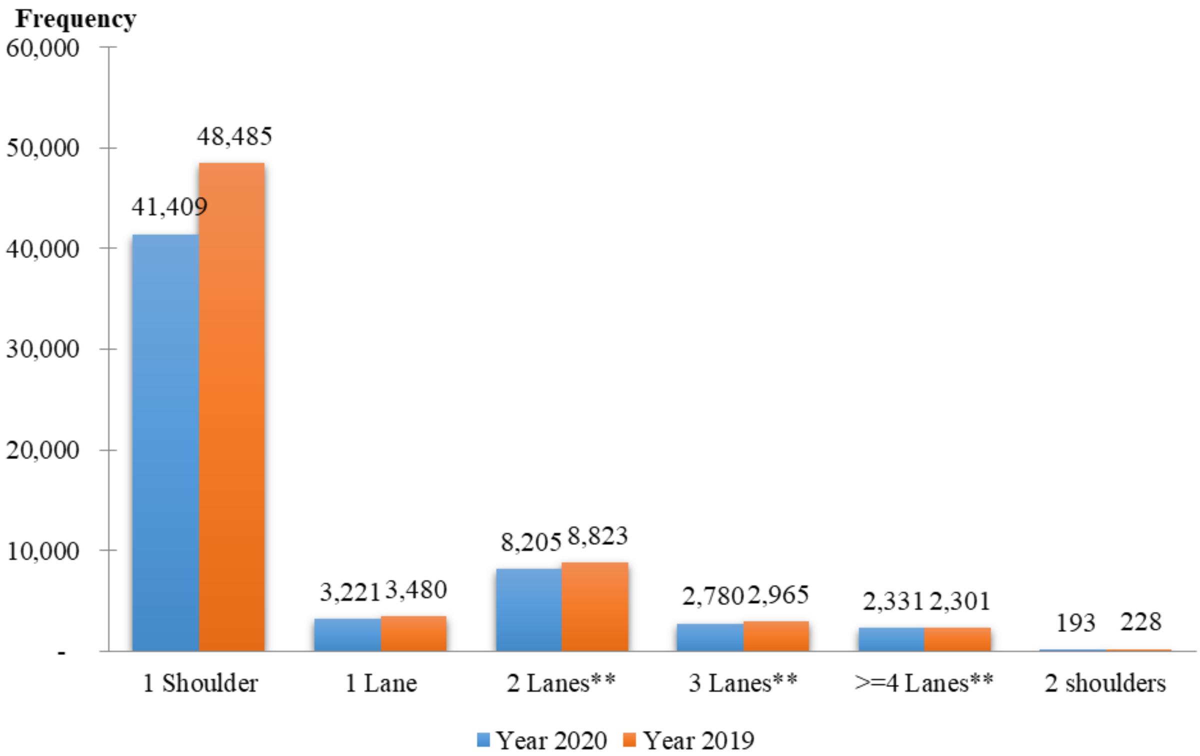
Figure 3.14 illustrates the distribution of incidents by lane blockage in 2020. A large portion of those incidents involved one-lane or two-lane blockages. The comparison of 2020 incidents/disabled vehicles distribution by lane blockage with 2019 data is illustrated in Figure 3.15. Note that all reported disabled vehicles are classified as shoulder lane blockages in Figure 3.14 and Figure 3.15.



*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

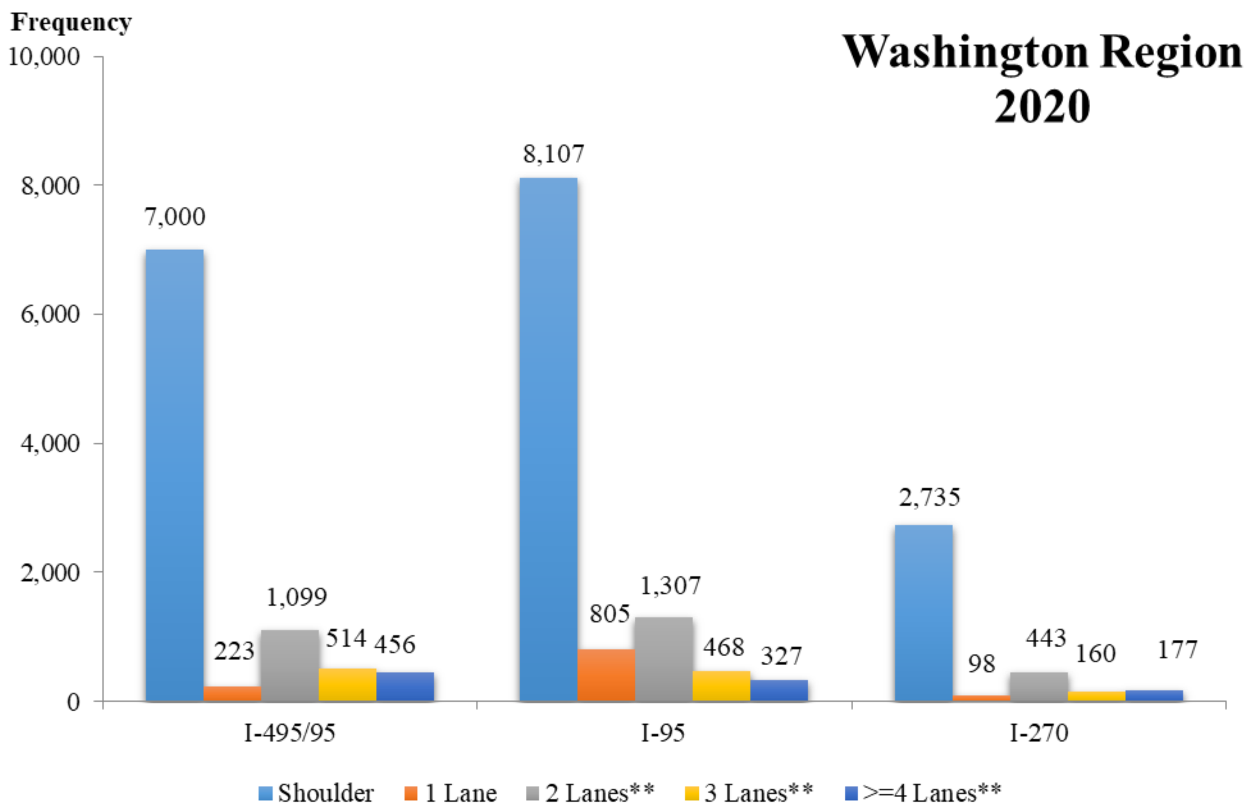


Note: * Disabled Vehicles are all classified as Shoulder Lane Blockages.
** Also includes Shoulder Lane Blockages.

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

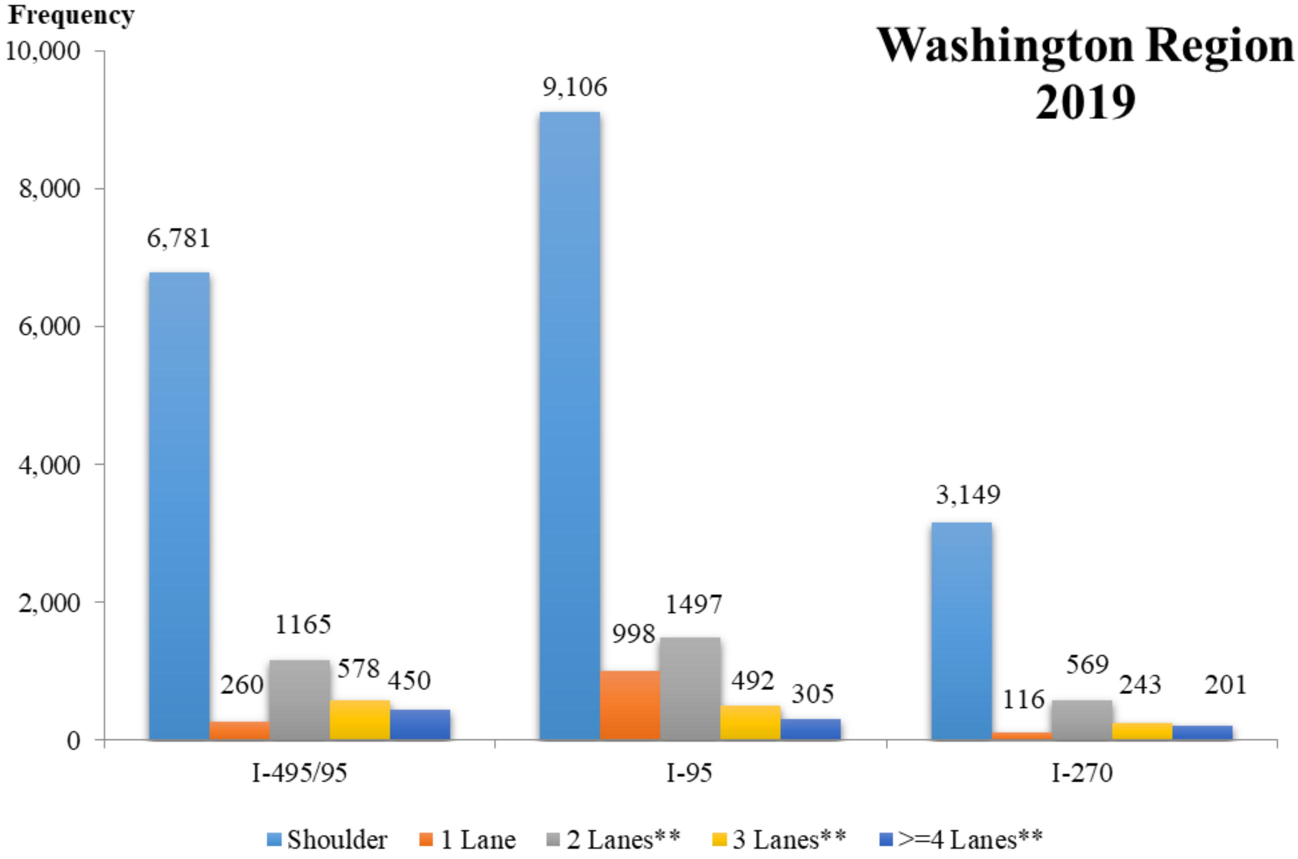
3.3 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY LANE BLOCKAGE TYPE

Figures 3.16 and 3.17 depict a comparison of lane blockage incidents between 2020 and 2019 for major roads in the Washington Metropolitan and Baltimore areas.



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

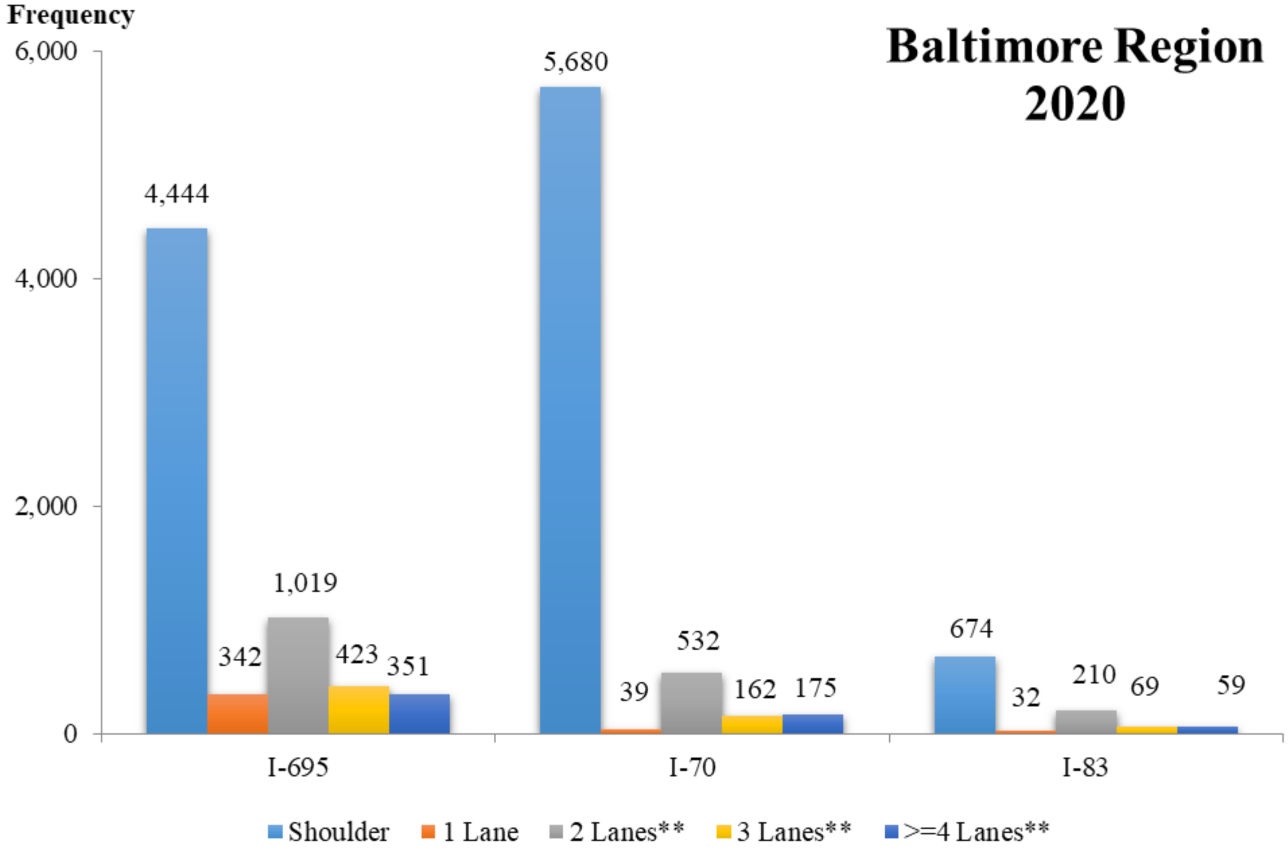
Figure 3.16 Distributions of Lane Blockages Occurring on Major Freeways in the Washington Area



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

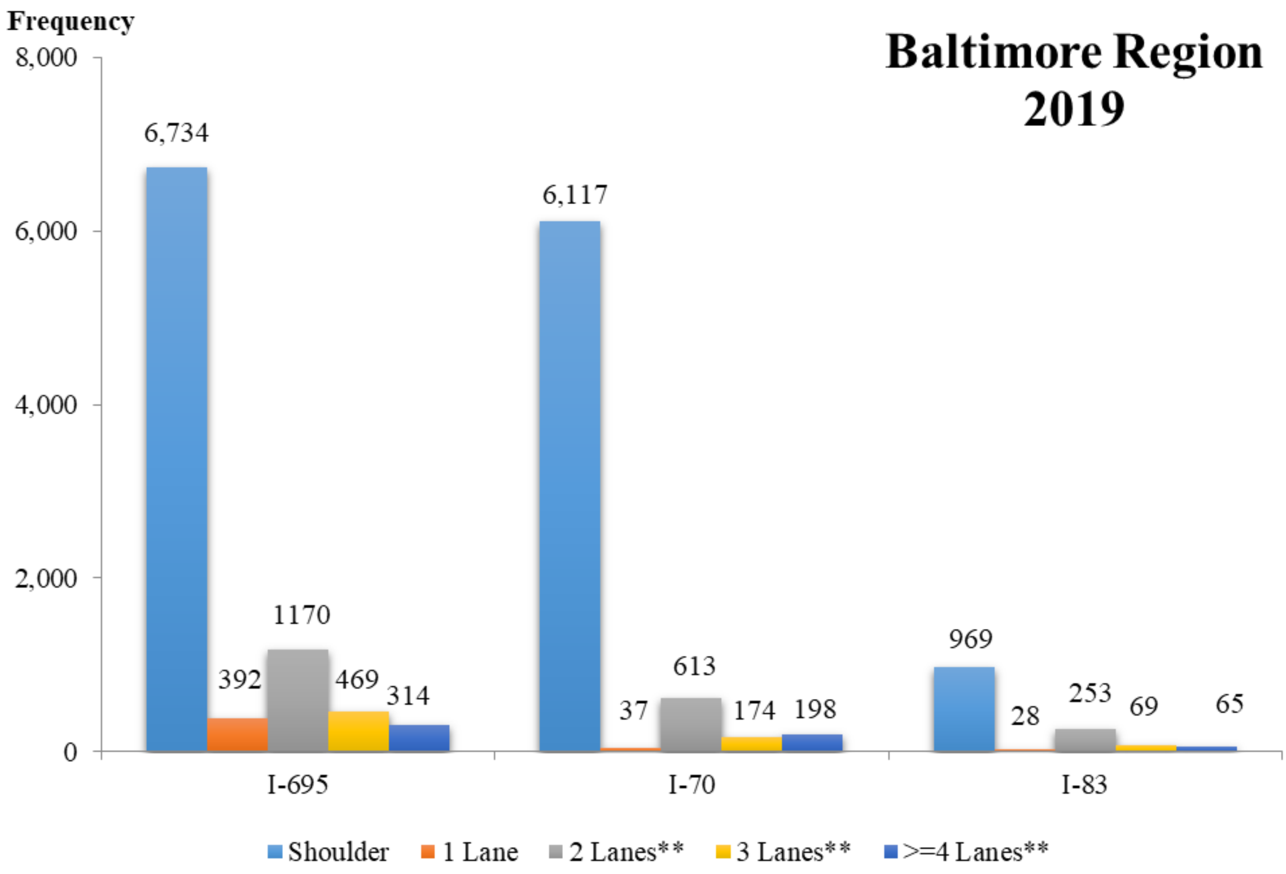
Figure 3.16 Distributions of Lane Blockages Occurring on Major Freeways in the Washington Area (Cont.)

3.3 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 3.17 Distributions of Lane Blockages Occurring on Major Highways in the Baltimore Region



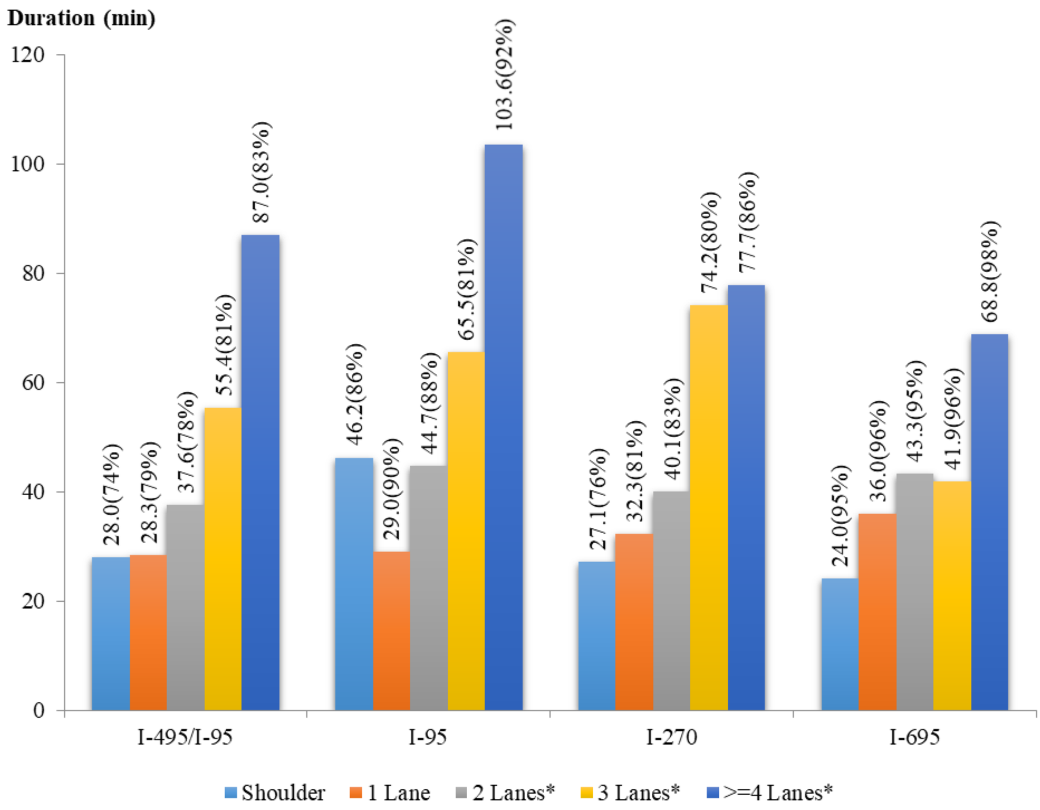
*Note: *Disabled Vehicles are all classified as Shoulder Lane Blockages*
***Also includes Shoulder Lane Blockages*

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 of Lane Blockages and Road

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

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.

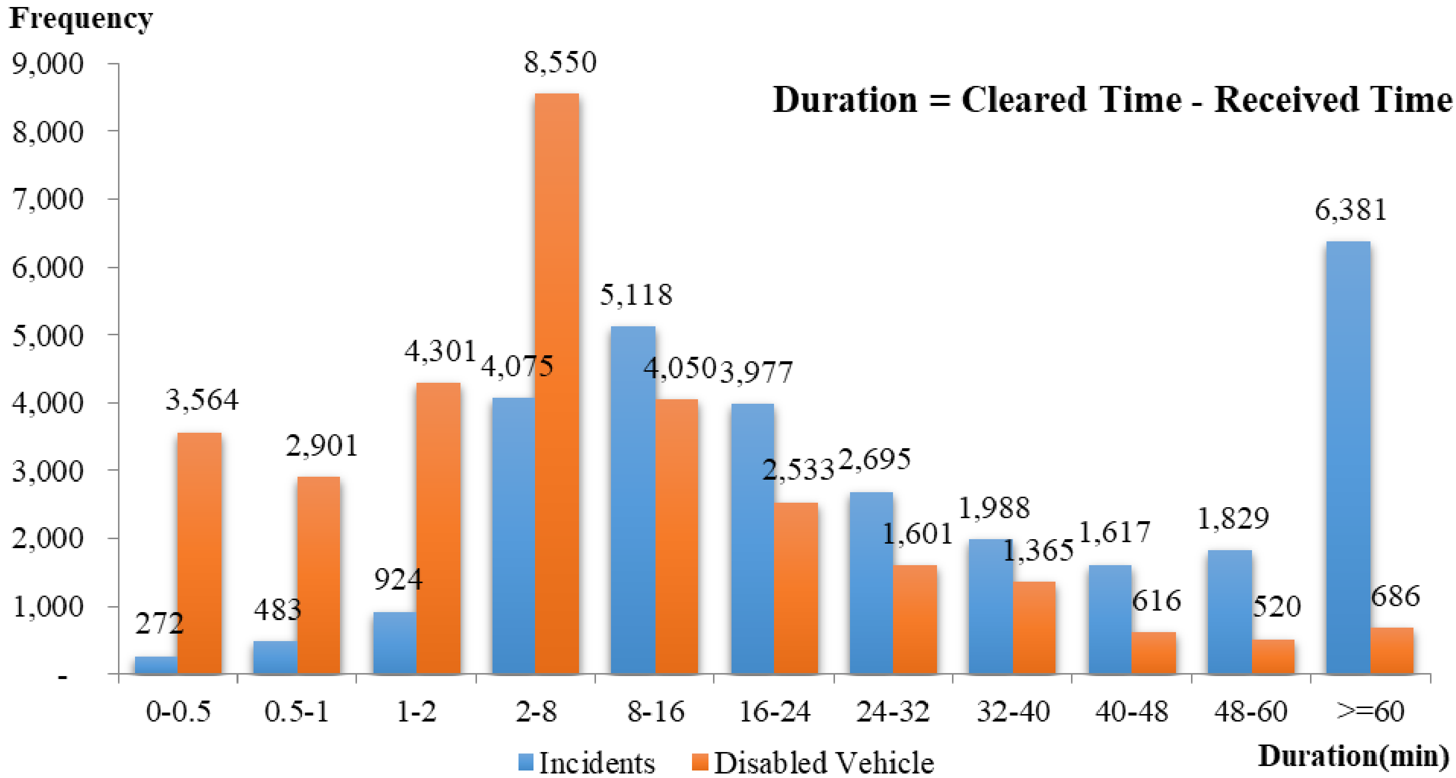


Figure 3.19 Distributions of Incidents/Disabled Vehicles by Duration in 2020

Although most incidents in 2020 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 2020 and its comparison with 2019 data. About 19 percent, 23 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 46 percent of reported incidents lasted longer than 30 minutes. This implies that only 27 percent of reports to which CHART responded lasted more than 30 minutes in 2020.

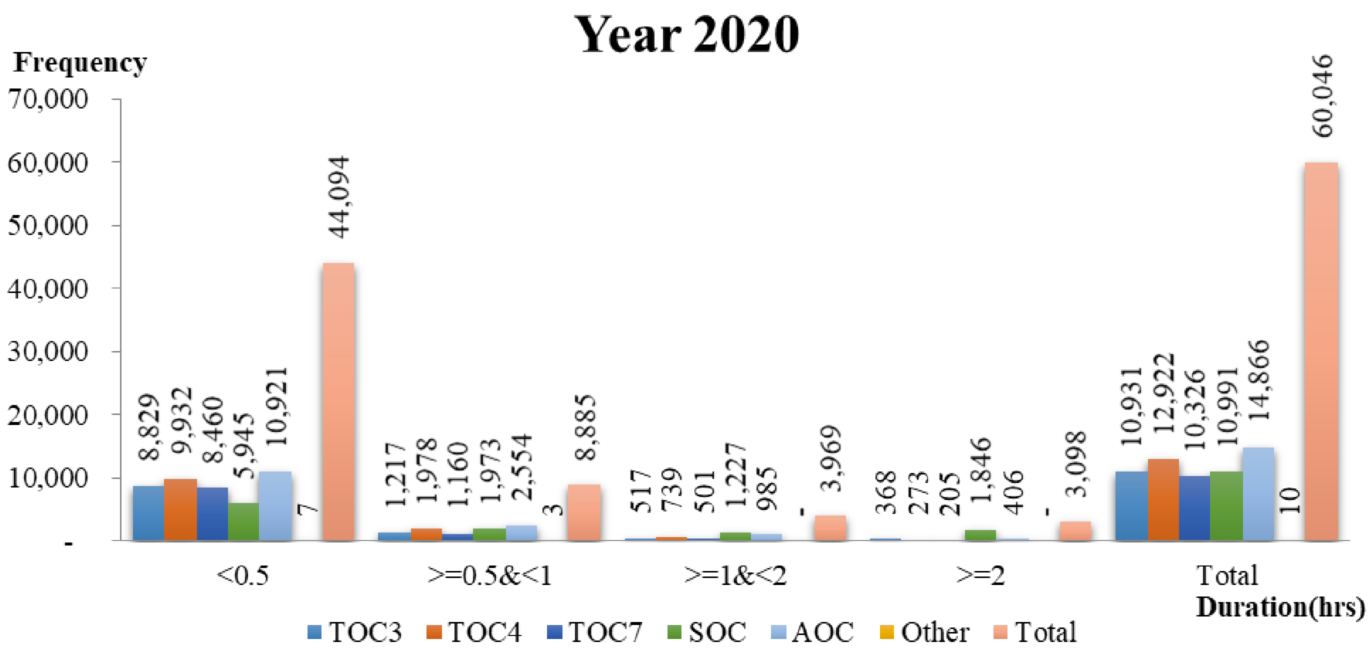


Figure 3.20 Comparisons of Incidents/Disabled Vehicles Distributions by Duration and Operation Center

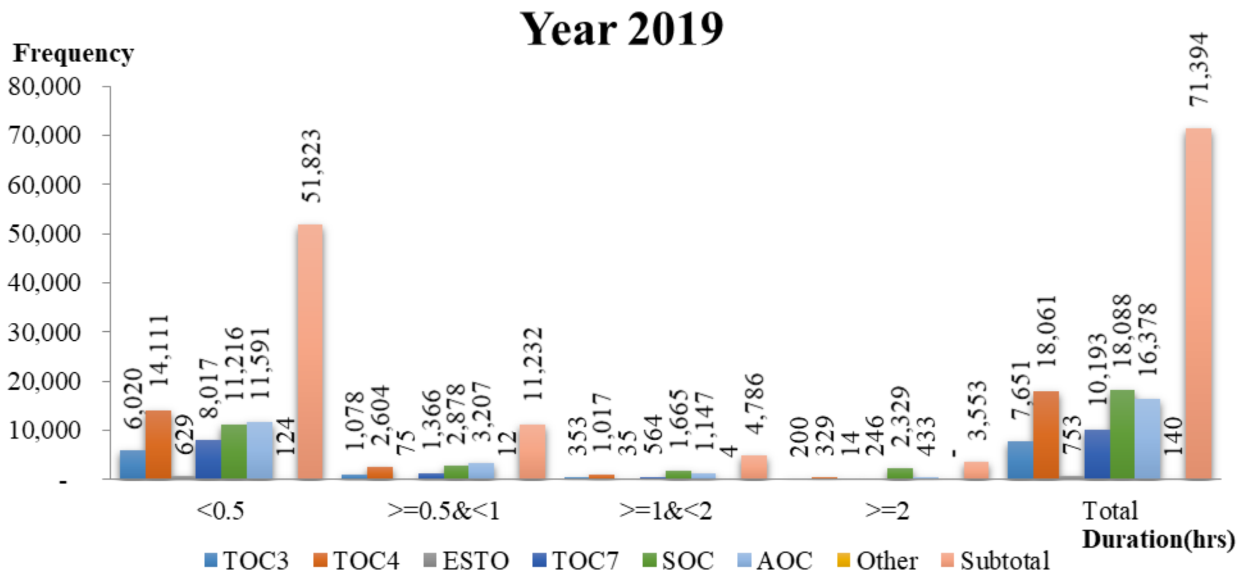


Figure 3.20 Comparisons of Incidents/Disabled Vehicles Distributions by Duration and Operation Center (Cont.)

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

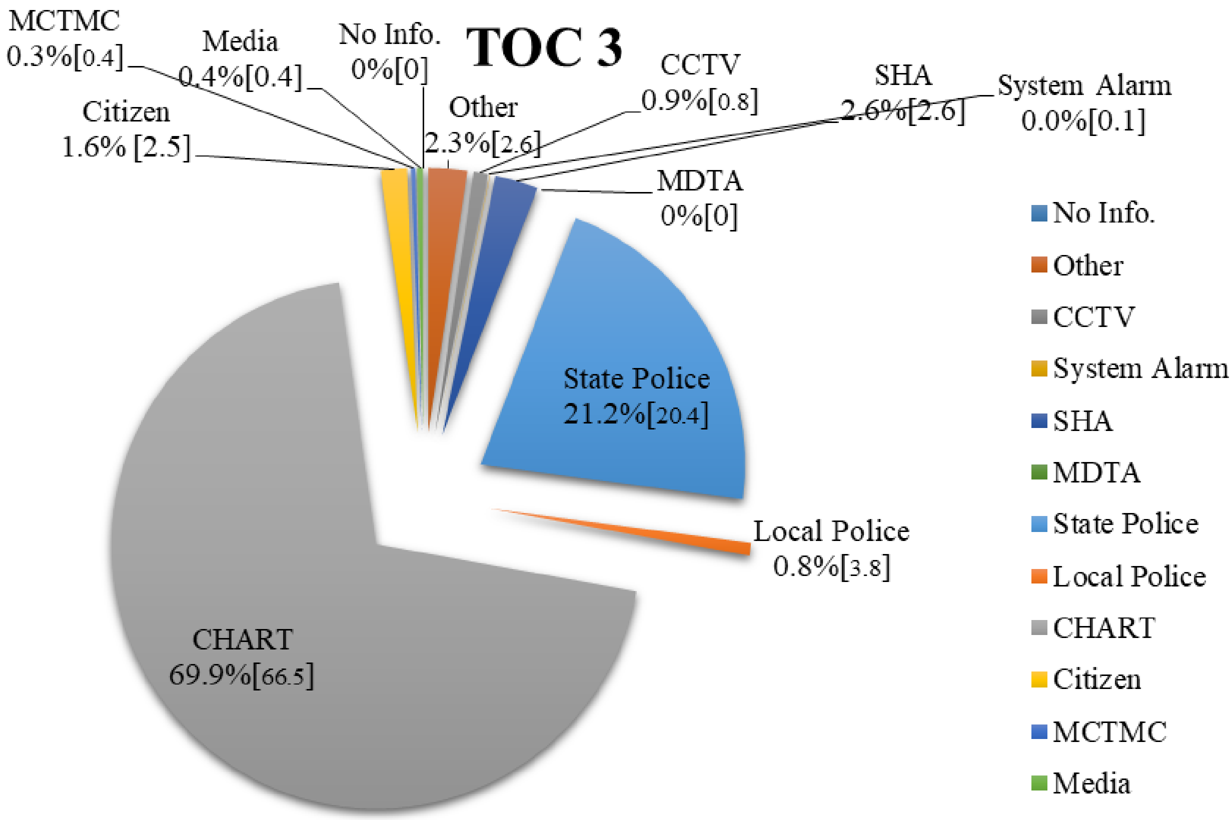
4.1 Evaluation of Detection Efficiency and Effectiveness

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 2020 incident management records, the overall response rate was 90.5 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.

4.1 EVALUATION OF DETECTION EFFICIENCY AND EFFECTIVENESS

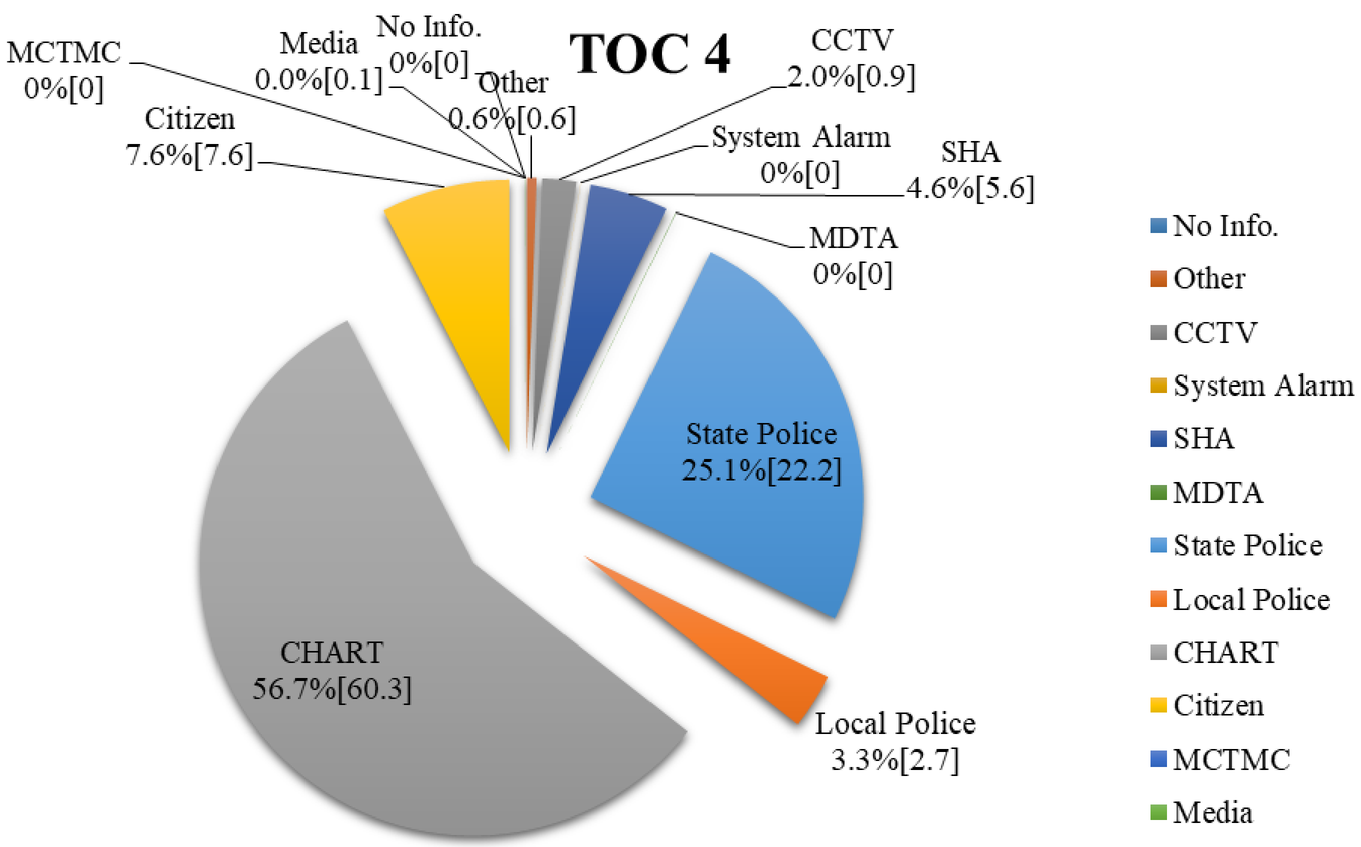
Figures 4.1, 4.2 and 4.3 illustrate the distributions of incidents/disabled vehicles by detection source for control centers TOC 3, TOC 4 and TOC7, respectively.



Note: Numbers in [ ] show the percentages from Year 2019.

** Actual frequencies for incidents/disabled vehicles detected by system alarm, No info. and MDTA are 5, 0 and 0 in the CHART-II database of year 2020*

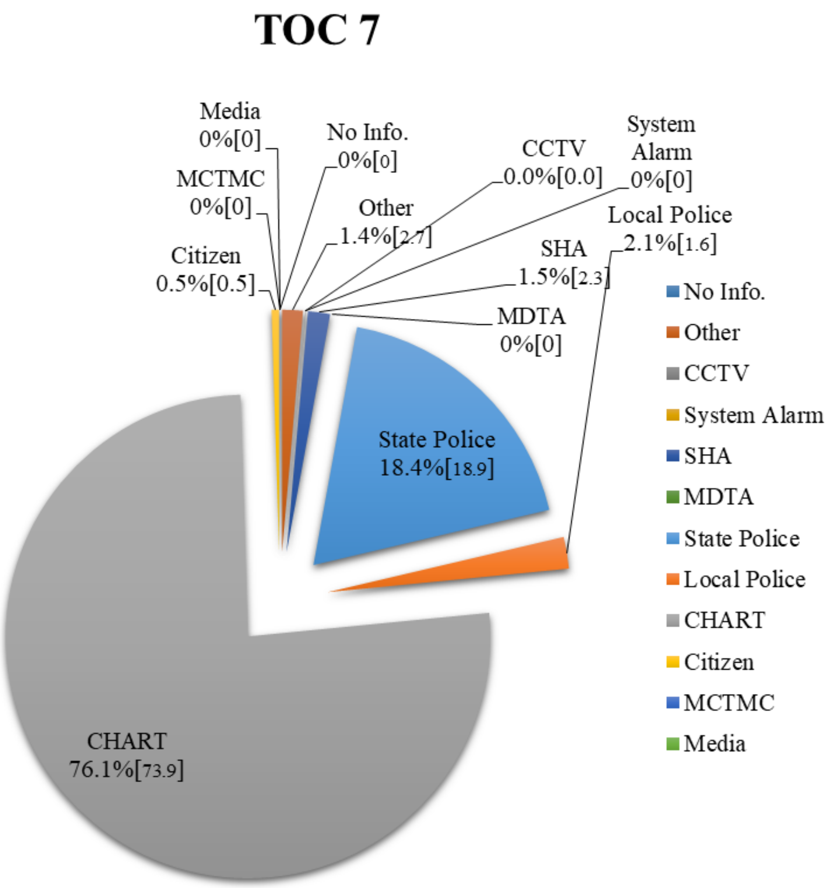
Figure 4.1 Distributions of Incidents/Disabled Vehicles by Detection Source for TOC 3



Note: Numbers in [ ] show the percentages from Year 2019

** Actual frequencies for incidents/disabled vehicles detected by No info., MCTMC, Media, System Alarm, and MDTA in 2020 are 0, 0, 3, 1 and 5 in the CHART-II database.*

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



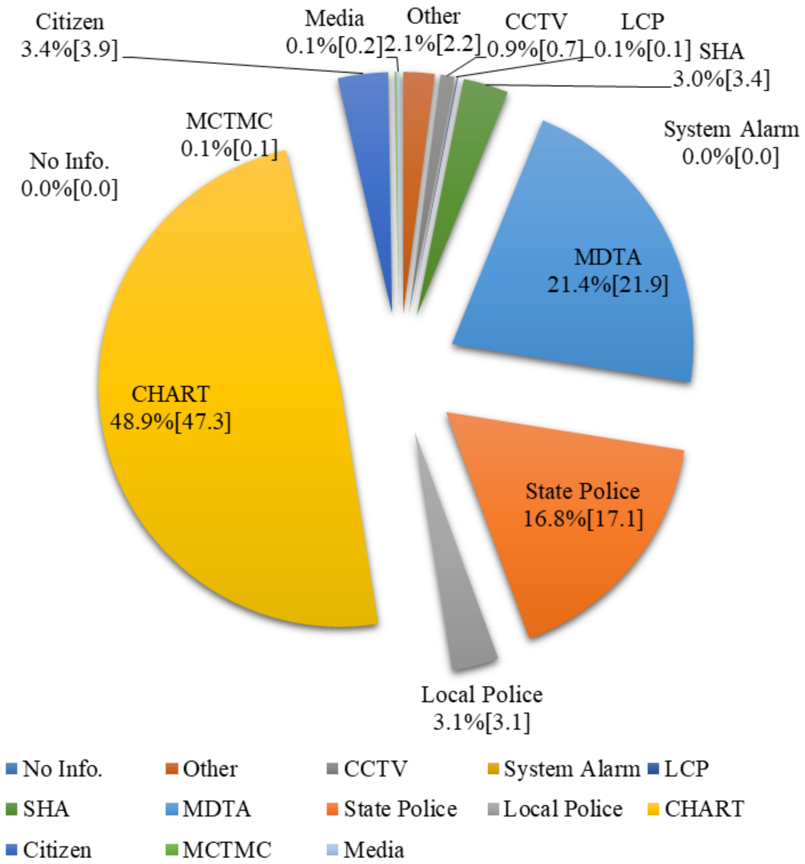
Note: Numbers in [ ] show the percentages from Year 2019.

** Actual frequencies for incidents/disabled vehicles detected by No info., MCTMC, Media, System Alarm, CCTV and MDTA in 2020 are 0, 1, 1, 0, 4, 0 in the CHART-II database.*

Figure 4.3 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 4.4 clearly show that about 49 percent of incidents in 2020 were detected by MDOT SHA/ CHART patrols, i.e., a higher percentage than in 2019. About 16.8 percent were reported by the MSP, similar to the 17.1 percent figure in 2019. Note that the numbers in parentheses indicate the 2019 statistics.



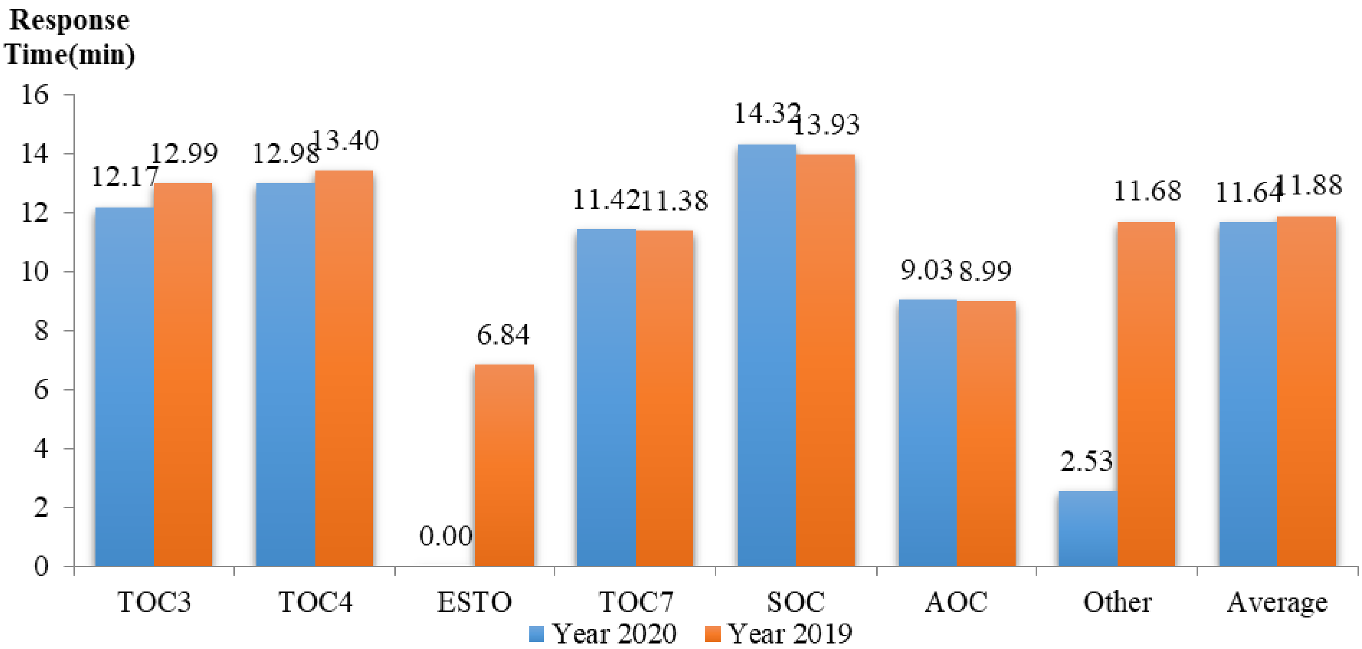
Note: Numbers in [ ] show the percentages from Year 2019.
** The actual frequency for incidents/disabled vehicles detected by No info. and System Alarm in 2020 is 0 and 11 in the CHART-II database.*

Figure 4.4 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 in 2020 is given in Figure 4.5. The average response time in 2020 was 11.64 minutes, slightly lower than that of 2019 (11.88 minutes).

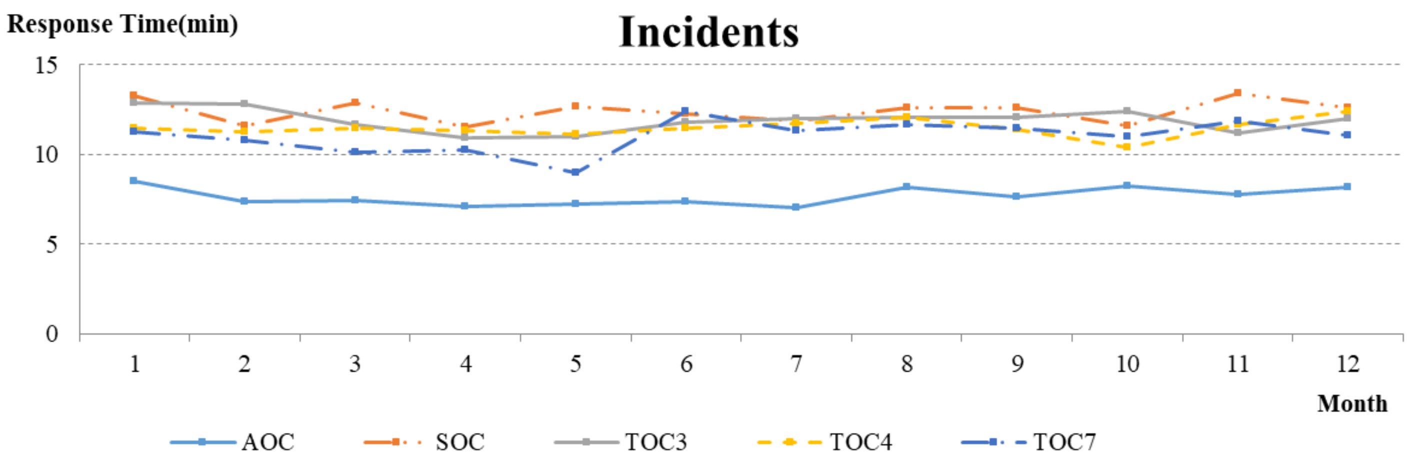


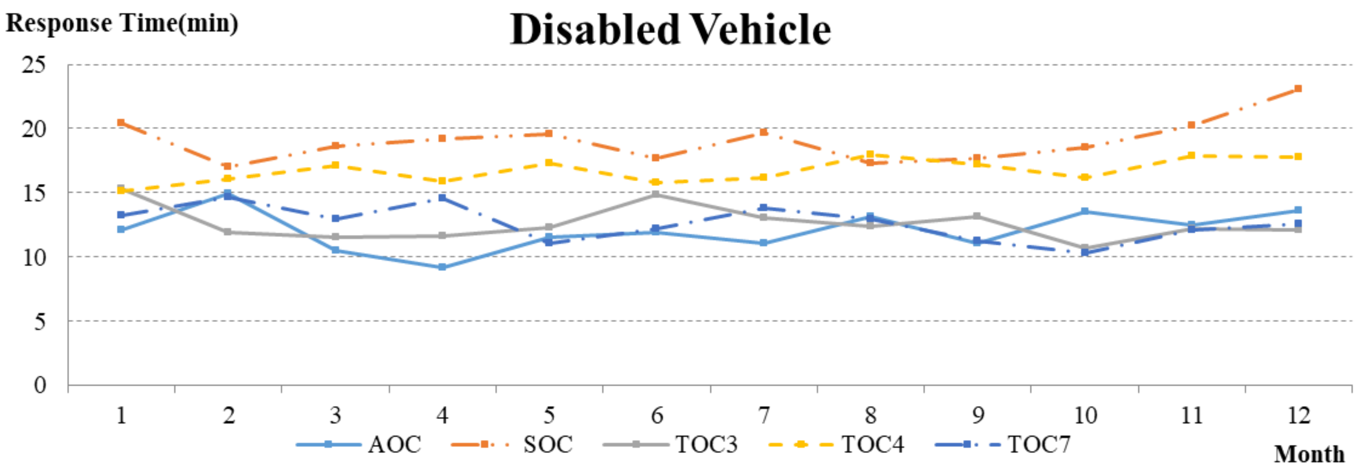
*Note:
TOC 6 closed from October 2015
TOC 3 was temporarily closed and relocated to SOC since August 2018, and has reopened in June 2019.
ESTO was closed in 2020.

Figure 4.5 Distributions of Average Response Times

4.2 ANALYSIS OF RESPONSE EFFICIENCY

In Figure 4.6 the average response times of incidents by TOC 3, TOC 4, and SOC are fairly consistent throughout the year and are mostly between eleven and thirteen minutes. AOC also shows fairly consistent response times up to nine minutes through year 2020. On the other hand, the response times for disabled vehicles show significant fluctuations for SOC and AOC. AOC shows an increase in the average response time for disabled vehicles in February, whereas it exhibits a big drop in the average response time for disabled vehicles in April. Overall, the average response times for AOC are relatively shorter than for TOCs in most months.

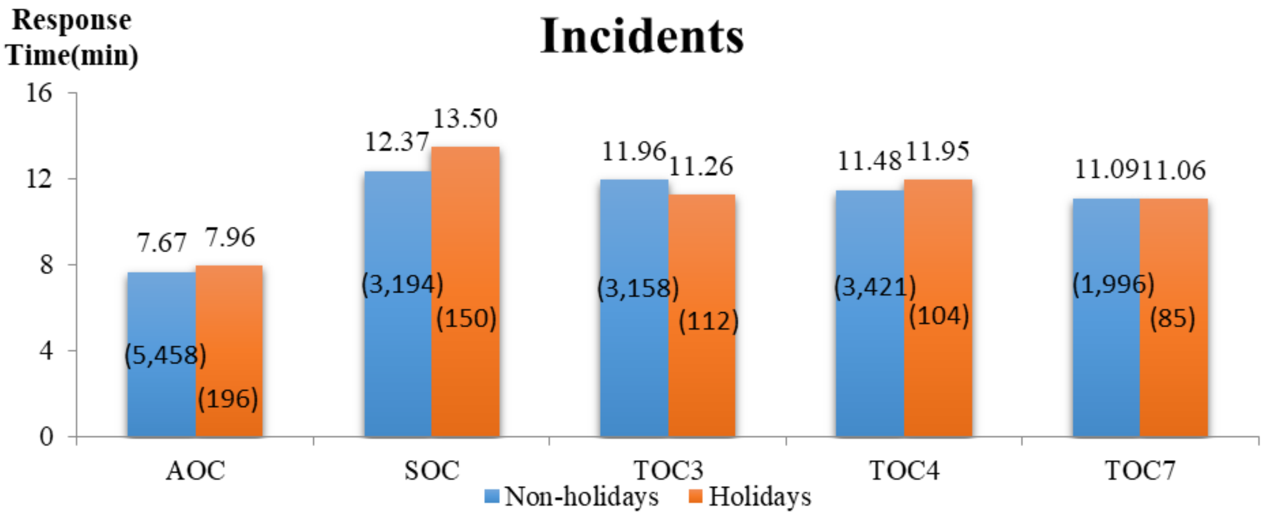


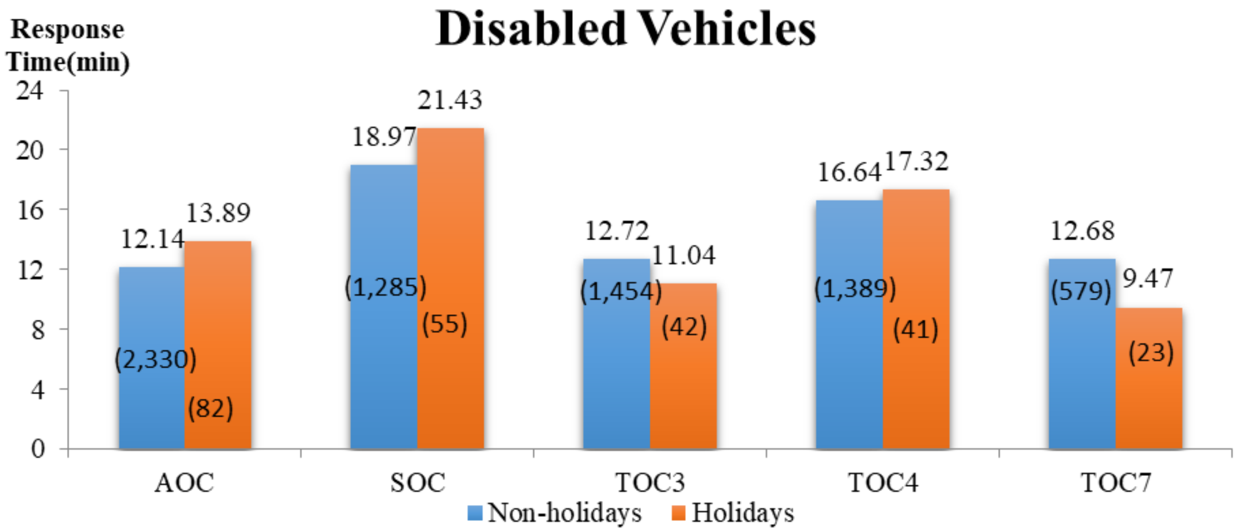


Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. ESTO and TOC 6 were excluded in this analysis, since they operate on a seasonal basis.

Figure 4.6 Average Response Times for Operation Centers by Month in 2020

Figure 4.7 illustrates the fact that AOC, SOC and TOC4 show slightly faster response times for incidents and disabled vehicles during non-holidays in 2020.





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

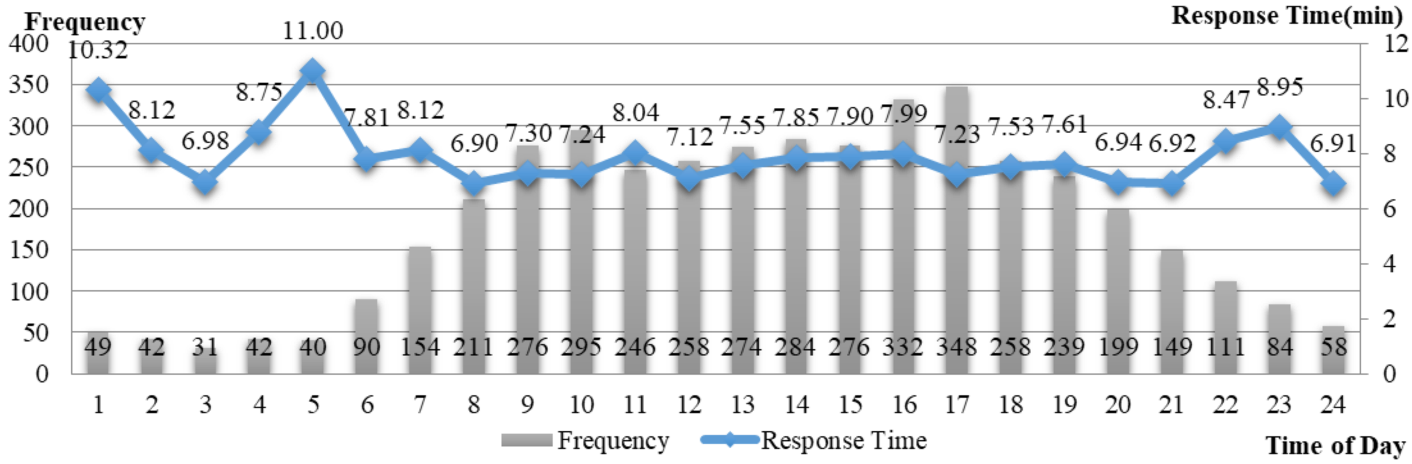
2. Numbers in each parenthesis show the data availability.

3. Holidays include New Year's Day, Martin Luther King, Jr. Day, Washington's Birthday, Memorial Day, Independence Day, Labor Day, Columbus Day, Veterans Day, Thanksgiving Day, and Christmas Day

Figure 4.7 Average Response Times for Operation Centers on Holidays and Non-Holidays in 2020

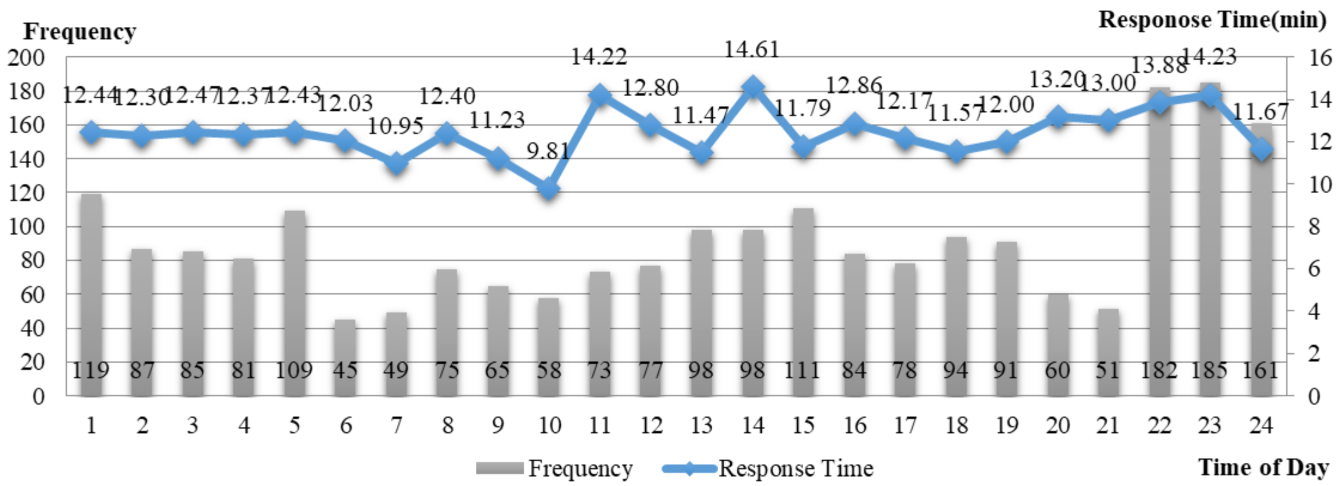
4.2 ANALYSIS OF RESPONSE EFFICIENCY

Figures 4.8 to 4.12 present the average response times by time of day during weekdays for each operation center. The bar graph represents the average incident frequencies to which the operation center responded while the line graph illustrates its average response times by the time of day. Overall, AOC shows quite consistent response time during the daytime. 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 back-up of TOCs 3, 4 and 7 after their operational hours (5 a.m. - 9 p.m.), their frequencies of incident responses during non-operational hours are much larger than those in major TOCs (see Figures 4.10 to 4.12).



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

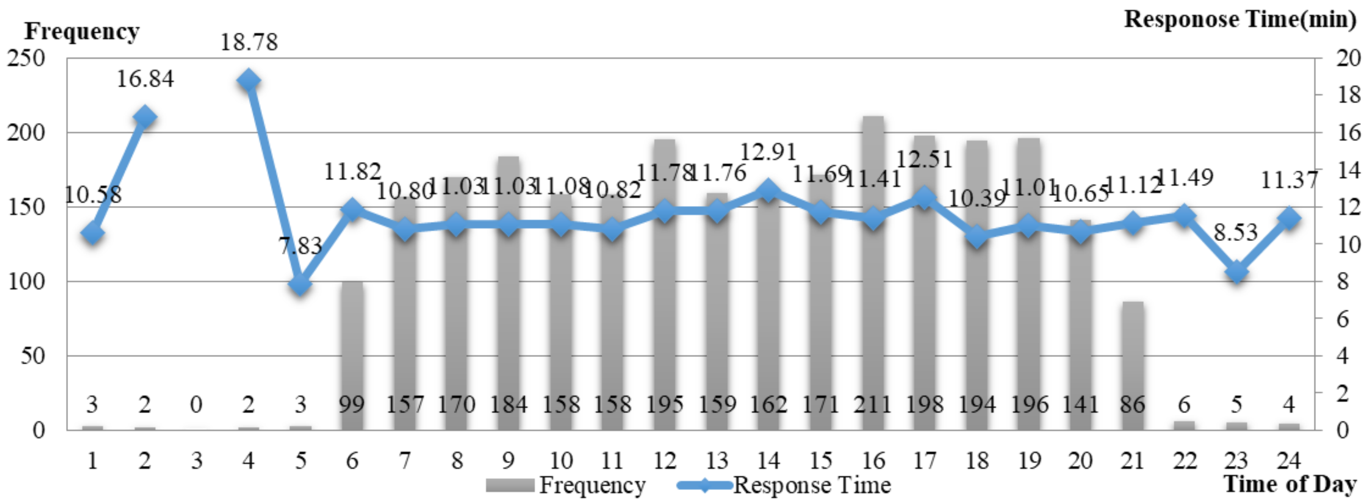
Figure 4.8 Average Response Times for AOC by Time of Day on Weekdays in 2020



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

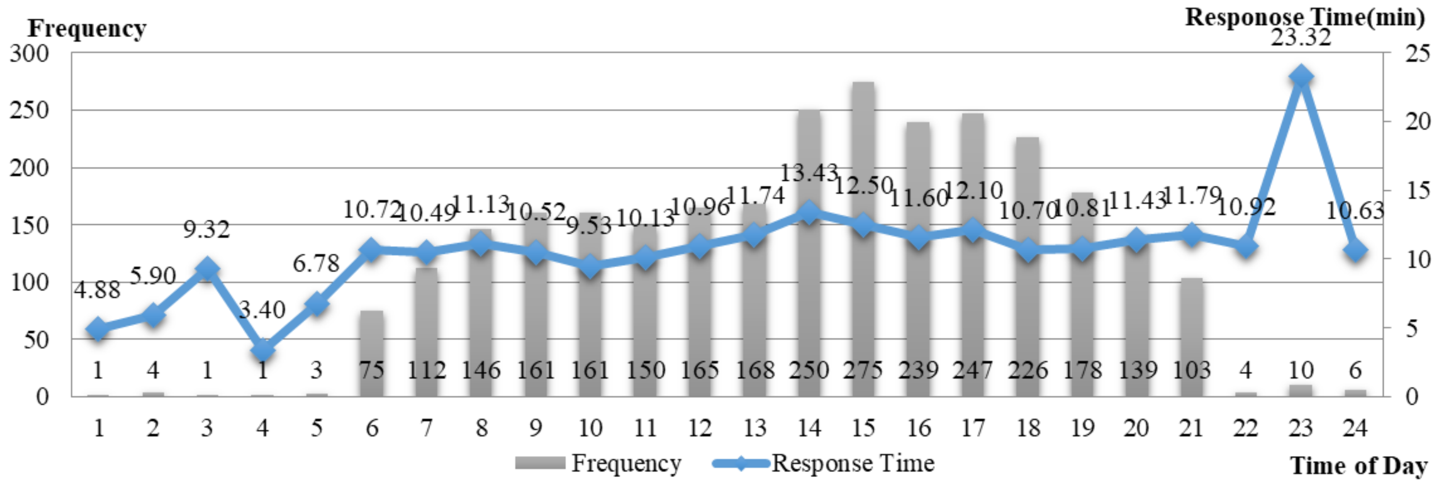
Figure 4.9 Average Response Times for SOC by Time of Day on Weekdays in 2020

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 by TOC3 and TOC 4 fluctuate during non-operational hours.



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

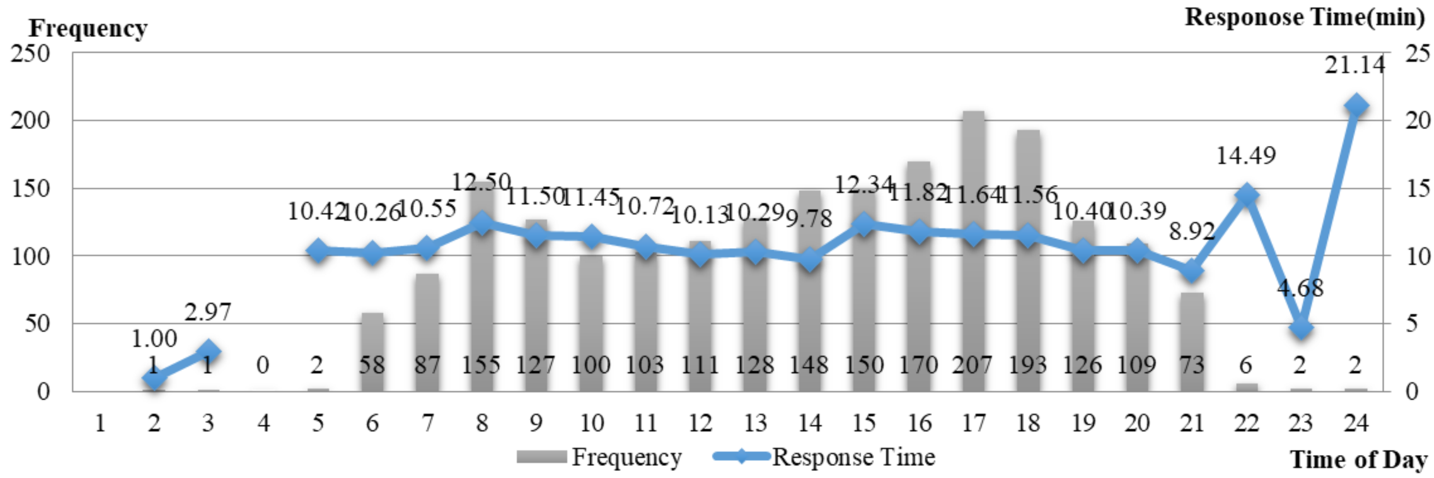
Figure 4.10 Average Response Times for TOC3 by Time of Day on Weekdays in 2020



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 TOC4 by Time of Day on Weekdays in 2020

As shown in Figure 4.12, the highest incident frequency for TOC7 has been exhibited around the PM peak period (4:00 p.m. - 6:30 p.m.), when their average response times are relatively longer than those during other operational hours.

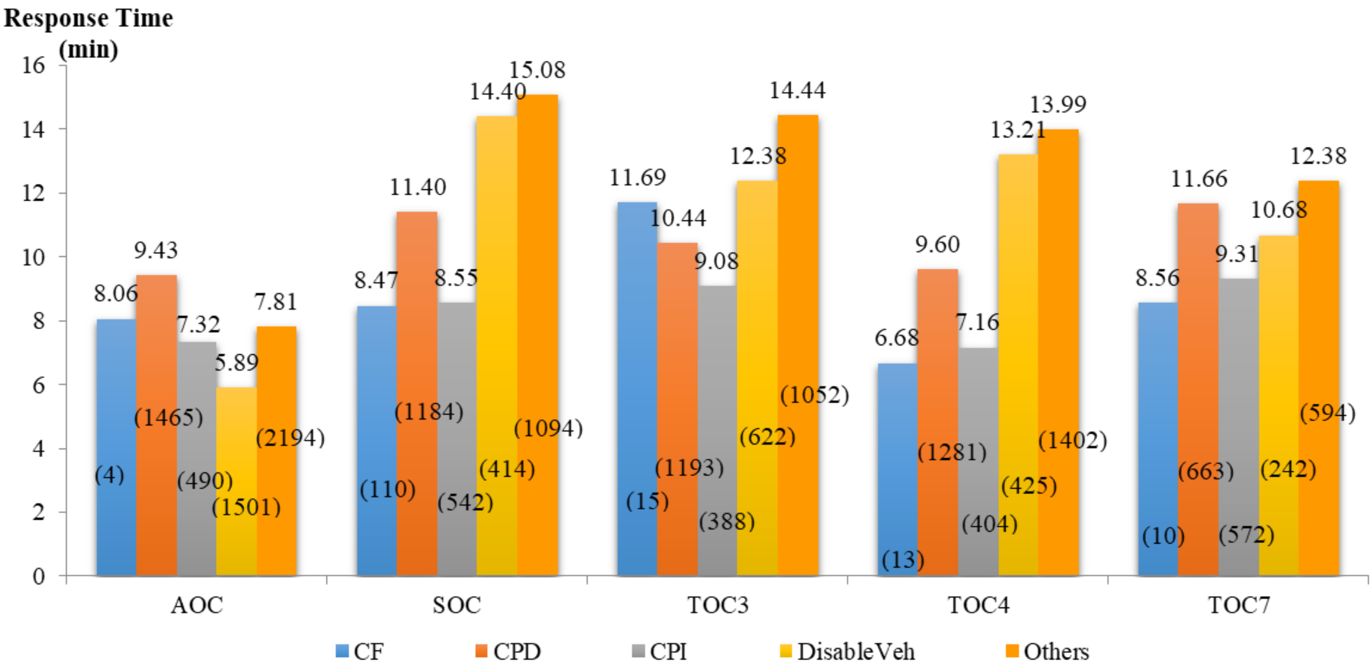


Note: Incident data only for response times between 1 minute and 60 minutes are used for this analysis.

Figure 4.12 Average Response Time for TOC7 by Time of Day on Weekdays in 2020

ANALYSIS OF RESPONSE EFFICIENCY

Figure 4.13 shows a further analysis of response efficiency, where most operation centers demonstrate relatively faster responses for incidents involving vehicle collision and injuries (CPI). On the other hand, SOC, TOC3 and TOC4 took relatively longer response times for disabled vehicles and other types of incidents such as fire, debris, police activities, etc.



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

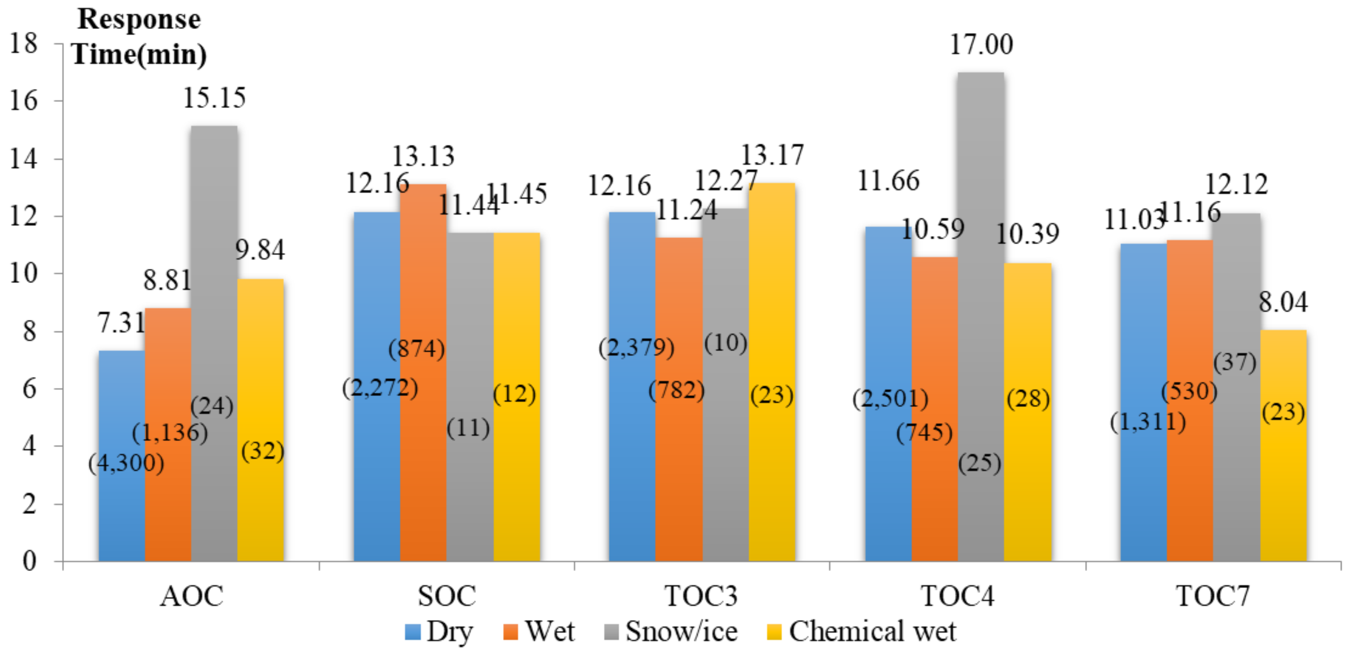
2. Numbers in parentheses show frequencies.

3. CF, CPD, and CPI represent collision-fatality, collision-property damage, and collision-personal injury, respectively. Others include police activities, off-road activities, emergency roadwork, debris in roadway, and vehicles on fire.

Figure 4.13 Average Response Times for Operation Centers by Incident Nature in 2020

4.2 ANALYSIS OF RESPONSE EFFICIENCY

With respect to the pavement conditions, most operation centers take shorter response times under dry or wet conditions than snow/ice conditions. Overall, AOC shows a shorter average response time than any other operation centers under dry or wet conditions (See Figure 4.14).



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

Figure 4.14 Average Response Times for Operation Centers by Pavement Conditions in 2020

Figures 4.15 through 4.19 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.

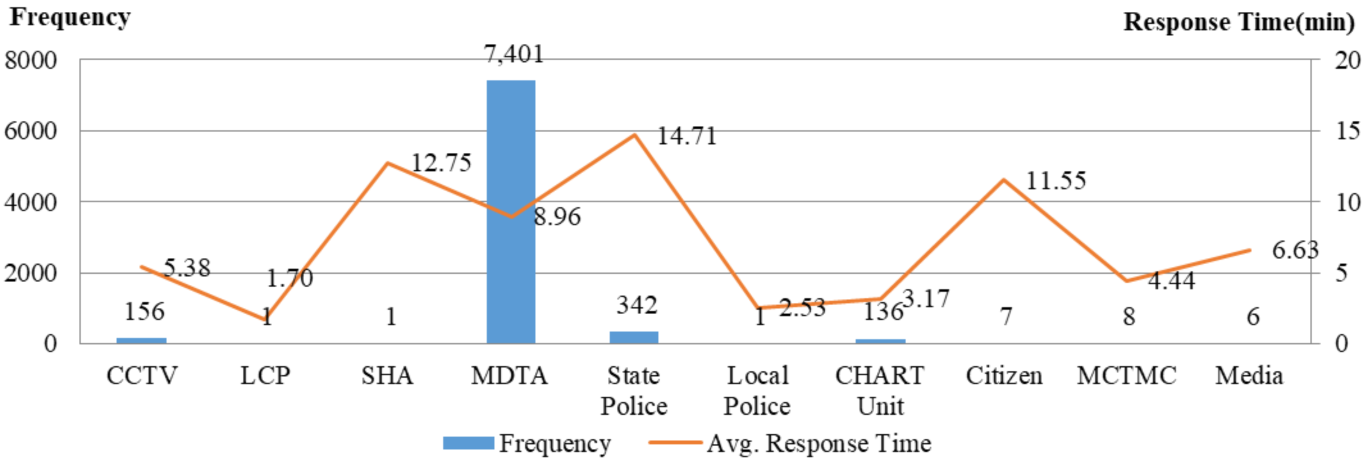


Figure 4.15 Average Response Times for AOC by Detection Source in 2020

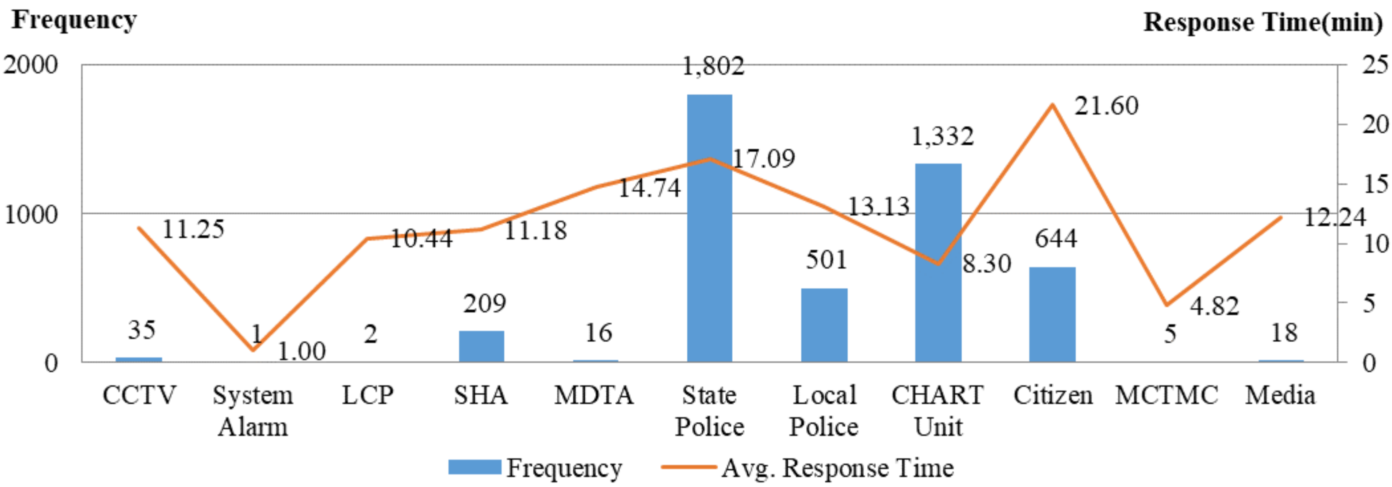


Figure 4.16 Average Response Times for SOC by Detection Source in 2020

4.2 ANALYSIS OF RESPONSE EFFICIENCY

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

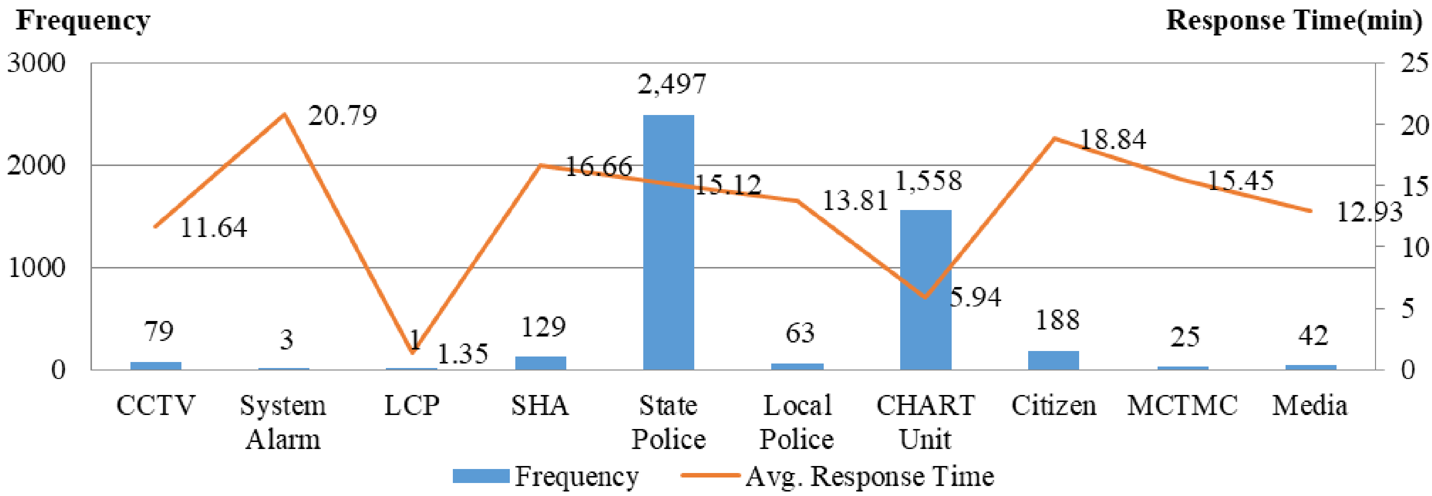


Figure 4.17 Average Response Times for TOC 3 by Detection Source in 2020

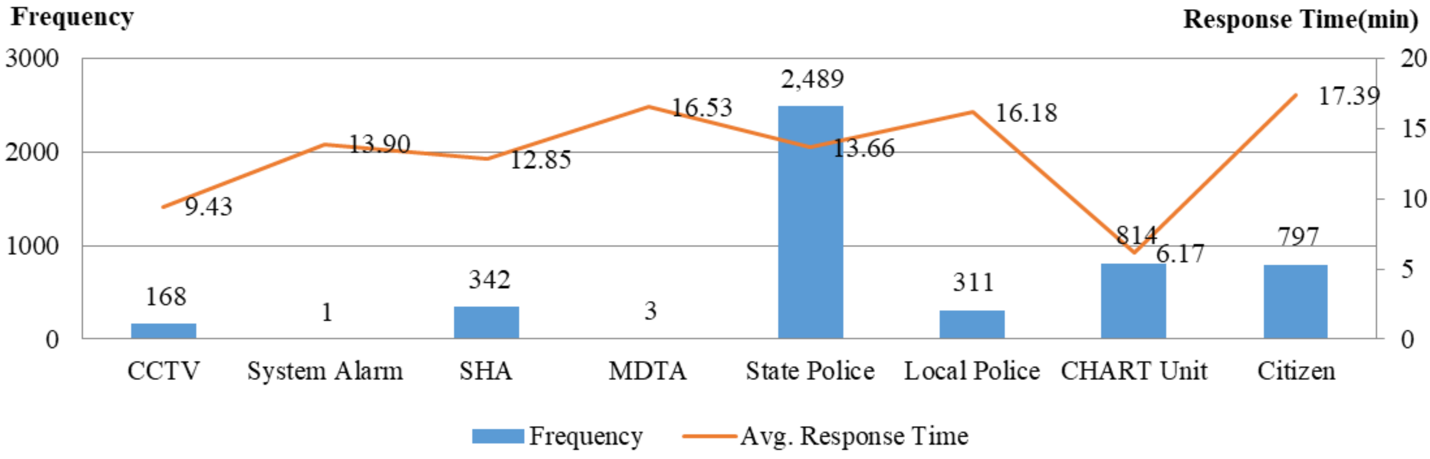


Figure 4.18 Average Response Times for TOC 4 by Detection Source in 2020

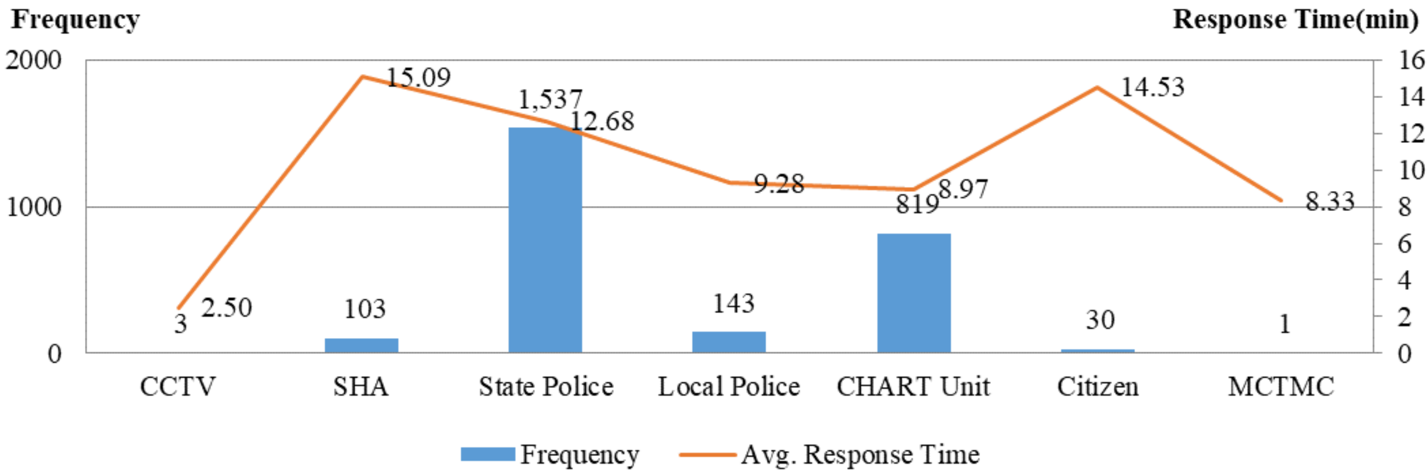
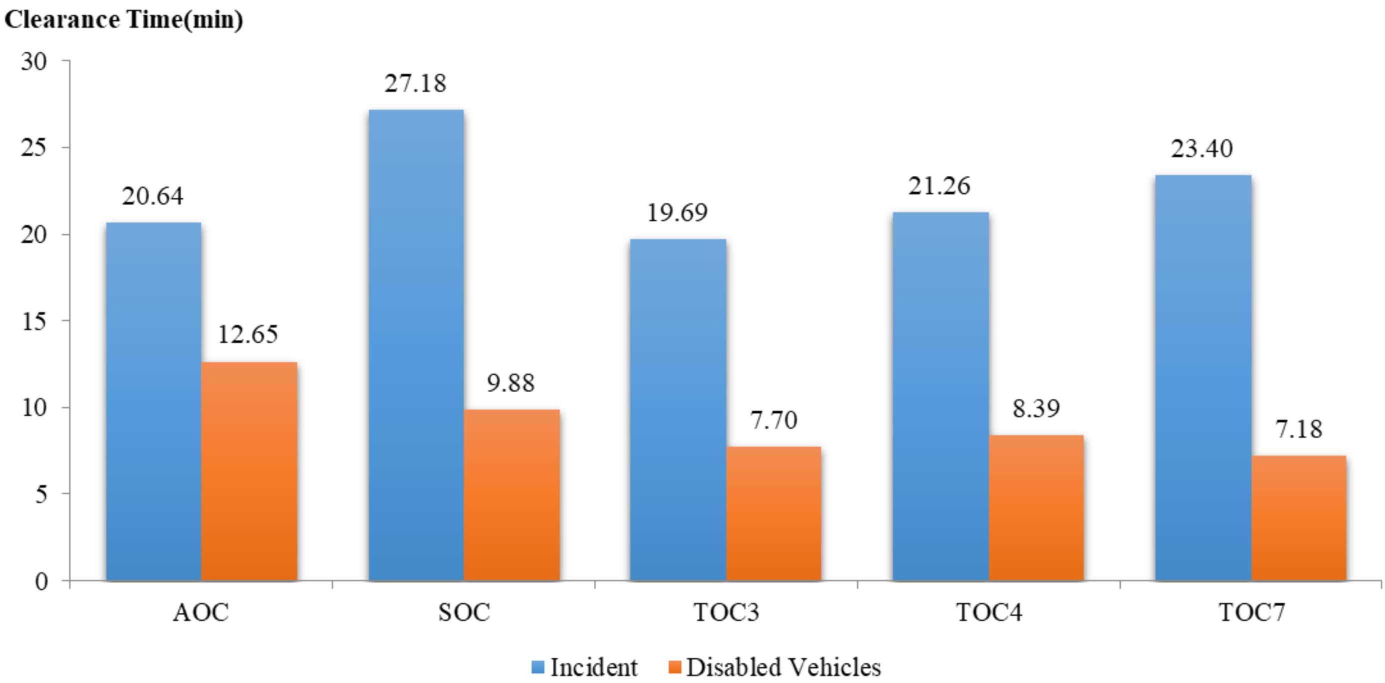


Figure 4.19 Average Response Times for TOC 7 by Detection Source in 2020

4.3 ANALYSIS OF CLEARANCE EFFICIENCY

As is well recognized, the efficiency of incident clearance could be varied by many factors. Figure 4.20 summarizes the performance of CHART incident clearance operations by operation center. The average clearance time by SOC is longer than any other for incidents, while 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 4.20 Average Clearance Times by Operation Center in 2020

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 2020 for non-responded incidents and those to which CHART responded. Since CHART's incident management team responded to most incidents in 2020, the data for non-CHART incidents are very limited.

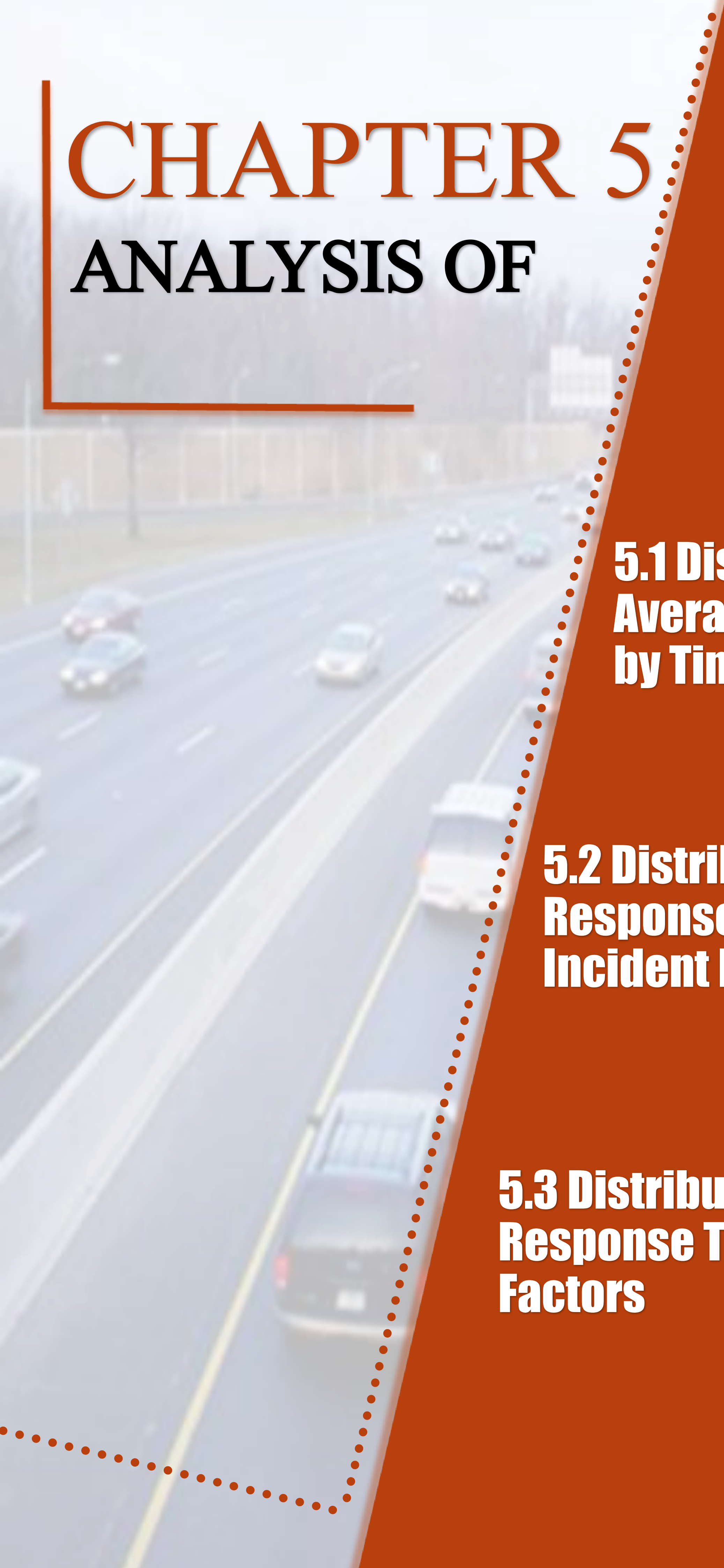
As shown in Table 4.1, the average durations for clearing an incident with and without the assistance of CHART were, respectively, about 25.35 minutes and 37.02 minutes in 2020. Note that incidents with durations of less than one minute were excluded from the analysis and incidents of "Unknown Lane Blockage" were redistributed to shoulder-only incidents and one-lane blockage incidents, which are mostly for minor incidents with the highest frequency. 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 2020 contributed to a reduction in blockage duration of about 31.52 percent, which has certainly contributed significantly to savings in travel times, fuel consumption, and related socioeconomic costs. Note that only about 84 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 2020 (Duration= Cleared Time-Received Time)

Blockage	With SHA Patrol		Without SHA Patrol		Incidents with CHART but took longer durations than the average duration of those without CHART	
	Duration (min)	Sample Frequency (A)	Duration (min)	Sample Frequency	Sample Frequency (C)	Percentage (C/A * 100)
Shoulder	20.68	5,358	35.16	384	991	18.49%
1 lane	22.56	11,166	34.93	696	2,436	21.82%
2 lanes	38.65	2,379	42.44	145	419	17.61%
3 lanes	45.64	702	52.80	58	246	35.04%
>=4 lanes	52.32	383	68.09	15	109	28.46%
Weighted Average	**25.35 (25.75)**	**19,988 (24,303)**	**37.02 (33.91)**	**1,298 (2,308)**		
Unknown	15.55	5,918	35.62	537		

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 2019



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

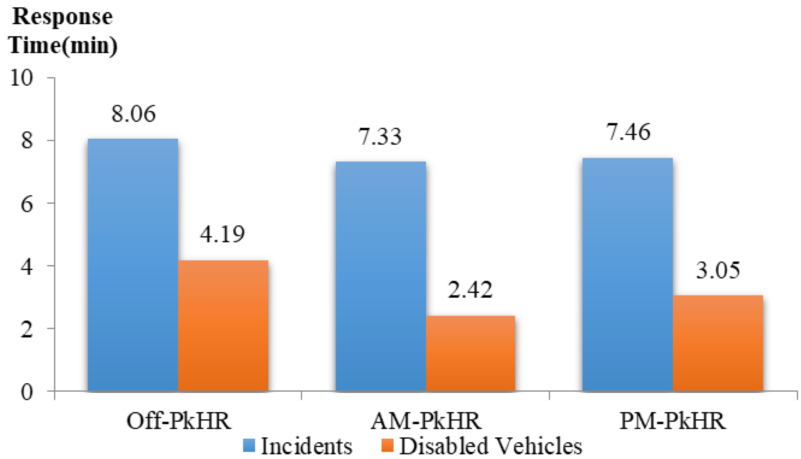
5.3 Distribution of Average Response Times by Various Factors

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).

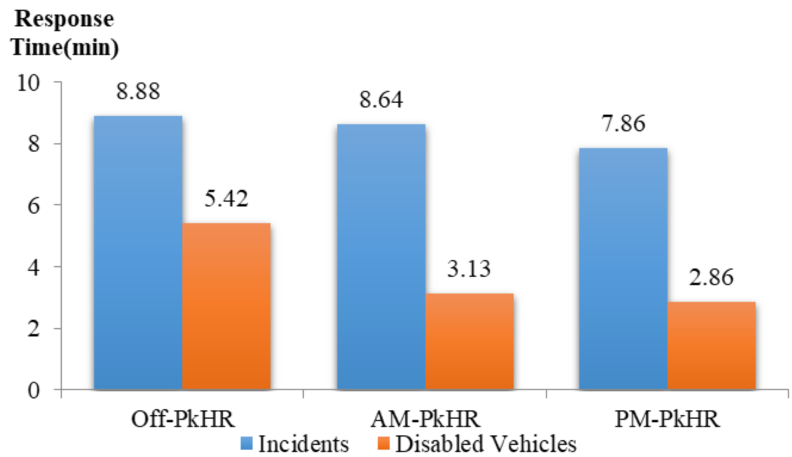
For these reasons, this chapter presents the results from the statistical analysis of incident response times; this analysis provides a fundamental insight into the characteristics of incident response times under various conditions.

5.1 DISTRIBUTION OF AVERAGE RESPONSE TIMES BY TIME OF DAY



Year 2020

Year 2019

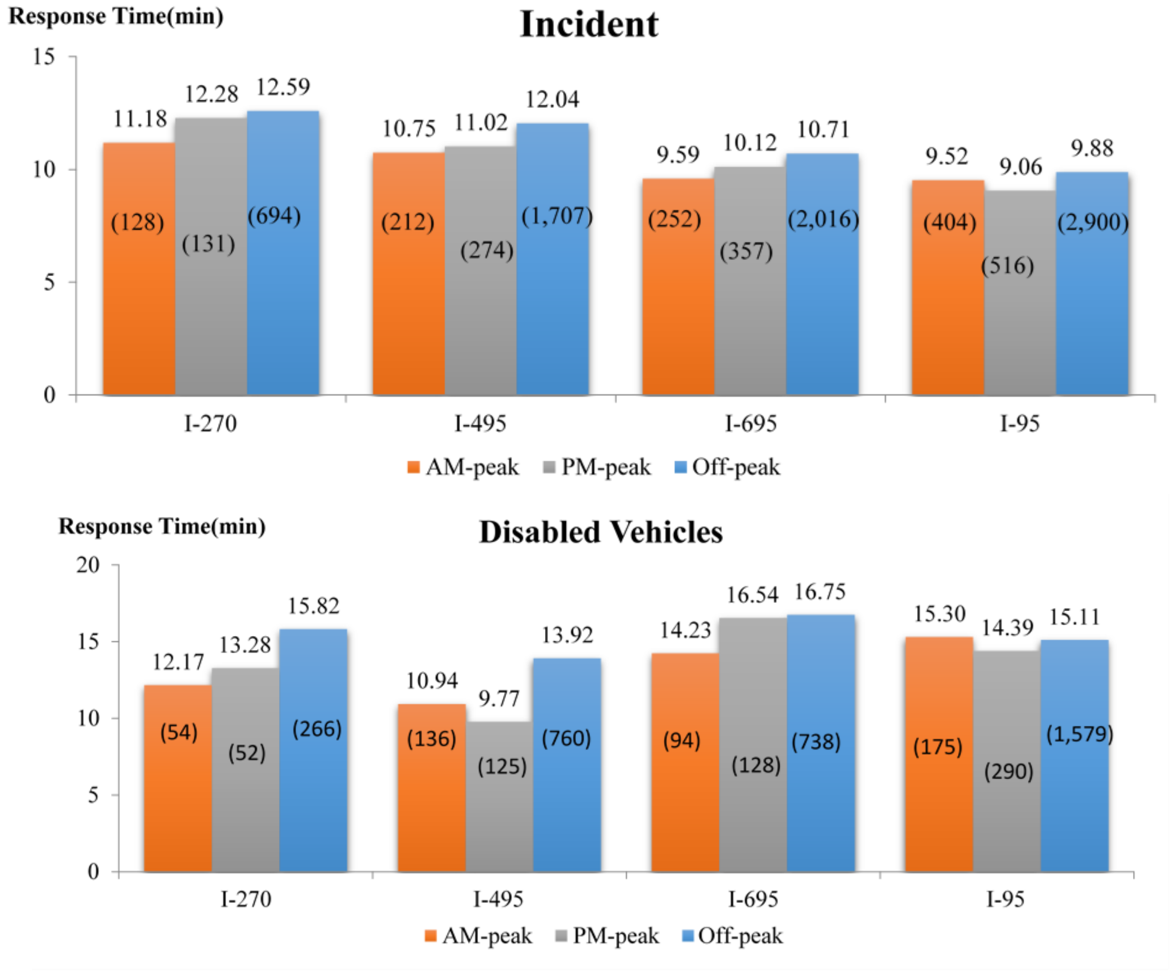


Note: Off-peak Hours include night times.

Figure 5.1 Distributions of Average Response Times by Time of Day in 2020 and 2019

Figure 5.1 compares response times by time of day in 2020 and 2019. In 2020, the average response time during a.m. peak hours was slightly shorter than that during p.m. peak hours for both incidents and disabled vehicles. The response times to incidents during peak hours were also shorter than those during off-peak hours in 2020.

DISTRIBUTION OF AVERAGE RESPONSE TIMES BY TIME OF DAY



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

Figure 5.2 Distributions of Average Response Times for Roads by Time of Day in 2020

Figure 5.2 shows the average response times by different times of day through the major roads. The incidents on I-270 experienced the longer durations during the both peak and off-peak periods. For disabled vehicles, the response times on I-95 during a.m. peak hours were longest, whereas disabled vehicles on I-695 had a longer response time during p.m. peak hours.

5.2 DISTRIBUTION OF AVERAGE RESPONSE TIMES BY INCIDENT NATURE

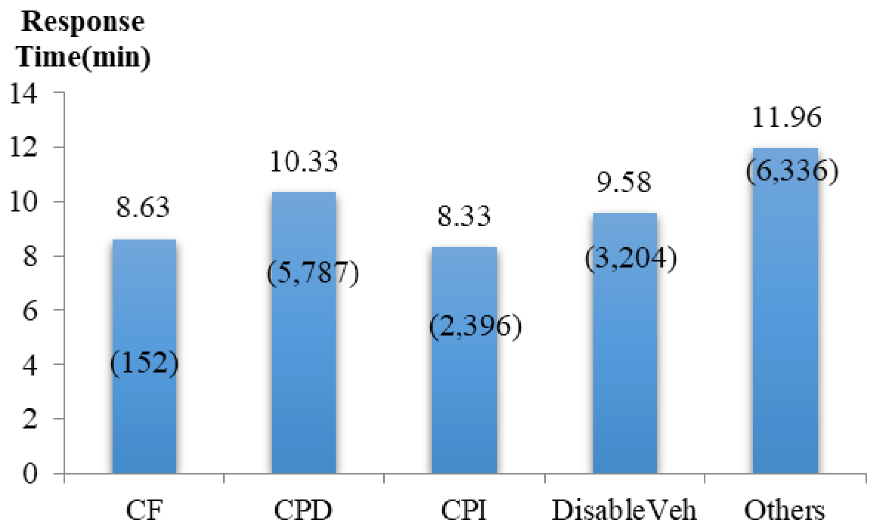
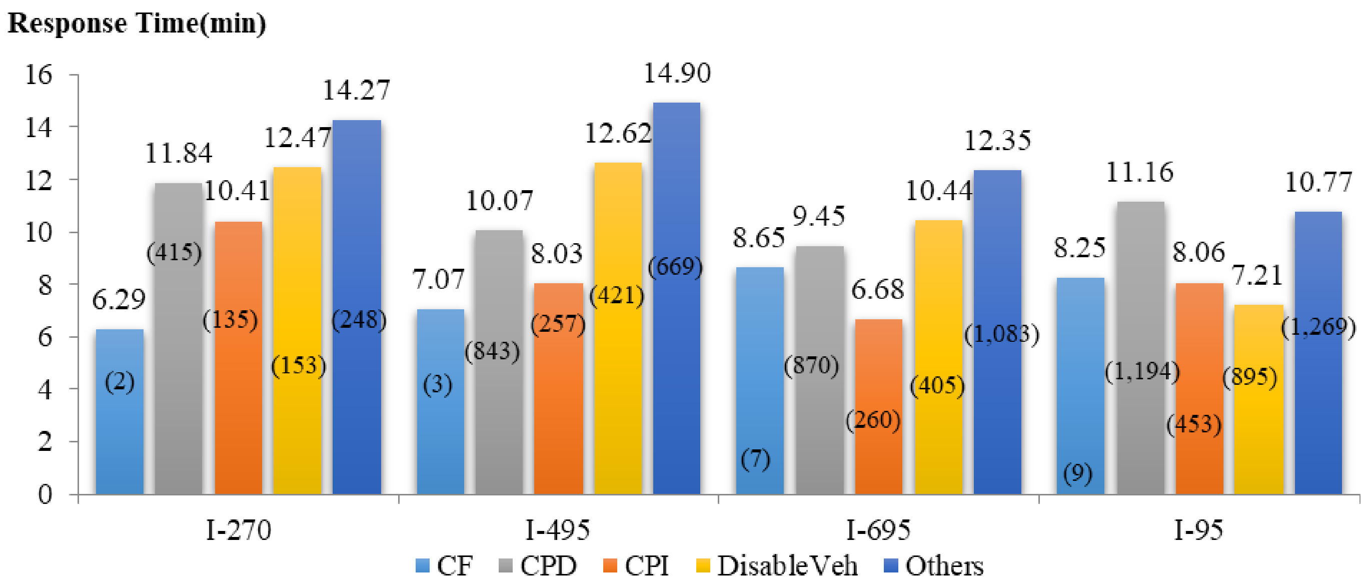


Figure 5.3 shows that the response times are likely to decrease as a detected incident becomes severe. For instance, the collision types of incidents, causing any fatality, injuries, or property damages (CF, CPI, and CPD), usually lead to quicker responses than other types of incidents.

Figure 5.3 Average Response Time by Incident Nature in 2020

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



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

Figure 5.4 Average Response Time for Roads by Incident Nature in 2020

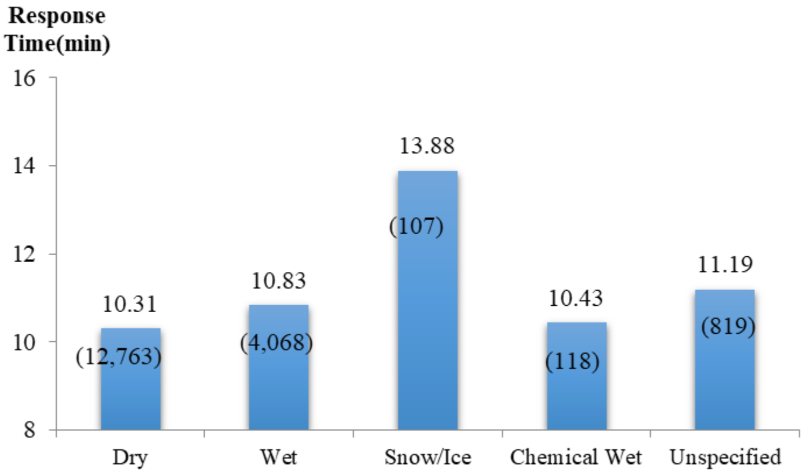
A similar pattern of decreased response times as the incident becomes severe appears on four major corridors as shown in Figure 5.4.

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 snow/ ice pavements, whereas they tend to be faster on wet or dry conditions. This factor reflects the weather conditions that are usually unavailable in most incident databases. When the pavement is chemically wet, the response time is likely to be similar to the dry condition.



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 2020

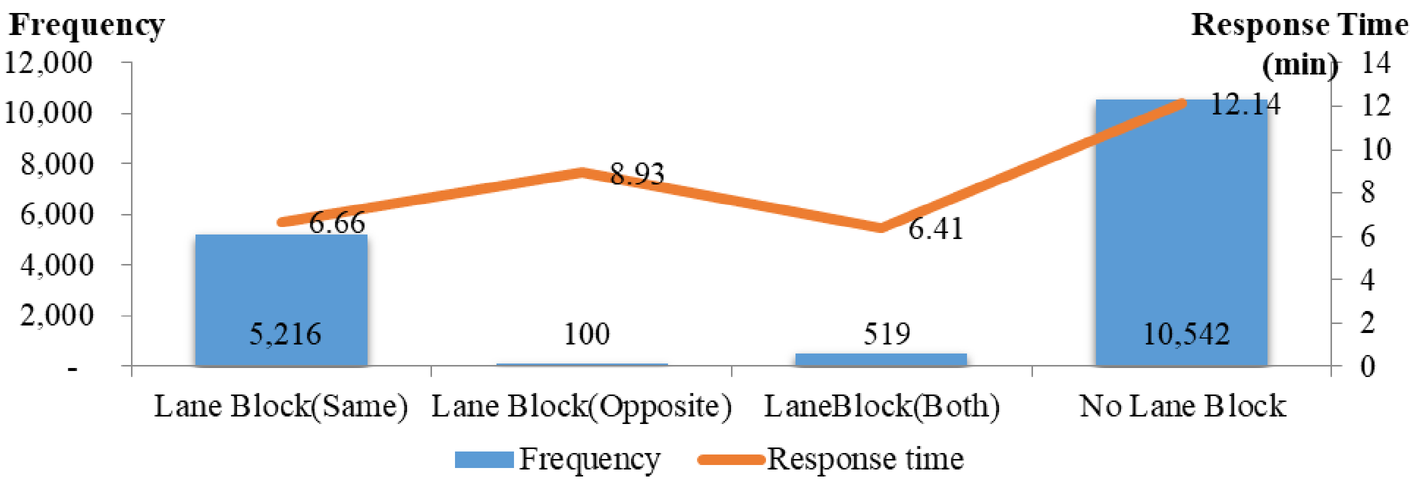
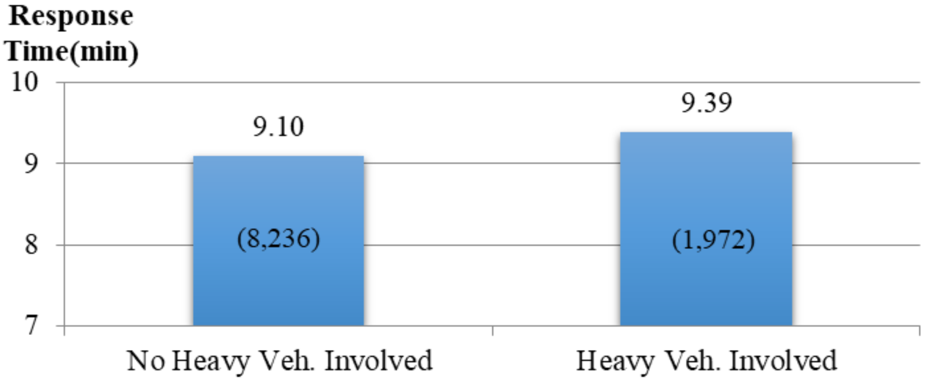


Figure 5.6 Average Response Time by Lane Blockage in 2020

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

5.3 DISTRIBUTION OF AVERAGE RESPONSE TIMES BY VARIOUS FACTORS

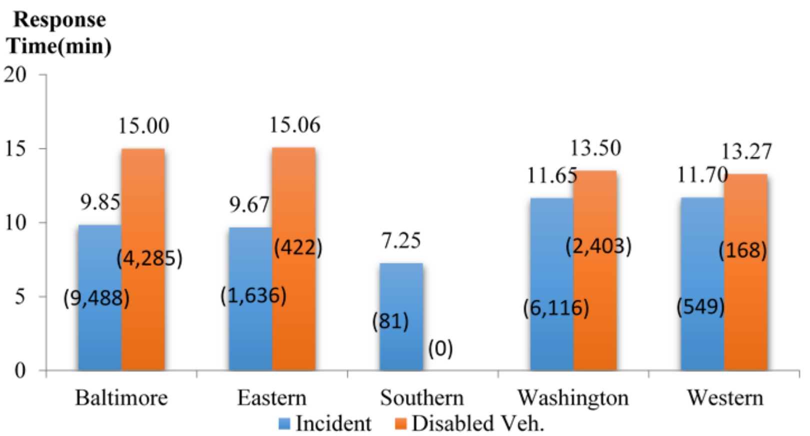
When a detected incident is involved with any heavy vehicles such as vans, SUVs, pick-up trucks, single-unit trucks, or tractor-trailers, the response is similar to the incidents which heavy vehicles are not involved in, as shown in Figure 5.7.



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

Figure 5.7 Average Response Time by Heavy Vehicle Involvement in 2020

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 Baltimore and Eastern regions for incidents. Urban areas like Washington region 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 all regions.



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

Figure 5.8 Average Response Time by Region in 2020

CHAPTER 6

ANALYSIS OF INCIDENT DURATIONS

6.1 Distribution of Average Incident Durations by Nature

6.2 Distribution of Average Incident Durations by County and Region

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

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

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 2020, about 36 percent of incidents without collisions were caused by Disabled Vehicles. A similar pattern was also observed in 2019, when about 39 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.

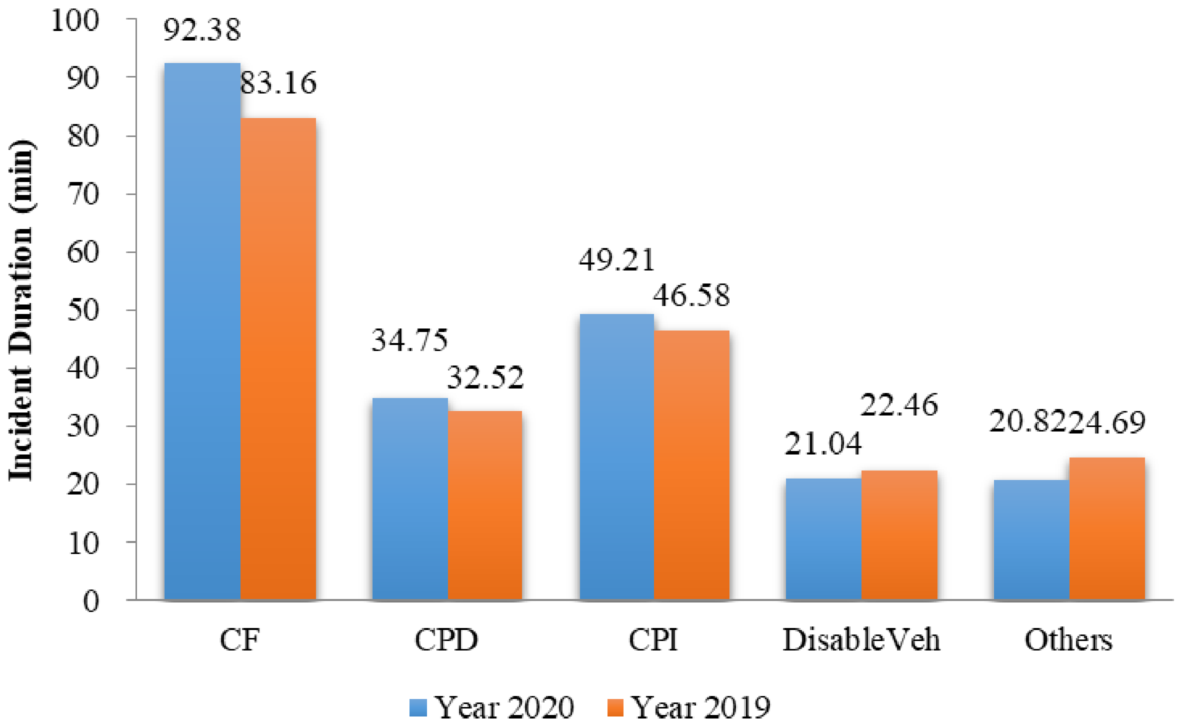
Table 6.1 Categories of Incident Nature

Incidents	With collision	Collisions-Fatalities (CF)	
		Collisions-Property Damage (CPD)	
		Collisions-Personal Injuries (CP)	
	Without collision	Disabled Vehicles	
		Others	Police Activities
			Off-Road Activities
			Emergency Roadwork
			Debris in Roadway
			Vehicles on Fire

DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY NATURE

6.1

Figure 6.1 summarizes the average incident duration for each type in year 2020. 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 than collisions.

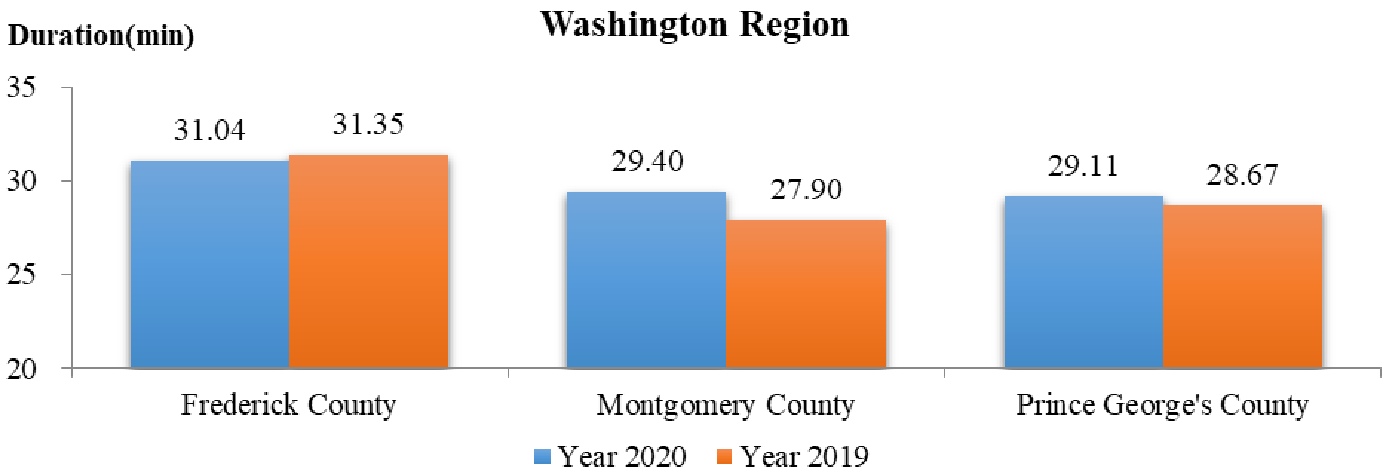


Note: 1. Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis
2. CF, CPD, and CPI represent collision-fatality, collision-property damage, and collision-personal injury, respectively.

Figure 6.1 Distribution of Average Incident Duration by Nature in 2020 and 2019

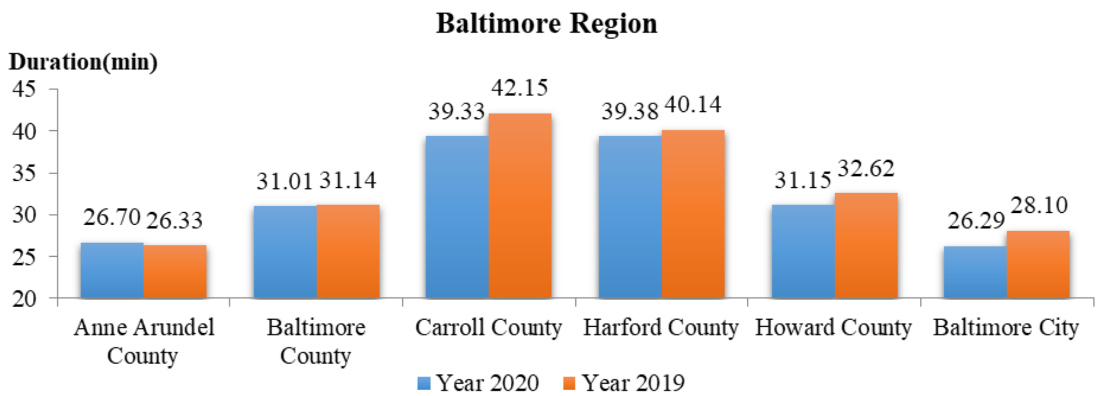
6.2 DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY COUNTY AND REGION

The distribution of incident durations also varies between counties and regions. In the Washington region, the area around Washington D.C. (Montgomery and P.G. Counties) has shorter incident duration then Frederick County, as shown in Figure 6.2. Figure 6.3 shows that the incidents especially around Carroll and Harford Counties had longer durations than incidents occurring in any other counties in the Baltimore region.



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

Figure 6.2 Distribution of Average Incident Duration by County in Washington Region in 2020 and 2019



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

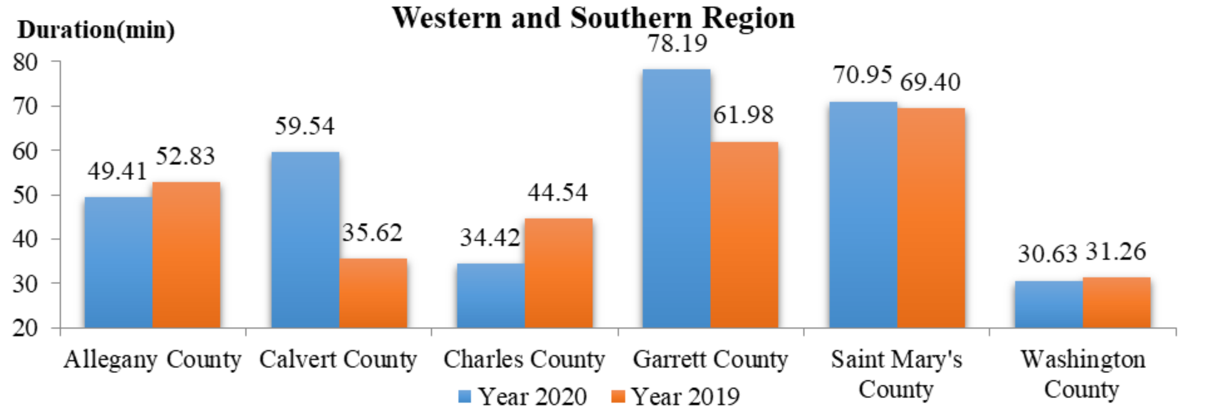
Figure 6.3 Distribution of Average Incident Duration by County in Baltimore Region in 2020 and 2019

DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY COUNTY AND REGION

6.2

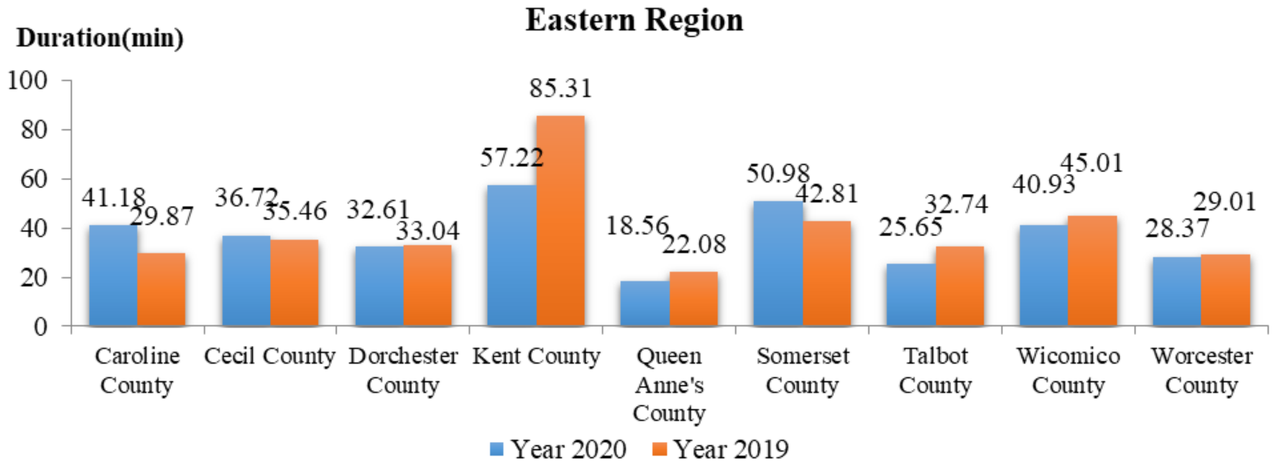
Incidents that occurred in counties of western and southern Maryland mostly resulted in relatively longer durations. Figure 6.4 shows that the average incident duration in some counties in these areas is usually close to one hour. Washington County had the shortest average incident duration in western and southern Maryland in the year 2020.

Similarly, the incidents occurring in Kent County on the Eastern Shore (Figure 6.5) are highly likely to result in longer durations than those in any other areas of Eastern Shore. On the other hand, incidents occurring in Queen Anne's County on the Eastern Shore take only about 18.6 minutes on average to be cleared.



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

Figure 6.4 Distribution of Average Incident Duration by County in Western and Southern Regions in 2020 and 2019



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 2020 and 2019

6.2 DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY COUNTY AND REGION

Table 6.2 summarizes the average response times, clearance times and incident durations by region. One can easily notice that the average response time in the Southern area was relatively long, and it took longer to clear the detected incident than in any other region. On the other hand, the Eastern region takes shorter to respond to an incident, and the average clearance time was shorter than for most other areas in Maryland in 2020.

Table 6.2 Summary of Incident Duration Components by Region

Region	Sample Frequency*	Avg. Response Time (mins)	Avg. Clearance Time (mins)	Avg. Incident Duration (mins)
Baltimore	11,566	7.11	22.29	29.40
Eastern	1,806	6.38	19.36	25.74
Southern	73	8.44	32.21	40.65
Washington	7,044	7.55	22.26	29.81
Western	788	7.11	24.78	31.89

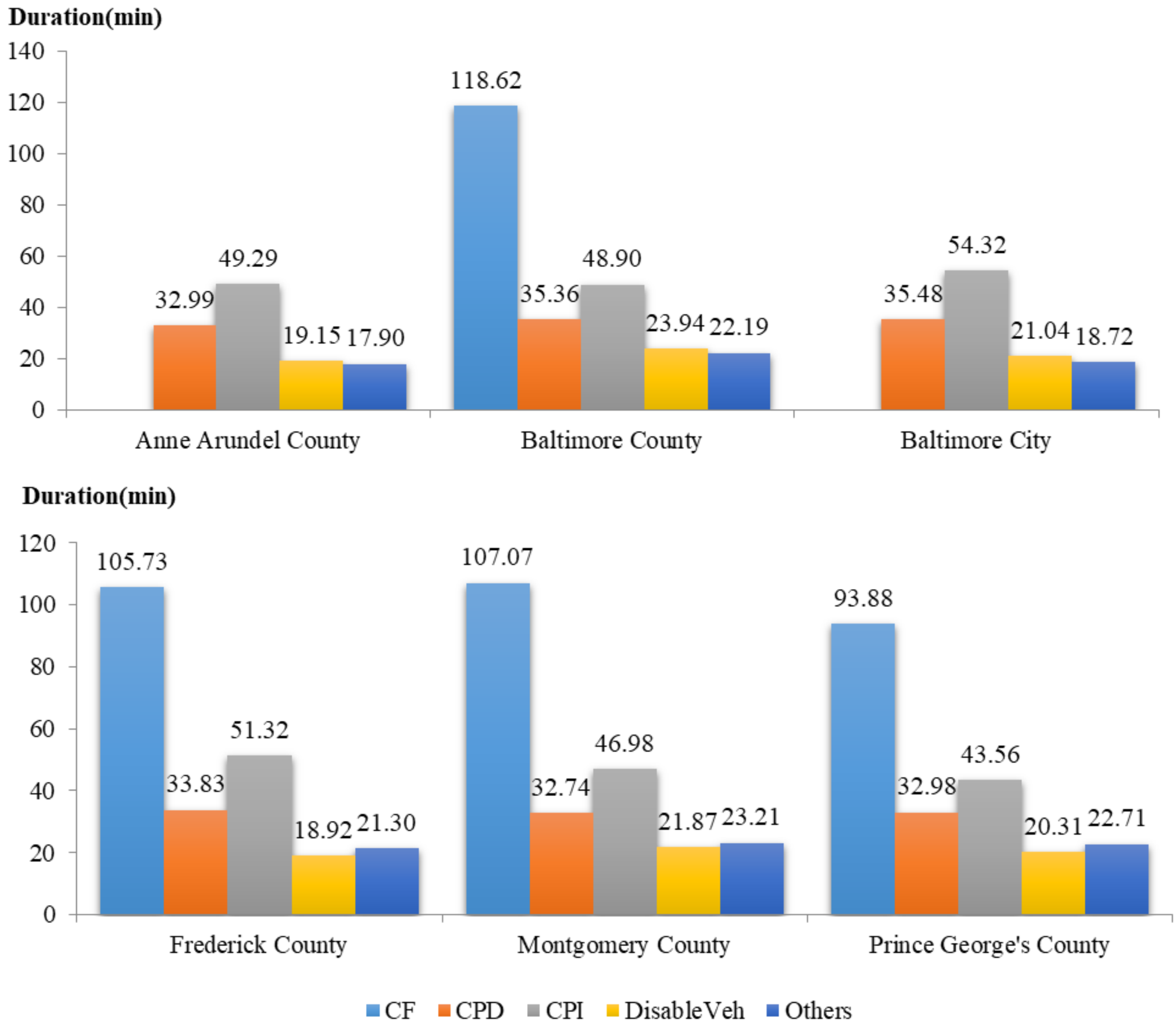
** Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis.*

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 Prince George's County was shorter than in any other area. On the other hand, CF-related incidents in Baltimore County resulted in relatively long durations.

DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY COUNTY AND REGION

6.2

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, the average response times for weekdays and weekends in 2020 have about 28 second's difference, while the average clearance time for weekends was also slightly 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	2020	16,986	7.11	22.00	29.11
	2019	20,631	7.46	22.05	29.51
Weekends	2020	4,293	7.57	22.78	30.35
	2019	5,739	7.75	23.74	31.49

**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	Avg. Clearance Time	Avg. Incident Duration
Off-Peak	2020	15,822	7.28	22.45	29.73
	2019	19,141	7.71	22.75	30.46
Peak*	2020	5,457	6.95	21.32	28.27
	2019	7,229	7.05	21.52	28.56

**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.

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.

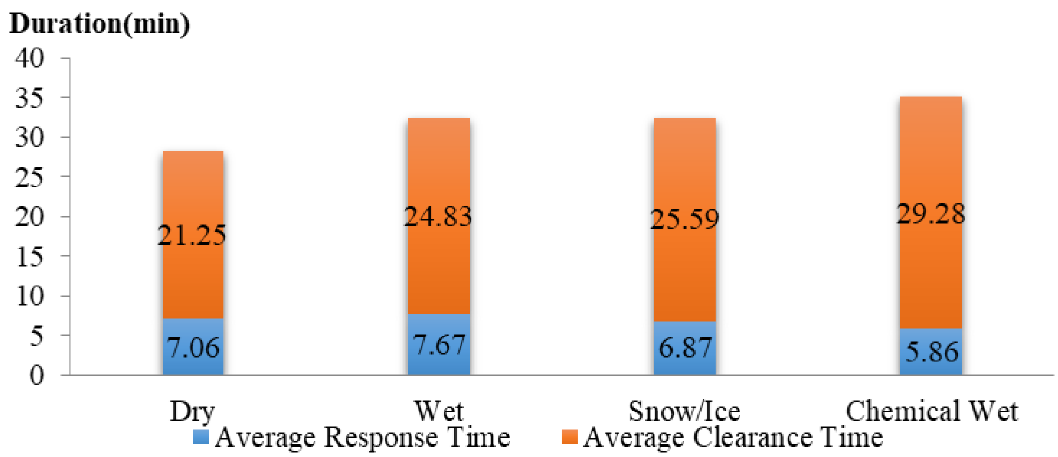
Table 6.5 Distribution of Average Incident Duration without and with CHART

	Year	Sample* Frequency	Avg. Response Time	Avg. Clearance Time	Avg. Incident Duration
w/o CHART	2020	900	15.16	31.85	47.01
	2019	1,781	9.18	29.14	38.32
w/ CHART	2020	20,379	6.85	21.73	28.58
	2019	24,589	7.41	21.93	29.33

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.

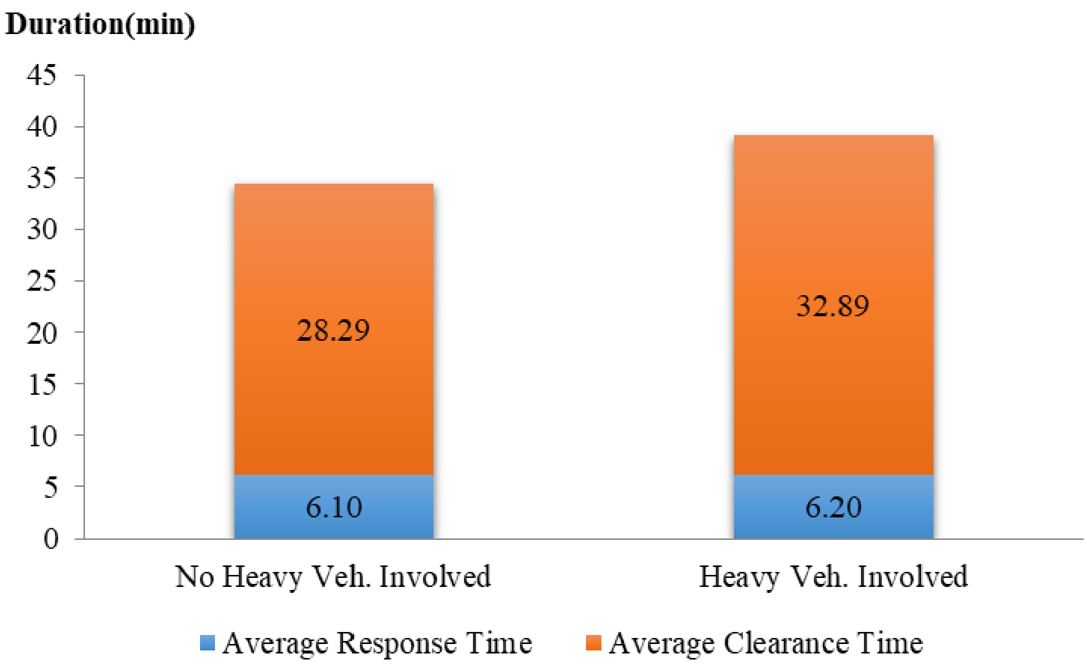
The response time and clearance time of incidents could vary with the pavement conditions, based on the pavement conditions. Figure 6.7 shows that chemical wet conditions (e.g., oil spill) may result in a faster response , but its average clearance time is likely to be longer.



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

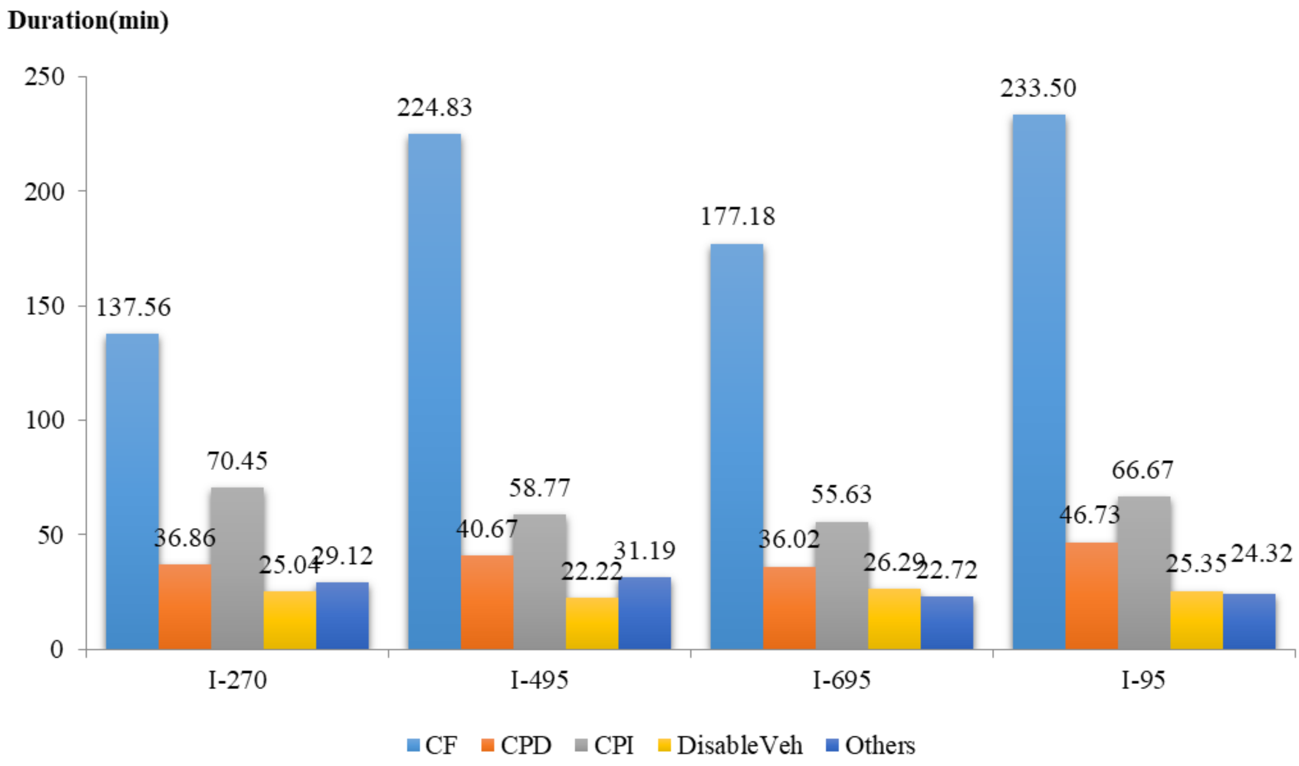
Figure 6.8 illustrates how a heavy vehicle influences the incident durations. In 2020, the response and clearance times for incidents involved with a heavy vehicle were likely to be longer than those without a heavy vehicle due to their incident severity.



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., 234 minutes).



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

Figure 6.9 Distribution of Average Incident Duration by Road and Nature

CHAPTER 7
BENEFITS FROM CHART'S INCIDENT MANAGEMENT

7.1 Assistance to Drivers

7.2 Potential Reduction in Secondary Incidents

7.3 Estimated Benefits due to Efficient Removal of Stationary Vehicles

7.4 Direct Benefits to Highway Users

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 2020 and Year 2019 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.

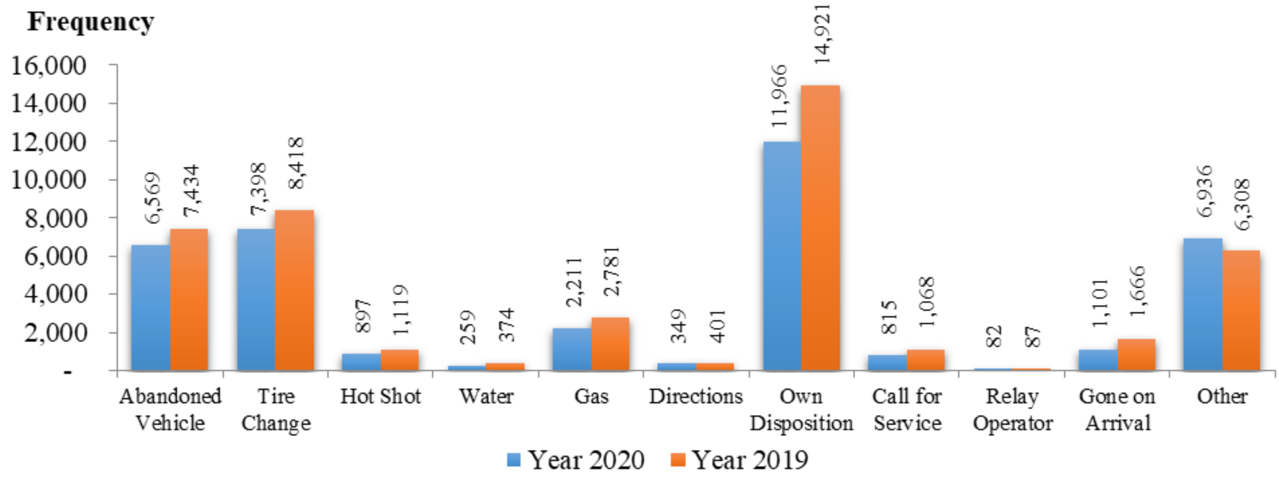


Figure 7.1 Classification of Driver Assistance Requests by Nature in 2020 and 2019

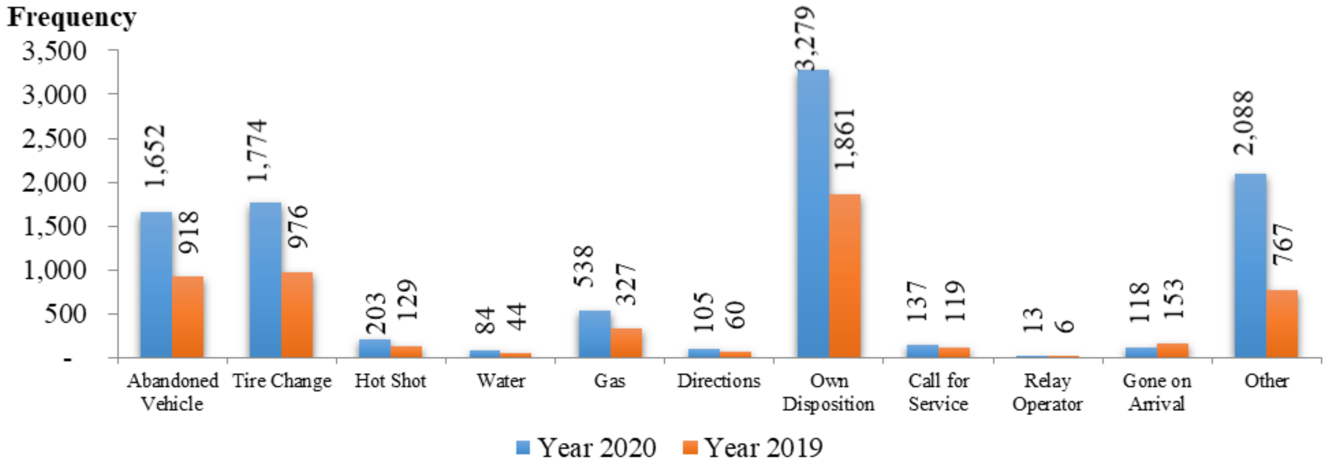


Figure 7.2 Classification of Driver Assistance Requests by Nature for TOC 3

ASSISTANCE TO DRIVERS

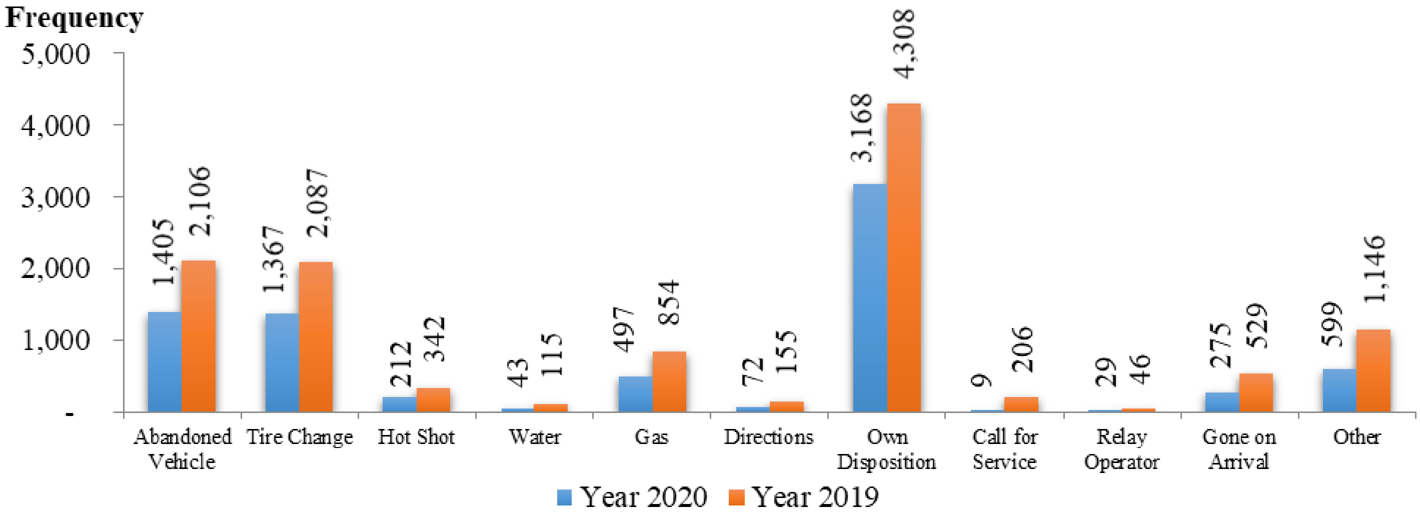


Figure 7.3 Classification of Driver Assistance Requests by Nature for TOC 4

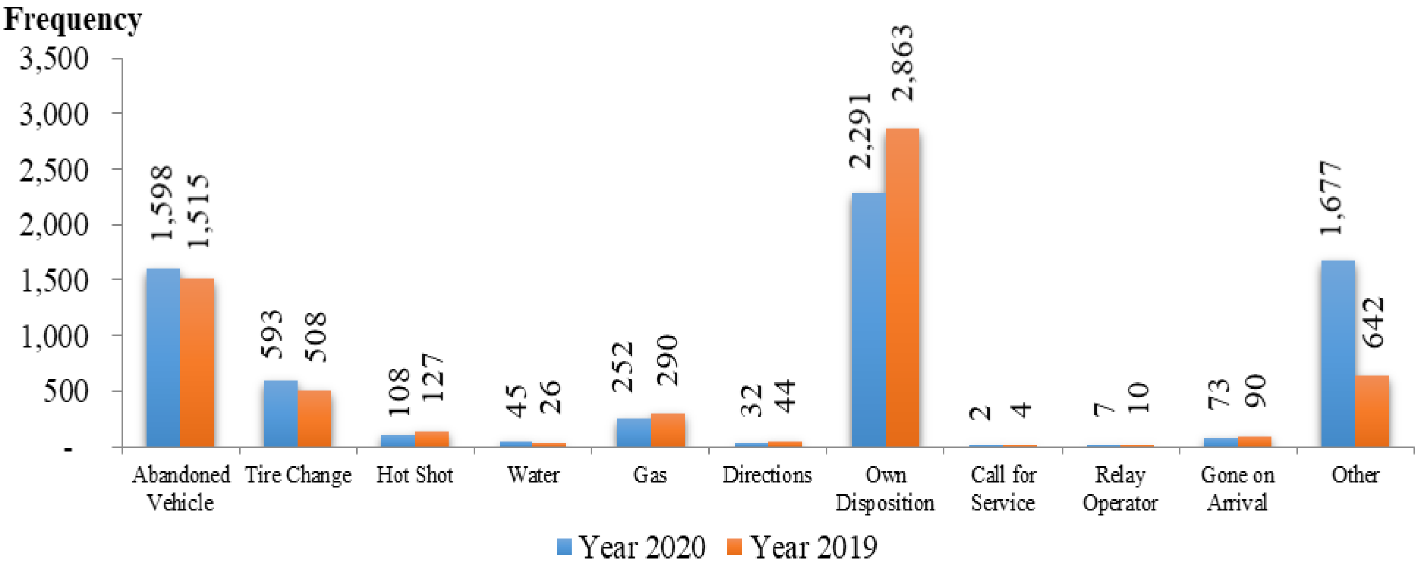


Figure 7.4 Classification of Driver Assistance Requests by Nature for TOC 7

These types of driver assistance in 2020 include flat tires, shortages of gas, or mechanical problems. Out of the 35,525 assistance requests, 9,609 assists were related to "out of gas" or "tire changes,", less than the number in 2019 (11,199 cases).

7.2 POTENTIAL REDUCTION IN SECONDARY INCIDENTS

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

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

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

Figure 7.5 shows the distribution of incidents classified as secondary incidents by our definition, using the accident database of the MSP for the year 2019. Notably, 1,003 secondary incidents occurred in 2020. A linear correlation is assumed between the number of secondary incidents and incident duration; the reduction in secondary incidents due to CHART's operations is estimated as follows:

- Number of reported secondary incidents: 1,003
- Estimated number of secondary incidents without CHART, which reduced incident duration by 28.41 percent, calculated as: 1,003/(1-0.2841) = 1,401 incidents
- The number of incidents potentially reduced due to CHART/MSHA operations: 1,401-1,003 = 398 secondary incidents .

Note that the 398 secondary incidents might have further prolonged the primary incident duration, increasing congestion, fuel consumption, and travel times. These associated benefits are not computed in this report due to data limitations but will be investigated in future studies.

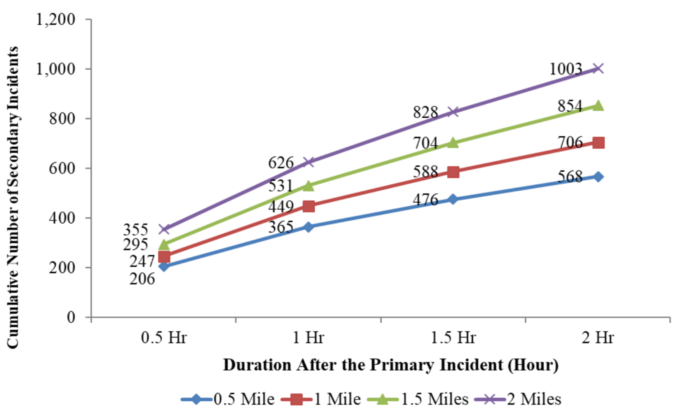


Figure 7.5 Distributions of Reported Secondary Incidents

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 (chartinput.umd.edu).

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	2020	170	264	49	137	71	26	30	53	800
	2019	175	286	62	156	73	30	21	57	860
	2018	173	231	57	184	74	33	28	69	849
	2017	229	212	62	207	79	45	23	98	955
	2016	228	264	58	223	88	47	29	94	1031

**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 (2020) and the Energy Information Administration (2020). Figure 7.6 also shows the difference in benefits between 2019 and 2020.

The evaluation for 2020 has adopted delay reduction for cars and trucks to convert the delays to fuel consumption. Please refer to Note 4 under Table 7.2 for details.

The estimated reductions in vehicle emissions for HC, CO, and NO were based on 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 26.91 million dollars. Thus, CHART operations in Year 2020 generated a total savings of 1,080.83 million dollars.

7.4 DIRECT BENEFITS TO HIGHWAY USERS

Table 7.2 Total Direct Benefits to Highway Users in 2020

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	Truck	1.49 (1.55)	Driver *$21.75/hour (20.60)* [1]	32.45 (31.93)
			Cargo $45.40/hour	67.74 (70.38)
	Car	22.03 (31.03)	*$42.80/hour (39.85)* [2]	942.71 (1,236.81)
Fuel Consumption (M gallon)		4.70 [4] (6.16)	Gasoline *$2.26/gal (2.69)* [3]	11.01 (17.05)
			Diesel *$2.56/gal (3.06)* [3]	
Emissions	HC (ton)	307.44 (425.97)	$6,700/ton	26.91 (37.20)
	CO (ton)	3,453.07 (4,784.28)	$6,360/ton	
	NO (ton)	147.24 (204.01)	$12,875/ton	
	CO_2 (metric ton)	43,372.14 (56,344.93)	$23/metric ton [5]	
Total		**$1,080.83 M (1,393.38)**		

<Note>
** The number in each parenthesis is the estimate in year 2019*
** 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 = 1, 492, 170.68… veh-hr * $21.75hr = $32, 447, 251. 40…*
<Source>
1. *The truck driver's unit cost is based on the information from the Bureau of Labor Statistics in year 2020*
2. *The car driver's unit cost is based on household income by the U.S. Census Bureau (2020).*
3. *The gasoline and diesel unit costs are from the Energy Information Administration in year 2020.*
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)*

7.4 DIRECT BENEFITS TO HIGHWAY USERS

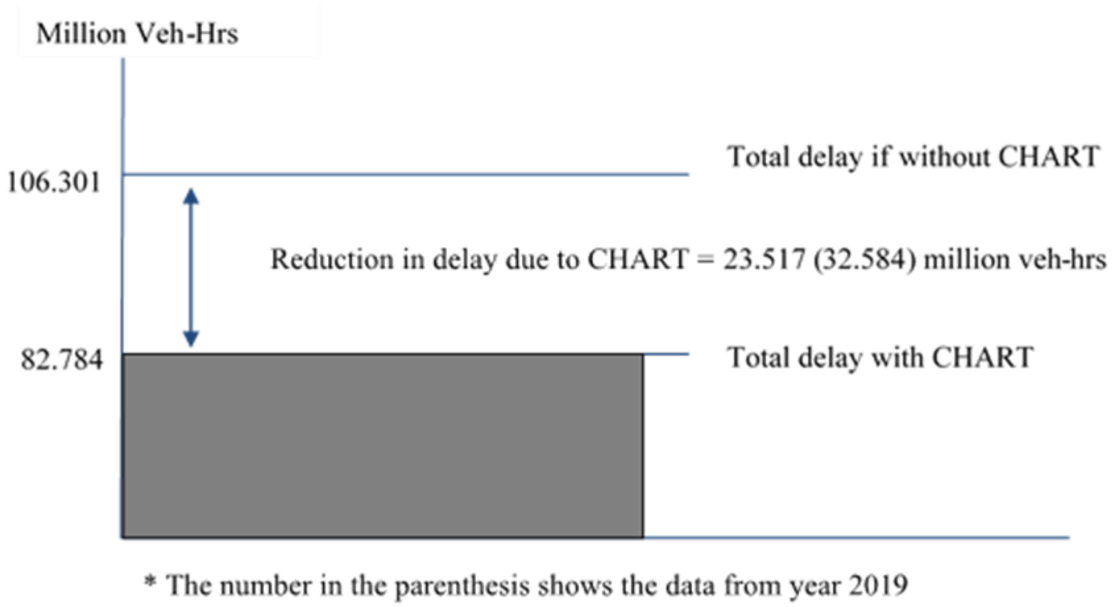


Figure 7.6 Reduction in Delay due to CHART in Year 2020

The total benefits decreased from 1,393.38 million dollars in 2019 to 1,080.83 million dollars in 2020, and the possible contributing factors are listed below:

- The total number of eligible incidents for the benefit estimate decreased by about 7.40 percent from year 2019 to year 2020 as shown in Table 7.3.
- The performance efficiency ratio, reflecting the difference between the incident duration with CHART and those without CHART, increased from 22.49 percent in 2019 to 28.41 percent in 2020 as shown in Table 7.4.
- Table 7.5 shows that the adjusted AADT with peak hour factors in 2020 for major roads in Maryland, compared with 2019, generally decreased by 18.30 percent.
- As shown in Table 7.6, truck percentage on major corridors in 2020 increased by 26.49 percent.

Table 7.3 Total Number of Incidents Eligible for the Benefit Estimate

	2019	2020	Δ('19 ~ '20) (%)
No. of Incidents	30,793	28,513	-7.40

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 2019 to Year 2020 is calculated as follows: $\Delta X(\%)=(X_{2020}-X_{2019})/X_{2019}*100$

Table 7.4 Comparison of Incident Duration Reduction between 2019 and 2020

	With CHART (mins)	Without CHART (mins)	Difference (mins)	Ratio in Difference
2019	27.67	35.70	8.03	22.49%
2020	27.06	37.80	10.74	28.41%
Δ('19 ~ '20)[2]	-2.20%	5.88%	33.73%	26.30%

Note: 1. The analysis is based on incidents that have main lanes blockage.

2.The percentage change in incident duration (X) from Year 2019 to Year 2020 is calculated as follows: $\Delta X(\%)=(X_{2020}-X_{2019})/X_{2019}*100$

7.4 DIRECT BENEFITS TO HIGHWAY USERS

Table 7.5 Changes in AADTs for Major Roads from 2019 to 2020

	Year	I-495	I-95	I-270	I-695	MD 295	US 50	US 1	I-83	I-70	Total
$\sum_{segments} AADT(vplph)*PHF$	2019	12,967	8,614	7,444	11,336	4,369	2,499	4,807	2,866	3,489	58,391
	2020	10,502	6,827	6,127	9,316	3,600	2,082	4,115	2,293	2,843	47,706
Δ('19~ '20) (%)		-19%	-21%	-18%	-18%	-18%	-17%	-14%	-20%	-19%	-18.30%

Note: The percentage change in the adjusted AADT(X) from Year 2019 to Year 2020 is calculated as follows: $\Delta X(\%)=(X_{2020}-X_{2019})/X_{2019}*100$

Table 7.6 Changes in Truck Percentage for Major Roads from 2019 to 2020

	Year	I-495	I-95	I-270	I-695	MD 295	US 50	US 1	I-83	I-70	Average
Truck Percentage (%)	2019	7.12	12.46	5.25	6.63	2.56	9.06	4.08	7.03	8.24	6.94
	2020	9.08	15.62	6.96	8.32	3.03	9.82	4.85	10.54	10.73	8.77
Δ('19~ '20) (%)		27.5%	25.4%	32.5%	25.6%	18.4%	8.4%	18.9%	49.9%	30.2%	26.49%

Note: The percentage change in the truck percentage from Year 2019 to Year 2020 is calculated as follows: $\Delta X(\%)=(X_{2020}-X_{2019})/X_{2019}*100$

Since each key factor has a different degree of exponential impact on the resulting benefit change, Table 7.7 has further illustrated the results of sensitivity analysis with respect to each key contributor.

Table 7.7 Sensitivity Analysis of key factors contributing to the Benefits (Unit: M dollar)

Benefit of the Previous Year (2019)			1, 393.38
Key Factor		**Δ('19~ '20)[1]**	**Estimated Benefits[2]**
Sensitivity Analysis	Adjusted AADT	▼ 18.30%	780.55（▼43.98%)
	Number of Incidents	▼ 7.40%	1,321.41 (▼5.17%)
	Incident duration percentage difference between w/ and w/o CHART	▲ 26.30%	1,759.79 (▲26.30%)
	Truck percentage	▲ 26.49%	1,404.98(▲0.83%)
	Monetary unit of gas price	▼ 16.12%	1,390.64 (▼0.20%)
	Monetary unit of time value	▲ 6.49%	1,486.62 (▲6.69%)
Benefit of the Current Year (2020)			1,080.83 (▼22.43%)

Note:1. This field is showing the difference in percentage between 2019 and 2020.
2. The numbers in each parenthesis show the percentage of the benefit change from year 2019.

Note that the sensitivity results shown in Table 7.7 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 2020 value, but setting all other factors identical to those in 2019; and

• Following the same procedures to analyze the sensitivity of the total 2019 benefits with respect to each key factor.

The decrease in the average adjusted AADT by 18.30 percent in 2020 contributed to a decrease of 43.98 percent in the total benefit while the 26.49 percent increase in truck percentage resulted in an increase of 0.83 percent in the benefit. The number of eligible incidents decreased by 7.40 percent in 2020, resulting in the benefit decrease of 5.17 percent. Note that the increasing ratio of the performance difference between incident durations with CHART and those without CHART by 26.30 percent resulted in a 26.30 percent increase in the total benefit. The total benefits increase by 6.69 percent due solely to the increase of 6.49 percent in drivers' income (i.e., a proxy for time value).

DIRECT BENEFITS TO HIGHWAY USERS 7.4

This chapter summarizes the benefits for major freeway corridors in 2020 due to CHART's incident response/operations. Table 7.8 shows the number of eligible main-lane-blockage incidents used for the benefit estimate, and the estimated delay reductions due to CHART for each corridor. The reductions in delay due to CHART's services on I-95, I-495/95, I-270, I-695, I-70, and I-83 are 4.61, 3.29, 1.04, 3.46, 1.50, and 0.45 million vehicle-hours, respectively, in 2020.

The total benefits produced from the reduction in delays, fuel consumption, and emissions for each major road in 2020 are summarized in Tables 7.9 (a) to 7.9 (f). The total benefits for I-95, I-495/95, I-270, I-695, I-70, and I-83 in 2020 are $219.43M, $154.22M, $47.62M, $159.13M, $70.65M, and $21.00M, respectively. Note that the benefits for those six major corridors account for 62.17% of the total CHART benefits of $1,080.83M.

Table 7.8 Number of Incidents Used for Benefit Estimate for the Six Major Corridors in 2020

Corridors	Number of Incidents	Reduction in Delay due to CHART (M vehicle-hours)
I-95	4,976	4.61
I-495	3,310	3.29
I-270	975	1.04
I-695	3,297	3.46
I-70	1,404	1.50
I-83	662	0.45
Others	13,889	9.16

Note: Only incidents causing main lanes blockage are included in the benefit estimates, but not those incidents causing only shoulder lanes blockage.

7.4 DIRECT BENEFITS TO HIGHWAY USERS

Table 7.9(a) Total Direct Benefits for I-95 in 2020

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	**Truck**	0.57	Driver *$21.75/hour*	12.43
			Cargo *$45.40/hour*	25.96
	Car	4.04	*$42.80/hour*	173.04
Fuel Consumption (M gallon)		1.12	Gasoline *$2.26/gal*	2.67
			Diesel *$2.56/gal*	
Emissions	**HC (ton)**	60.33	$6,700/ton	5.33
	CO (ton)	677.57	$6,360/ton	
	NO (ton)	28.89	$12,875/ton	
	CO_2 (metric ton)	10,531.81	$23/metric ton [5]	
Total		**$219.43 M**		

Table 7.9(b) Total Direct Benefits for I-495 in 2020

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	**Truck**	0.32	Driver *$21.75/hour*	7.04
			Cargo *$45.40/hour*	14.69
	Car	2.97	*$42.80/hour*	126.96
Fuel Consumption (M gallon)		0.74	Gasoline *$2.26/gal*	1.75
			Diesel *$2.56/gal*	
Emissions	**HC (ton)**	43.01	$6,700/ton	3.78
	CO (ton)	483.04	$6,360/ton	
	NO (ton)	20.60	$12,875/ton	
	CO_2 (metric ton)	6,899.33	$23/metric ton [5]	
Total		**$154.22 M**		

DIRECT BENEFITS TO HIGHWAY USERS 7.4

Table 7.9(c) Total Direct Benefits for I-270 in 2020

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	**Truck**	0.06	Driver *\$21.75/hour*	1.34
			Cargo *\$45.40/hour*	2.79
	Car	0.98	*\$42.80/hour*	41.82
Fuel Consumption (M gallon)		0.20	Gasoline *\$2.26/gal*	0.48
			Diesel *\$2.56/gal*	
Emissions	**HC (ton)**	13.58	\$6,700/ton	1.19
	CO (ton)	152.49	\$6,360/ton	
	NO (ton)	6.50	\$12,875/ton	
	CO_2 (metric ton)	1,883.62	\$23/metric ton [5]	
Total		**\$47.62 M**		

Table 7.9(d) Total Direct Benefits for I-695 in 2020

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	**Truck**	0.22	Driver *\$21.75/hour*	4.76
			Cargo *\$45.40/hour*	9.95
	Car	3.24	*\$42.80/hour*	138.83
Fuel Consumption (M gallon)		0.69	Gasoline *\$2.26/gal*	1.62
			Diesel *\$2.56/gal*	
Emissions	**HC (ton)**	45.27	\$6,700/ton	3.96
	CO (ton)	508.45	\$6,360/ton	
	NO (ton)	21.68	\$12,875/ton	
	CO_2 (metric ton)	6,381.89	\$23/metric ton [5]	
Total		**\$159.13 M**		

Table 7.9(e) Total Direct Benefits for I-70 in 2020

Reduction due to CHART		**Amount**	**Unit rate**	**In M Dollar**
Delay (M veh-hr)	**Truck**	0.16	Driver *$21.75/hour*	3.38
			Cargo *$45.40/hour*	7.05
	Car	1.35	*$42.80/hour*	57.59
Fuel Consumption (M gallon)		0.34	Gasoline *$2.26/gal*	0.81
			Diesel *$2.56/gal*	
Emissions	**HC (ton)**	19.62	$6,700/ton	1.73
	CO (ton)	220.38	$6,360/ton	
	NO (ton)	9.40	$12,875/ton	
	CO_2 (metric ton)	3,203.82	$23/metric ton [5]	
Total		**$70.56 M**		

Table 7.9(f) Total Direct Benefits for I-83 in 2020

Reduction due to CHART		**Amount**	**Unit rate**	**In M Dollar**
Delay (M veh-hr)	**Truck**	0.04	Driver *$21.75/hour*	0.90
			Cargo *$45.40/hour*	1.89
	Car	0.41	*$42.80/hour*	17.46
Fuel Consumption (M gallon)		0.10	Gasoline *$2.26/gal*	0.23
			Diesel *$2.56/gal*	
Emissions	**HC (ton)**	5.88	$6,700/ton	0.52
	CO (ton)	65.99	$6,360/ton	
	NO (ton)	2.81	$12,875/ton	
	CO_2 (metric ton)	923.41	$23/metric ton [5]	
Total		**$21.00 M**		

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 7.10(a) and 7.10(b), where the daily delay reductions for the Washington region in 2020 were 1,836.06 hours/day and 30,440.80 hours/day for trucks and cars, respectively, compared with the 1,779.29 hours/day for trucks and 40,555.44 hours/day for cars in 2019. The delay reduction for trucks in the Baltimore region decreased from 4,183.18 hours/day in 2019 to 3,903.06 hours/day in 2020, and decreased from 78,803.63 hours/day in 2019 to 54,271.27 hours/day in 2020 for passenger cars. The overall reductions in emissions (i.e., by cars and trucks) for the entire region were $103,518/day and $143,094/day for the years 2020 and 2019, respectively.

Table 7.10(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	
		2020	2019	2020	2019	2020	2019
Annual Delay Reduction	hour	1,492,171	1,550,244	477,375	462,616	1,014,796	1,087,628
Daily Delay Reduction	hour	5,739	5,962	1,836	1,779	3,903	4,183
Emission Reduction							
HC reduction	ton/day	0.075	0.078	0.028	0.029	0.047	0.049
	$/day	502.68	522.25	190.50	196.61	312.18	325.64
CO reduction	ton/day	0.843	0.875	0.319	0.330	0.523	0.546
	$/day	5,359.45	5,568.03	2,031.05	2,096.14	3,328.40	3,471.89
NO reduction	ton/day	0.036	0.037	0.014	0.014	0.022	0.023
	$/day	462.63	480.64	175.32	180.94	287.31	299.70
CO2 reduction	metric ton/day	49.54	51.46	18.77	19.37	30.76	32.09
	$/day	1,139.31	1,183.65	431.76	445.60	707.55	738.05
Total	$/day	7,464.07	7,754.56	2,828.63	2,919.29	4,635.44	4,835.27

Table 7.10(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	
		2020	2019	2020	2019	2020	2019
Annual Delay Reduction	hour	22,025,139	31,033,360	7,914,609	10,544,415	14,110,530	20,488,944
Daily Delay Reduction	hour	84,712	119,359	30,441	40,555	54,271	78,804
Emission Reduction							
HC reduction	ton/day	1.107	1.560	0.420	0.587	0.688	0.973
	$/day	7,419.85	10,454.55	2,811.88	3,935.73	4,607.98	6,518.83
CO reduction	ton/day	12.438	17.526	4.714	6.598	7.725	10.928
	$/day	79,107.96	111,462.89	29,979.26	41,961.39	49,128.71	69,501.51
NO reduction	ton/day	0.530	0.747	0.201	0.281	0.329	0.466
	$/day	6,828.67	9,621.58	2,587.84	3,622.15	4,240.84	5,999.43
CO2 reduction	metric ton/day	117.28	165.25	44.45	62.21	72.84	103.04
	$/day	2,697.46	3,800.71	1,022.25	1,430.82	1,675.21	2,369.89
Total	$/day	96,053.95	135,339.74	36,401.21	50,950.08	596,52.73	84,389.66

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 2020 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 2020 was 11.64 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 2020 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 2020, 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

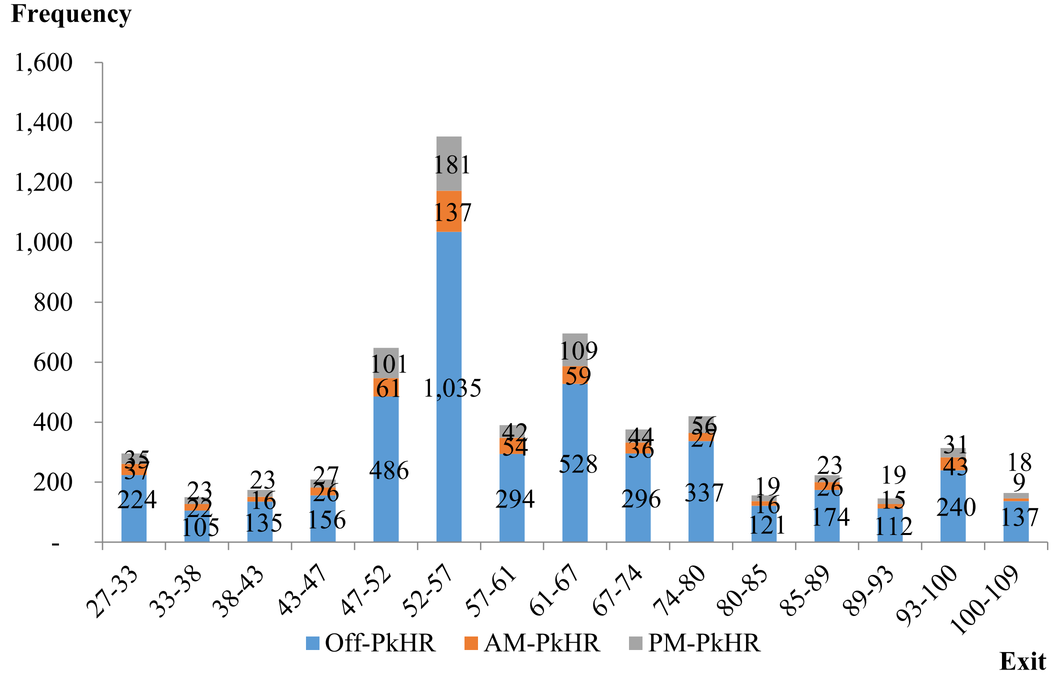


Figure A.1 Distribution of Incidents by Time of Day on I-95 in Year 2020

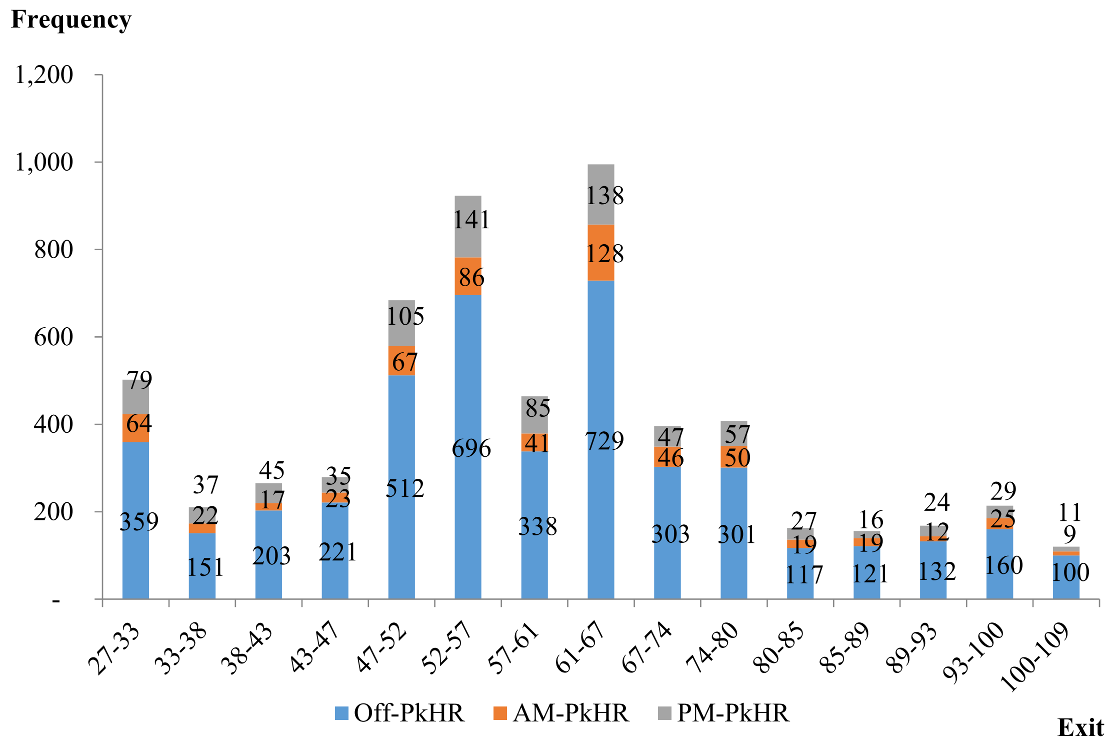


Figure A.2 Distribution of Disabled Vehicles by Time of Day on I-95 in Year 2020

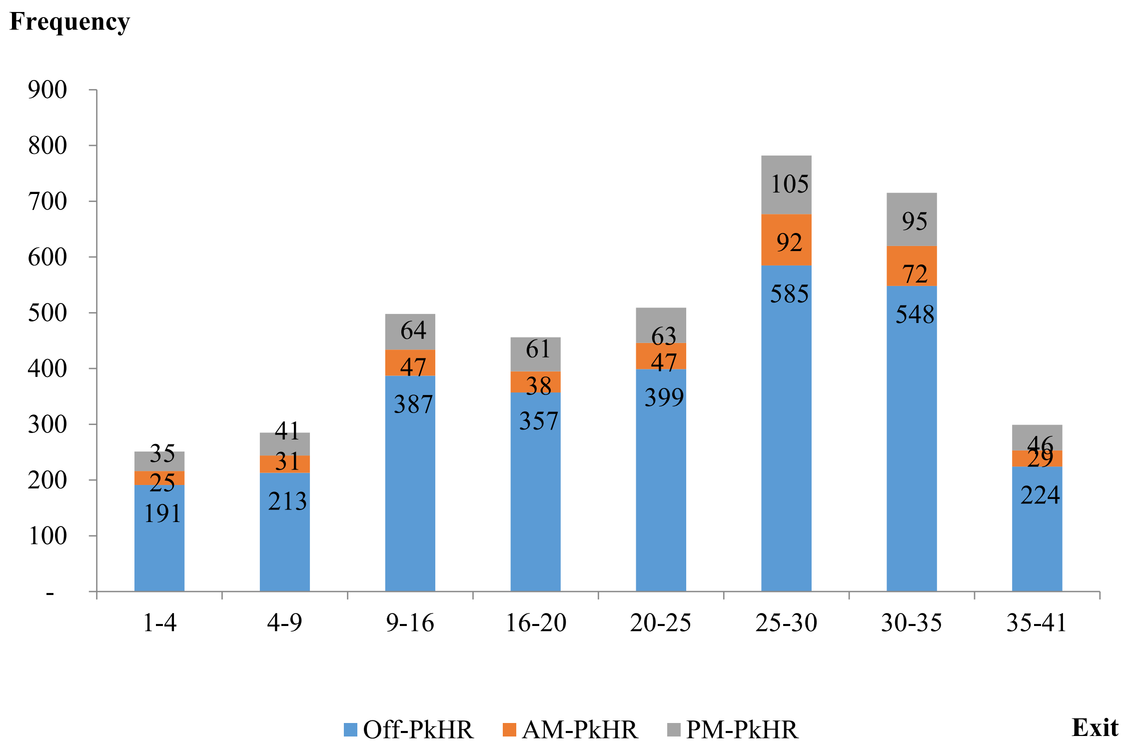


Figure A.3 Distribution of Incidents by Time of Day on I-495 in Year 2020

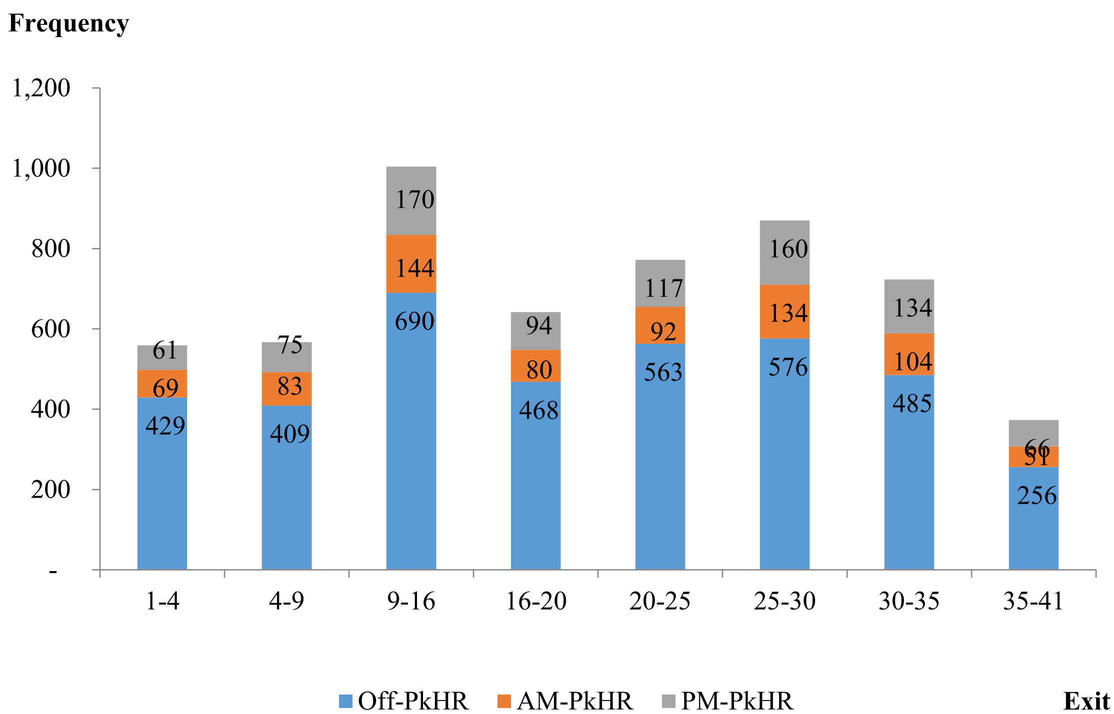


Figure A.4 Distribution of Disabled Vehicles by Time of Day on I-495 in Year 2020

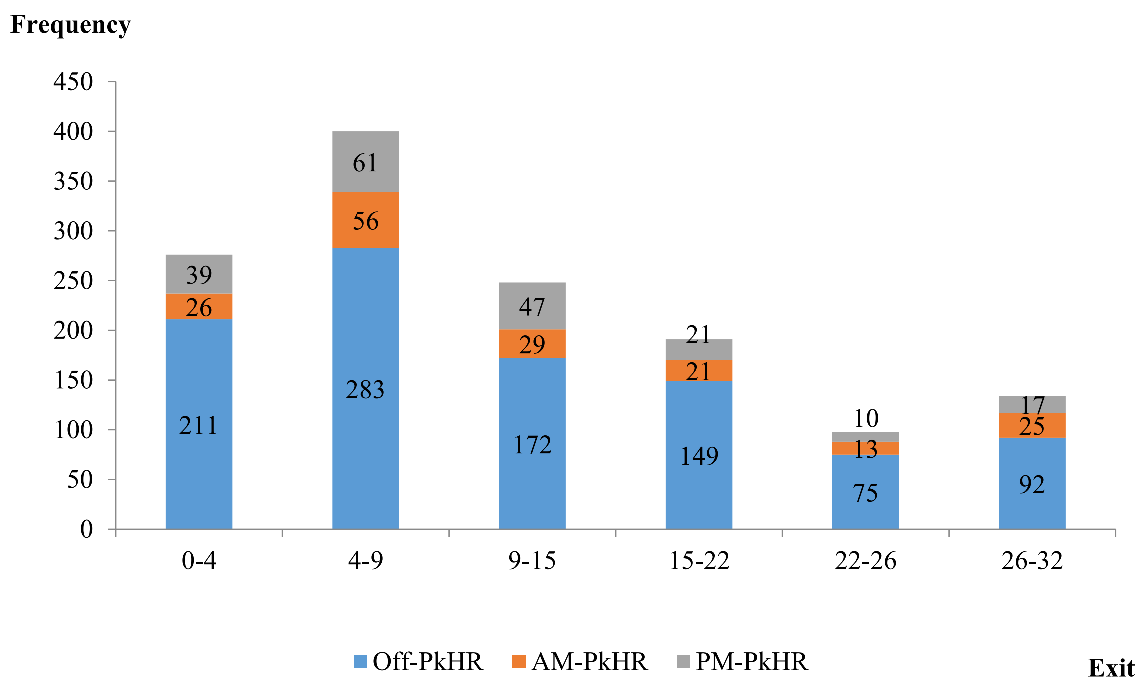


Figure A.5 Distribution of Incidents by Time of Day on I-270 in Year 2020

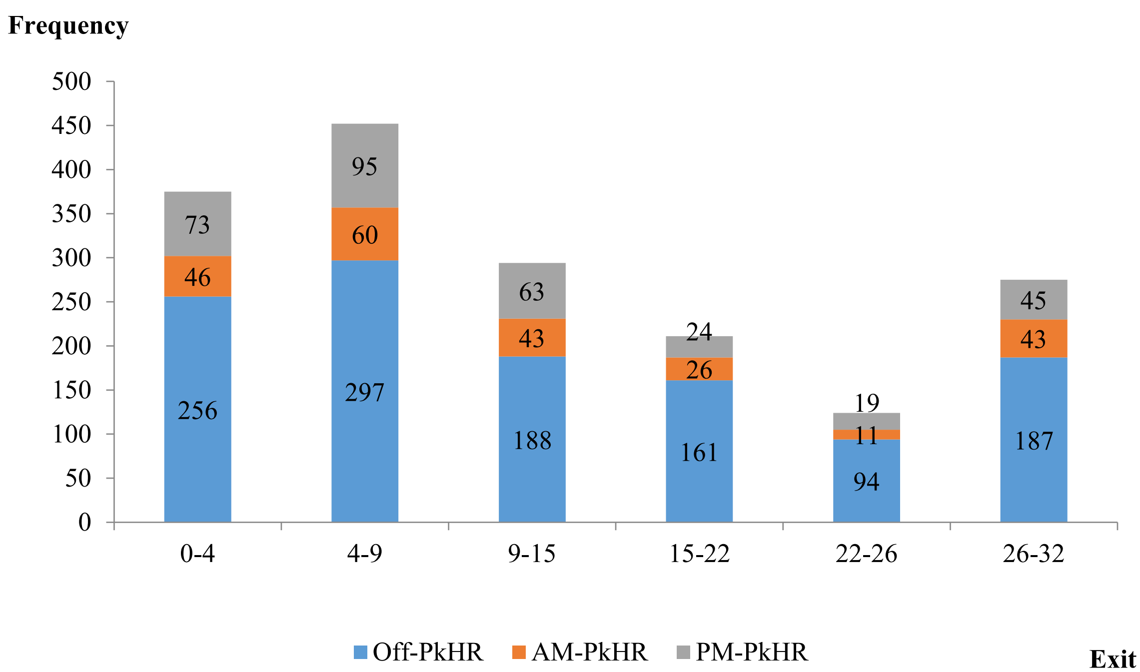


Figure A.6 Distribution of Disabled Vehicles by Time of Day on I-270 in Year 2020

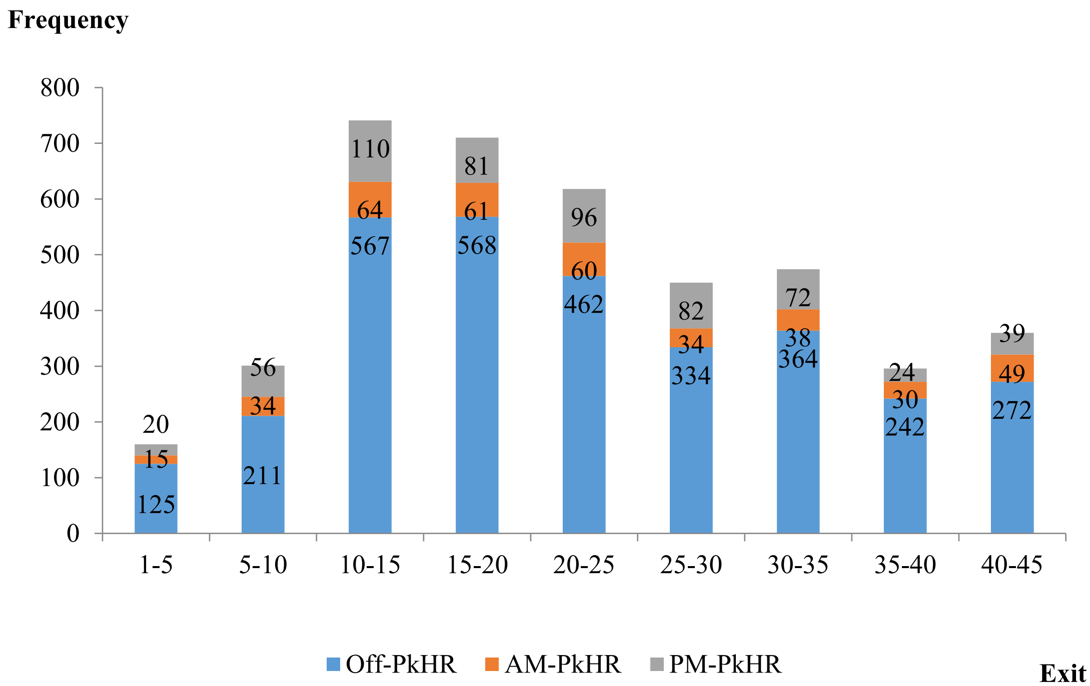


Figure A.7 Distribution of Incidents by Time of Day on I-695 in Year 2020

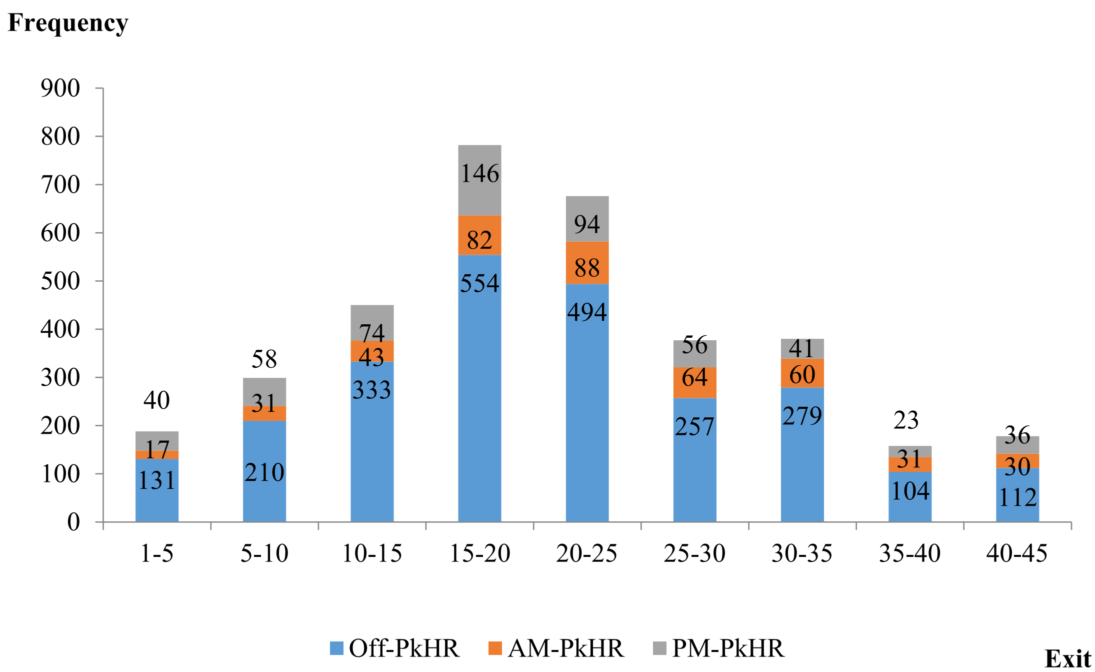


Figure A.8 Distribution of Disabled Vehicles by Time of Day on I-695 in Year 2020

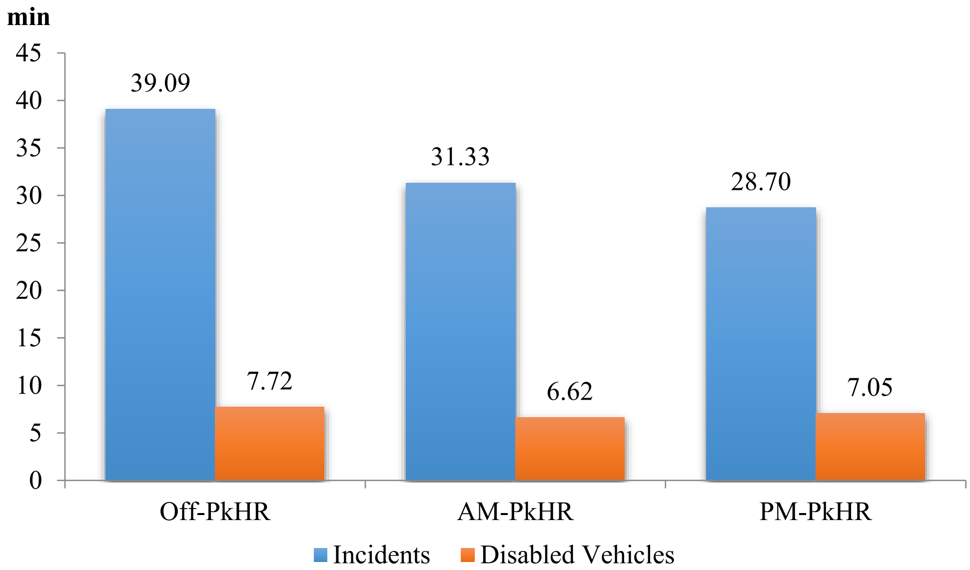


Figure A.9 Distribution of Clearance Time by Time of Day in Year 2020

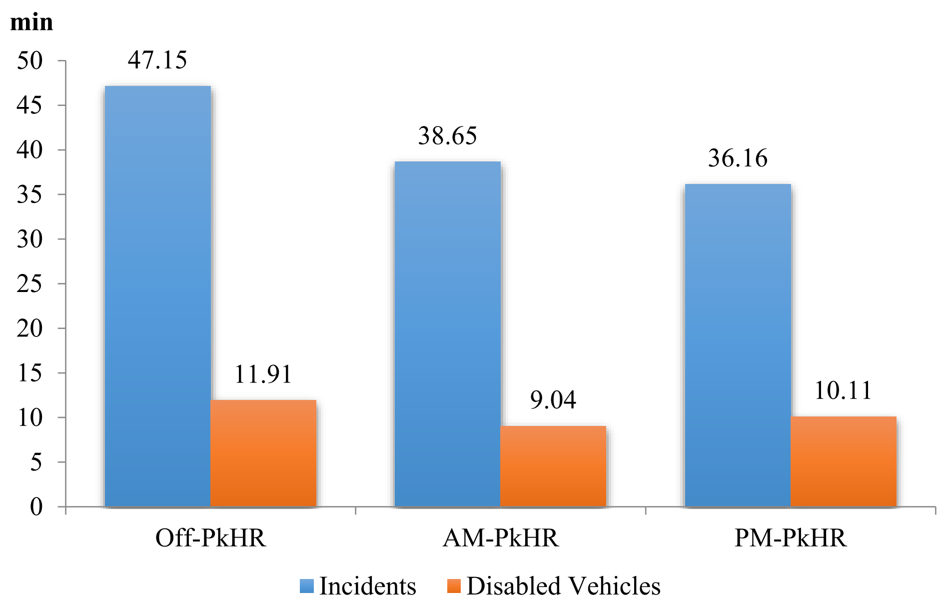


Figure A.10 Distribution of Incident Duration by Time of Day in Year 2020

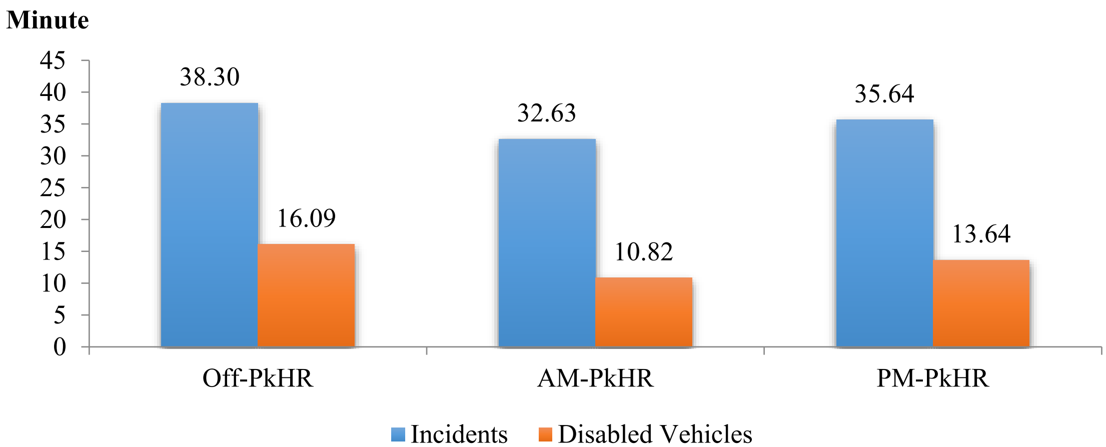


Figure A.11 Distribution of Incident Duration by Time of Day on I-95 in Year 2020

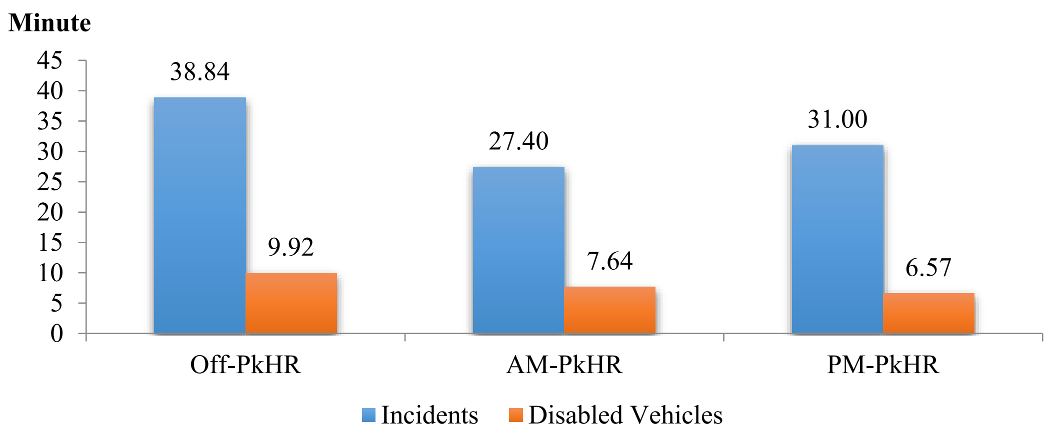


Figure A.12 Distribution of Incident Duration by Time of Day on I-495 in Year 2020

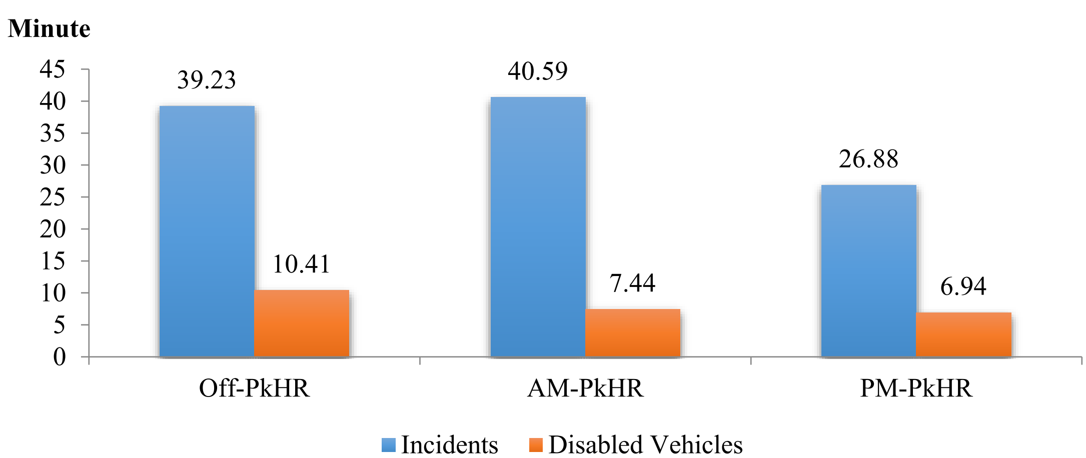


Figure A.13 Distribution of Incident Duration by Time of Day on I-270 in Year 2020

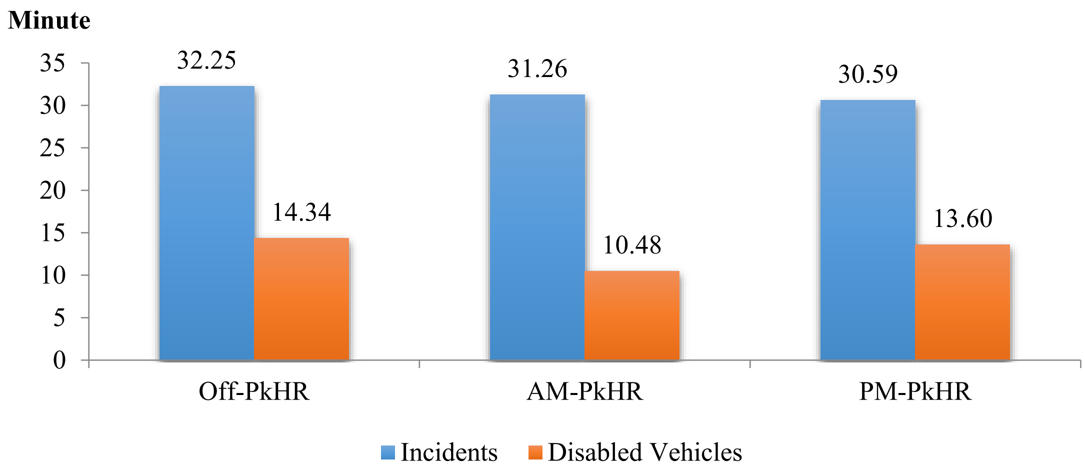


Figure A.14 Distribution of Incident Duration by Time of Day on I-695 in Year 2020

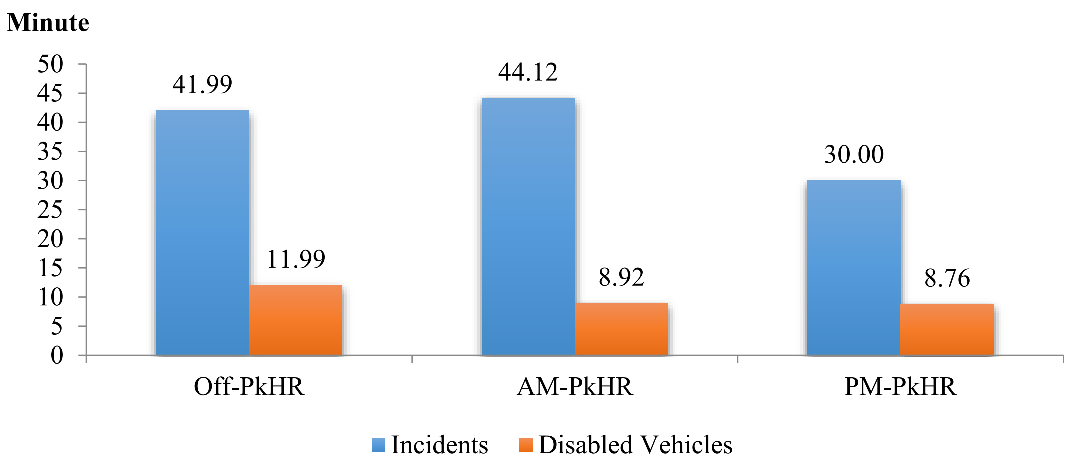


Figure A.15 Distribution of Incident Duration by Time of Day on I/MD-295 in Year 2020

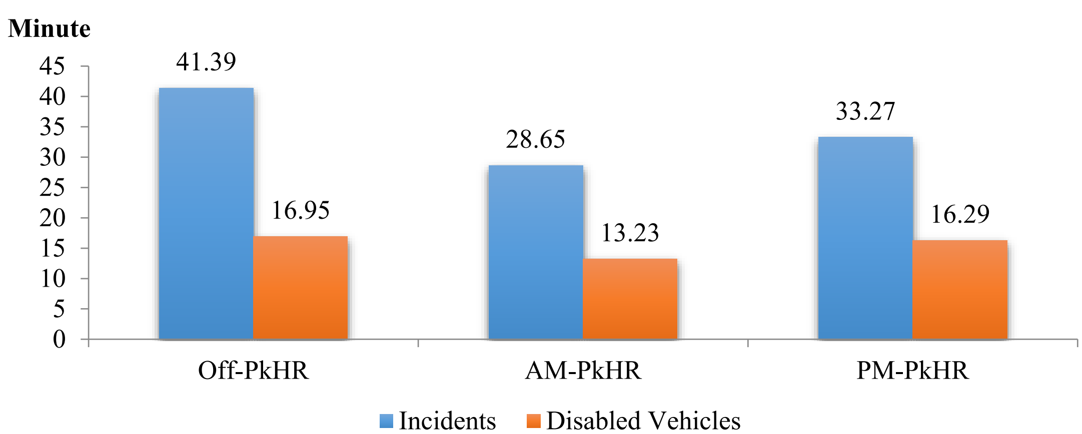


Figure A.16 Distribution of Incident Duration by Time of Day on I-83 in Year 2020

APPENDIX B - Benefit Estimation Procedure and Sensitivity Analysis

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

Step 1: Obtain info. regarding lane blockages, durations, locations, and response units for incidents from CHART-II DB

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Step 2: Collect additional data - AATD, peak hour factor(PHF), and % of truck for major roads in MD (I-495, I-95, I-270, I-695, I/MD 295, US 50, US 1, I-70, and I-83)

↓

Step 3: Compute the total delay by segment (*TDseg*) for each major road based on traffic volume, lane blockage ratio, average incident duration, and number of incidents

↓

Step 4: Estimate the total delay (*TD*) for all roads in MD based on the number of incidents detected during the target year

↓

Step 5: Estimate the total delay reduction (ΔTD) by the CHART performance based on the estimated CHART efficiency

↓

Step 6: Convert the total delay reduction (ΔTD) by the CHART performance into fuel consumption reduction ($\Delta fuel$) and emission reduction ($\Delta emission$) using conversion factors (α) (e.g., $\Delta fuel = \Delta TD \times \alpha$)

↓

Step 7: Convert the total delay reduction, fuel consumption reduction, emission reduction into monetary values

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