Year 2022

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Performance Evaluation and Benefit Analysis For CHART

– Coordinated Highways Action Response Team –

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Office of Transportation
Mobility and Operations
State Highway Administration

Performance Evaluation of CHART

The Real-Time Incident Management System (Year 2022)

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EXECUTIVE SUMMARY

Objectives

This report presents the performance evaluation study of the Coordinated Highways Action Response Team (CHART) for the Year 2022, including its operational efficiency and resulting benefits. The research team at the Civil Engineering Department of the University of Maryland, College Park (UM), has conducted the annual CHART performance analysis over the past twenty-four years for the State Highway Administration (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 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 2022 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 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 in view of the fact that the Statewide Operations Center (SOC) has been opened in August of 1995, those associated with the evaluation study concluded that the analysis should be based on actual performance data from the CHART program. Hence, in 1996, the UM (Chang and Point-Du-Jour, 1998) was contracted to work jointly with SHA staff to collect, and subsequently research item to analyze incident management data.

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

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

Unlike previous studies, the quality and quantity of data available for performance evaluation have been increased considerably since 1999. This results from CHART reflect the need to keep an extensive operational record in order to justify its costs and to evaluate the benefits of the emergency response operations. Due to CHART's efficient data collection, the records of lane-closure-related incidents increased from 2,567 in 1997 to 38,957 in 2022.

Table E.1 shows the total number of emergency response operations assiduously documented from 2018 to 2022.

Table E.1 Summary of the Total Number of Emergency Responses from 2018 to 2022

	2018	2019	2020	2021	2022	Δ (2022-2021)
Incidents only	41,247 (34,692)[2]	38,383 (31,750)	34,590 (26,702)	38,275 (29,546)	38,957 (28,972)	1.78% (-1.94%)
Total [1]	88,138 (79,956)	79,506 (71,233)	70,115 (60,665)	76,722 (65,839)	75,841 (63,474)	-1.15% (-3.59%)

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.

The main findings from Table E.1 are listed below:

- The total number of recorded incidents in 2022 increased by 1.78% compared to 2021.
- The number of incidents responded by CHART in 2022 decreased by 1.94% compared to 2021.
- The numbers of both total emergency responses (including disabled vehicles) and those responded by CHART slightly decrease in 2022.

Evolution of the Evaluation Work

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

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

Distribution of Incidents/Disabled Vehicles

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

As shown in Table E.2, the 2022 incident records indicate that there were a total of 3,320 incidents resulting in one-lane blockage, 9,238 incidents causing two-lane closures, and 5,692 incidents blocking three or more lanes. In addition, either disabled vehicles or minor incidents caused a total of 44,933 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

	2018	2019	2020	2021	2022	Δ (2022-2021)
Shoulder[2]	54,630	48,485	41,409	45,258	44,933	-4.77%
1 lane	3,948	3,480	3,221	3,290	3,320	0.91%
2 lanes[3]	9,589	8,823	8,205	9,328	9,238	-0.96%
3 lanes[3]	3,086	2,965	2,780	3,062	3,235	5.65%
≥ 4 lanes[3]	2,458	2,301	2,331	2,472	2,457	-0.61%

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

Most of those incidents/disabled vehicles were distributed along six major commuting corridors: I-495/95, which experienced a total of 10,371 incidents/disabled vehicles in 2022; I-695, I-95, US-50, I/MD-295, and I-270 with 9,529, 14,052, 6,272, 2,738, and 4,200 incidents/disabled vehicles, respectively. CHART managed an average of 38 emergency requests per day on I-95 alone, and 28, 26, 17, 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 2018 and 2022 is shown in Table E.3:

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

	2018	2019	2020	2021	2022	Δ (2022 - 2021)
I-495/95	11,807	10,589	10,339	12,068	10,371	-14.06%
I-695	11,752	10,705	8,025	8,585	9,529	11.00%
I-95	15,619	14,729	12,937	12,838	14,052	9.46%
US-50	7,940	7,208	6,492	7,807	6,272	-19.66%
I/MD-295	3,578	3,152	2,694	3,120	2,738	-12.24%
I-270	5,086	4,892	4,058	4,484	4,200	-6.33%

** 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 hours in 2022 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 67 and 74 in AM and PM peaks, respectively. The southbound segment on I-95 between Exits 67 and 74, and the eastbound segment of US 50 between Exits 16 and 21 ranked the first with the respect to the number of disabled vehicle requests in 2022 in AM and PM peak hours, respectively.

Table E.4 Top 10 Freeway Segments with the Most Incidents/Disabled Vehicles in 2022

	Incidents				Disabled vehicles			
	AM Peak		PM Peak		AM Peak		PM Peak	
1	I-95 S	Exit 56&57	I-95 N	Exit 67&74	I-95 S	Exit 67&74	US 50 E	Exit 16&21
2	I-95 N	Exit 67&74	I-95 N	Exit 55&56	I-95 N	Exit 61&64	I-95 N	Exit 67&74
3	I-95 S	Exit 67&74	I-695 IL	Exit 11&12	I-95 N	Exit 67&74	US 50 W	Exit 16&21
4	I-495 OL	Exit 27&28	I-95 S	Exit 56&57	I-95 S	Exit 50&52	I-695 IL	Exit 11&12
5	I-95 N	Exit 55&57	I-95 S	Exit 67&74	I-95 N	Exit 64&67	I-695 OL	Exit 17&18
6	I-695 IL	Exit 43&1	I-95 S	Exit 80&85	I-95 S	Exit 61&64	I-695 IL	Exit 17&18
7	I-95 S	Exit 58&59	I-495 IL	Exit 33&34	I-495 IL	Exit 19&20	I-95 S	Exit 67&74
8	I-95 S	Exit 62&64	I-695 OL	Exit 18&19	I-95 S	Exit 49&50	I-95 N	Exit 61&64
9	I-895 S	Exit 8&12	I-95 S	Exit 49&50	I-495 OL	Exit 19&20	I-495 IL	Exit 13&15
10	I-95 N	Exit 74&77	I-695 IL	Exit 25&26	I-95 S	Exit 80&85	I-695 OL	Exit 18&19

** 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 freeways did not block traffic for more than one hour. For instance, about 72 percent of incidents/disabled vehicles had durations shorter than 30 minutes in 2022. 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 2018 to 2022 are summarized in Table E.5:

Table E.5 Distribution* of Incidents/Disabled Vehicle Duration from 2018 to 2022

Duration(Hrs)	2018	2019	2020	2021	2022
D < 0.5	74%	73%	73%	72%	72%
0.5 ≤ D < 1	15%	16%	15%	15%	16%
1 ≤ D < 2	6%	7%	7%	8%	8%
2 ≤ D	5%	5%	5%	5%	5%

** This analysis is based on incidents and disabled vehicles (i.e., assists to drivers) which 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 the major commuting highway corridors, such as I-95, I-270, I-495/95, and I-695.

Efficiency of Operations

Detection, response, and traffic recovery are the three vital performance indicators associated with an incident management program. Unfortunately, data needed for the detection and response time analysis are not yet available under the CHART data system. 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 4.65, 14.52, 11.77, 14.79, and 10.04 minutes for TOC-3, TOC-4, TOC-7, SOC, and AOC, respectively, in 2022. Note that as of January 2022, TOC-3 has been relocated to SOC due to staff related issues. TOC-7 provided more prompt response services in 2022 than in 2021, while TOC-4, SOC and AOC experience a slightly increase in response time in 2022. Note that incidents/disabled vehicles included in this analysis were responded by various units, including CHART and non-CHART agencies.

Table E.6 Evolution of Response Times[1,2,3] by Center from 2018 to 2022

Response Time (mins)	2018	2019	2020	2021	2022		
					During OH[4]	After OH	Overall
TOC-3[6]	13.00	12.99	12.17	12.64	4.65 (1)[5]	N/A	4.65 (1)
TOC-4	14.01	13.40	12.98	14.03	14.52 (4,878)	12.81 (24)	14.51 (4,902)
TOC-7	11.46	11.38	11.42	11.83	11.77 (3,069)	11.80 (827)	11.78 (3,896)
SOC	13.78	13.93	14.32	14.67	14.79 (10,010)	N/A	14.79 (10,010)
AOC	8.74	8.99	9.03	9.45	10.04 (8,079)	N/A	10.04 (8,079)
OTHER	8.91	11.68	2.53	8.58	N/A	13.09 (3)	13.09 (3)
Weighted Average	**11.99**	**11.88**	**11.64**	**12.25**	**12.91 (26,037)**	**11.83 (854)**	**12.88 (26,891)**

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

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

3. Events included in this analysis were responded by various units, including CHART, fire boards, state/local polices, private towing companies, etc.

4. OH stands for Operational Hours: TOC-7 operates 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-days-a-week basis.

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

6. As of January 2022, TOC-3 has been relocated to SOC.

Table E.7 presents that incidents are likely to be responded more promptly than disabled vehicles, especially during operational hours.

Table E.7 Comparisons of CHART Response Performance[1,2,3] during and after Operational Hours

Response Time (mins)	Operational Hours[4]		Non-operational Hours		Total		
	Incident	Disabled Vehicle	Incident	Disabled Vehicle	Incident	Disabled Vehicle	Sub-total
TOC-3[6]	4.65 (1)[5]	N/A	N/A	N/A	4.65 (1)	N/A	4.65 (1)
TOC-4	14.29 (3,397)	17.77 (1,536)	13.61 (17)	10.94 (6)	14.29 (3,414)	17.75 (1,542)	15.36 (4,956)
TOC-7	12.02 (2,371)	13.14 (697)	12.36 (600)	11.69 (234)	12.09 (2,971)	12.78 (931)	12.26 (3,902)
SOC	13.84 (6,597)	18.96 (3,130)	N/A	N/A	13.84 (6,597)	18.96 (3,130)	15.49 (9,727)
AOC	8.11 (5,352)	11.21 (2,153)	N/A	N/A	8.11 (5,352)	11.21 (2,153)	9.00 (7,505)
OTHER	N/A	N/A	7.54 (2)	31.53 (1)	7.54 (2)	31.53 (1)	15.54 (3)
Weighted Average	**11.95 (17,718)**	**15.96 (7,516)**	**12.38 (619)**	**11.76 (241)**	**11.97 (18,337)**	**15.82 (7,757)**	**13.11 (26,094)**

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

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

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

4. Operational Hours: TOC-7 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-days-a-week basis.

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

6. As of January 2022, TOC-3 has been relocated to SOC.

Also, the 2022 data show that CHART's response operations are more efficient when incidents are more severe and cause lane blockages. In general, more severe incidents, especially involving in fatalities or heavy vehicles, demand longer clearance times.

Analysis of Incident Durations

To better understand the contributions of the incident management program, the study compared the average duration of incidents to which CHART responded and those managed by other agencies. For example, the difference on the average response times for one-lane-blockage incidents between with and without CHART involvement is about 10.31 minutes.

The duration of incidents managed by CHART response units averaged 26.02 minutes, shorter than the average duration of 37.54 minutes for those incidents by other agencies. On average, CHART operations in Year 2022 reduced the average incident duration by about 31 percent.

Performance improvement of CHART operations from years 2018 to 2022 is summarized in Table E.8:

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

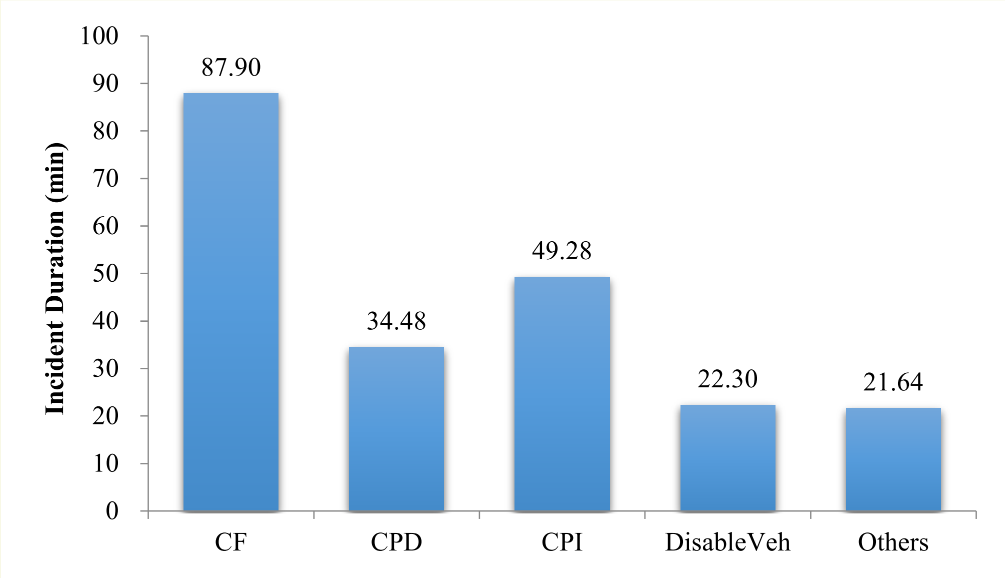
Year	With CHART (mins)	Without CHART (mins)
2018	25.42	33.08
2019	25.75	33.91
2020	27.04	37.02
2021	26.31	37.82
2022	26.02	37.54

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

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

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

The average duration for incidents involving fatalities (CF) was 88 minutes, while those causing property damage (CPD) and personal injuries (CPI) lasted, on average, 34 and 49 minutes, respectively (see Figure E.1). The average duration for incidents by only disabled vehicles was 22 minutes, close to those classified as "Others" (e.g., debris, vehicles on fire, police activities, etc.).



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

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

Figure E.1 Distribution of Average Duration by Incident Nature in 2022

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 2022, CHART responded to a total of 38,957 incidents, and assisted 36,884 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 1,084 potential lane-changing-related collisions in 2022, as vehicles approaching those conditions would have been forced to perform unsafe mandatory lane changes.

CORSIM, a traffic simulation program produced by the Federal Highway Administration (FHWA), was used to estimate the direct benefits attributed to delay reduction time, and it was discovered that various factors, including traffic and heavy vehicle volumes, the number of lane closures, the number of incident responses, and incident durations, affect the resulting delay (see Chapter 7 for further information on benefits estimate). For instance, several primary factors (such as the number of incidents eligible for the benefit estimate and gas price) have increased in 2022. The ratio in difference between incident durations of with and without CHART also exhibits an increase in 2022. Overall, the delay reduction due to CHART's services in 2022 (40.99 million vehicle-hours) increased by 3.16 percent, compared to the performance in 2021 (39.74 million vehicle-hours). The collective impacts of all those key contributing factors have resulted in a net benefit increase from $1,875.25M in 2021 to $2,030.56M in 2022. A comparison of the direct benefits from reduced delay times, fuel consumptions, and emissions, from 2018 to 2022, is summarized in Table E.9:

Table E.9 Comparison of Direct Benefits from 2018 to 2022

	Total Direct Benefits (million)[1,2,3,4]	# of Incidents Eligible for the Benefit Estimate[5]
2018	$1,311.89	33,243
2019	$1.393.38	30,793
2020	$1,080.83	28,513
2021	$1,875.25	31,253
2022	$2,030.56	32,130

Note: 1. Results are based on the data of the corresponding year from the U.S Census Bureau and Energy Information Administration.

2. The direct benefits represent reductions from delay time, fuel consumptions, and emissions due to the CHART effective operations.

3. The direct benefits rely on numerous factors (i.e., traffic and heavy vehicle volumes, the number of lane blockages, the number of incidents responded, and incident durations).

4. The direct benefits are estimated based on the car delay reduction occurring over all roads covered by CHART and the truck delay reduction only occurring along major roads.

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

Most benefits were produced from delay reductions due to CHART's efficient incident response and management, especially along the major corridors which 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 9.79, 4.20, 1.43, 5.30, 2.97, and 0.99 million vehicle-hours, respectively, in 2022. Such direct benefits for users over each major road in 2022 are summarized in Table E.10:

Table E.10 Direct Benefits for Major Roads in 2022 due to CHART operations

Roads	Total Direct Benefits (million)[1,2,3]	# of Incidents Eligible for the Benefit Estimate
I-95	$495.60	5,858
I-95/495	$209.38	3,479
I-270	$70.23	1,049
I-695	$262.55	3,588
I-70	$150.24	1,745
I-83	$51.05	927
Others	$791.51	15,484
Total	$2,030.56	32,130

Note: 1. Results are based on the data of the corresponding year from the U.S Census Bureau and Energy Information Administration.

2. The direct benefits represent reductions in car/truck delay times, fuel consumptions, 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 on estimating benefits are listed and tabulated as follows:

- The total number of incidents used for the benefit estimate increased by about 2.81 percent from year 2021 to year 2022, as shown in Table E.11.
- The ratio, reflecting the difference between incident durations with CHART and those without CHART, increased from 28.04 percent in 2021 to 29.12 percent in 2022, as shown in Table E.12.
- Table E.13 shows that the adjusted AADT in 2022 decreased by 0.13 percent on the major roads in Maryland compared to 2021.
- Table E.14 shows that average truck percentage decreased in year 2022 over all major roads in Maryland, by 20.28 percent on average.

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

	2021	2022	Δ('21 ~ '22) [2]
No. of Incidents [1]	31,253	32,130	***2.81%***

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 2021 to Year 2022 is calculated as follows: $\Delta\mathbf{X}(\%) = \frac{X_{2022} - X_{2021}}{X_{2021}} \times 100$

Table E.12 Incident duration reduction in year 2021 and 2022[1]

	With CHART(mins) (A)	Without CHART(mins) (B)	Difference(mins) (B-A)	Ratio in Difference ((B-A)/B)
2021	27.99	38.89	10.90	28.04%
2022	27.67	39.04	11.37	29.12%
Δ('21 ~ '22) [2]	-1.13%	0.39%	4.27%	***3.87%***

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

2.The percentage change in incident duration (X) from Year 2021 to Year 2022 is calculated as follows:

$$\Delta\mathbf{X}(\%) = \frac{X_{2022} - X_{2021}}{X_{2021}} \times 100$$

Table E.13 The adjusted AADT (with peak hour factor) for Major Roads from 2021 and 2022

	Year	I-495	I-95	I-270	I-695	MD 295	US 50	US 1	I-83	I-70	Total
$\sum_{\text{segments}}$ AADT(vplph)*PHF	**2021**	11,912	7,981	6,987	10,586	4,087	2,342	4,746	2,434	3,162	**54,237**
	2022	11,836	7,927	7,076	10,529	4,112	2,356	4,655	2,457	3,220	**54,167**
Δ('21 ~ '22) (%)*		-0.6%	-0.7%	1.3%	-0.5%	0.6%	0.6%	-1.9%	1.0%	1.8%	***-0.13%***

Note: The percentage change in the adjusted AADT(X) from Year 2021 to Year 2022 is calculated as follows:

$$\Delta\mathbf{X}(\%) = \frac{X_{2022} - X_{2021}}{X_{2021}} \times 100$$

Table E.14 Truck percentage for Major Roads from year 2021 and 2022

	Year	I-495	I-95	I-270	I-695	MD 295	US 50	US 1	I-83	I-70	Average
Truck %	**2021**	7.76	11.98	5.41	7.57	2.72	11.30	4.84	13.25	10.47	**8.37**
	2022	6.15	9.91	4.26	5.88	1.83	8.09	2.77	12.93	8.19	**6.67**
Δ('21 ~ '22)(%)*		-27.8%	-17.3%	-21.2%	-22.3%	-32.5%	-28.4%	-42.8%	-2.4%	-21.8%	***-20.3%***

Note: The percentage change in the truck percentage (X) from Year 2021 to Year 2022 is calculated as follows:

$$\Delta\mathbf{X}(\%) = \frac{X_{2022} - X_{2021}}{X_{2021}} \times 100$$

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 2022 value, but setting all other factors identical to those in 2021; and
- Following the same procedures to analyze the sensitivity of the total 2022 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 0.13 percent in 2022 contributed to a decrease of 0.11 percent in the total benefit. The number of lane-blockage incidents increased by 2.81 percent in 2022, resulting in the benefit increase of 2.13 percent. Note that the ratio with respect to the performance difference between incident durations with- and without-CHART involvements increased by 3.87 percent, and thus directly resulted in a 3.87 percent increase in the total benefit. An increase of 4.73 percent in the total benefit is due solely to the average income raise of 2.90 percent in the MD's populations (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 (2021)			1,875.25
Key Factor		Δ ('21 - '22)	Estimated Benefit
Sensitivity Analysis	Adjusted AADT	▼0.13%	1,873.10 (▼0.11%)[1]
	Number of incidents	▲2.81%	1,915.10 (▲2.13%)
	Incident duration difference between w/ and w/o CHART	▲3.87%	1,947.77 (▲3.87%)
	Truck percentage	▼20.28%	1,863.61 (▼0.62%)
	Monetary unit of gas price	▲41.86%	1,884.01 (▲0.47%)
	Monetary unit of time value	▲2.90%	1,963.89 (▲4.73%)
Benefit of the Current Year (2022)			**2,030.56 (▲8.29%)**

Note: 1.The number in each parenthesis shows the percentage of benefit change from year 2021.

Conclusions and Recommendations

Grounded on the lessons from the earlier studies, this study has conducted a rigorous evaluation of CHART's performance in 2022 and its resulting benefits under the constraints of data availability and quality. Overall, CHART has made significant progress in recording more reliable incident reports, especially after implementation of the CHART-II Database.

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

With respect to overall performance, CHART has maintained nearly the same level of efficiency in responding to incidents and driver assistance requests in recent years. The average response time in Year 2022 was 12.88 minutes (See Figure 4.5). 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 2022, are listed below:

- Increase the resources for CHART to sustain the high-quality incident response operation, including more staffs and hardware supports.
- Provide constant 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 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 2022 CHART Performance Evaluation

- Both the total number of statewide emergency responses and CHART responses slightly decreased from Year 2021 to Year 2022 (by 1.15% and 3.59%, respectively).
- Since TOC-3 has been relocated to SOC as of January 2022, the number of responses by SOC increased significantly in 2022 (from 18,176 in 2021 to 31,570 in 2022).
- In 2022, the average incident duration with CHART was 26.02 minutes, much shorter than the average of 37.54 minutes for those incidents responded by other agencies. The reduction in the average incident duration is about 31 percent. The average incident duration with CHART of 26.02 minutes was at the same level as to that of 2021 (i.e., 26.31 minutes).
- **While AADT on major roads does not exhibit significant change in 2022, the average truck percentage decreased by 20.28 percent on average in year 2022 over all major roads in Maryland. Such significant change is reported to be likely due to the new software installed on Maryland traffic sensors. Some rigorous calibration tasks ought to be done to ensure the data reliability for benefit assessment and related analyses.**
- Among major corridors, I-695 experienced the most significant increase in its emergency response frequency in 2022 compared to 2021 (by about 11%); the total emergency response frequency on US 50 and I-495/I-95 shows a reduction of 20% and 14%, respectively, compared to 2021.
- **The total benefit of CHART operation increased by 8.29 percent, where the three main contributors to such benefit increase are gas price hike, higher average income, and more efficient response operations which contribute 0.47%, 4.73%, and 3.87%, respectively, to the total benefit increase.**

The aforementioned changes, along with other factors, collectively contributed to the direct benefits by CHART's performance in 2022.

CHAPTER 1

INTRODUCTION

1 Introduction

CHART (Coordinated Highways Action Response Team)

is the highway incident management system of the Maryland State Highway Administration **(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 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 38,957 reports in 2022. A summary of total emergency response operations documented from 2018 to 2022 is presented in Table 1.1.

Table 1.1 Total Number of Emergency Response Operations

Records	2018	2019	2020	2021	2022
Incidents*	41,247 (34,692)	38,383 (31,750)	34,590 (26,702)	38,275 (29,546)	38,957 (28,972)
Disabled Vehicles	46,891 (45,264)	41,123 (39,483)	35,525 (33,963)	38,447 (36,293)	36,884 (34,502)
Total	88,138 (79,956)	79,506 (71,233)	70,115 (60,665)	76,722 (65,839)	75,841 (63,474)

**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. The number in each parenthesis shows 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 SHA programs from the general public and state policymakers largely depends on the benefits the state obtains from its ongoing programs. In order to conduct a comprehensive analysis using available data to ensure the reliability of the evaluation results, the evaluation study has been divided into the following three principal tasks:

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

Task 2: Statistical Analysis and Comparison — entails performing comparisons based on data available in 2021 and 2022, with an emphasis on these target areas: incident characteristics, efficiency of incident detection, distribution of detection sources, efficiency of incident response, and effectiveness of incident traffic management.

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

1.1 INTRODUCTION

The subsequent chapters are structured as follows:

Chapter 2 assesses the quality of data available for the 2022 CHART performance evaluation. This includes the total available incident reports, the percentage of missing data for each critical performance parameter, and a comparison of 2022 data quality with that of 2021.

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

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 2022 performance evaluation and compares it with the data from CHART 2021.

2.1 Analysis of Data Availability

2.2 Analysis of Data Quality

2

2.1 Analysis of Data Availability

In 2022, CHART recorded a total of 75,841 emergency response cases. These are categorized into two groups: incidents and disabled vehicles. A summary of the total available incident reports for the years 2020, 2021, and 2022 is shown in Table 2.1.

Table 2.1 Comparison of Available Data for 2020, 2021, and 2022

Available Records		2020		2021		2022	
		Records	Ratios (%)	Records	Ratios (%)	Records	Ratios (%)
CHART II Data-base	Disabled Vehicles	35,525	50.7	38,447	50.1	36,884	48.6
	Incidents	34,590	49.3	38,275	49.9	38,957	51.4
Total		70,115	100	76,722	100	75,841	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 2021 and 2022.

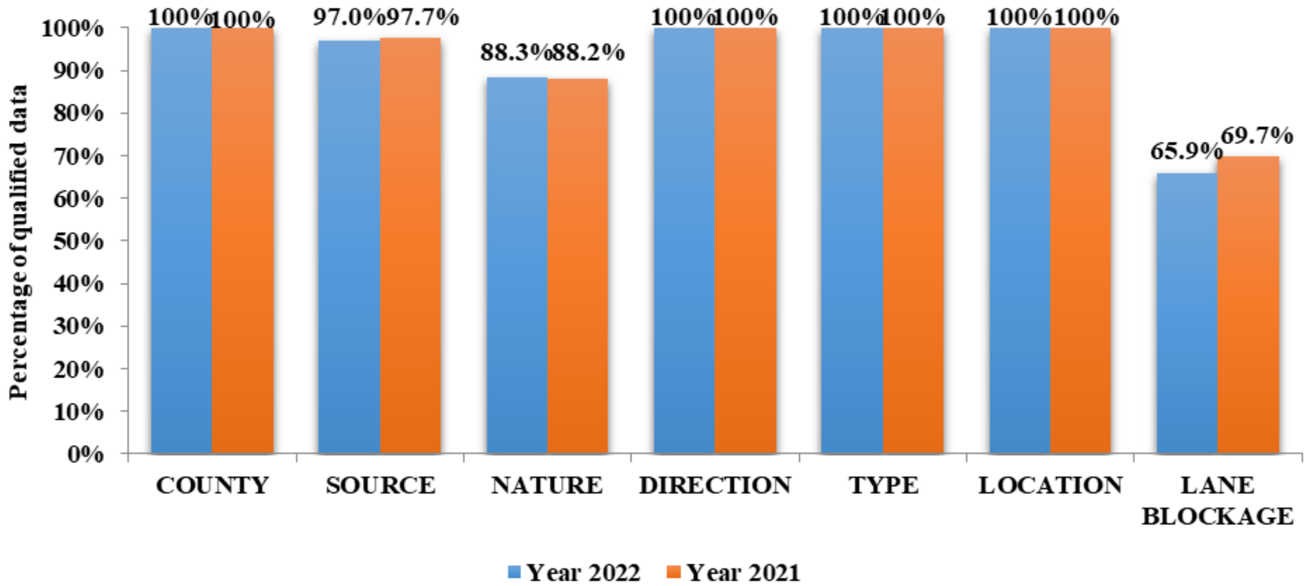


Figure 2.1 Summary of Data Quality for Critical Indicators

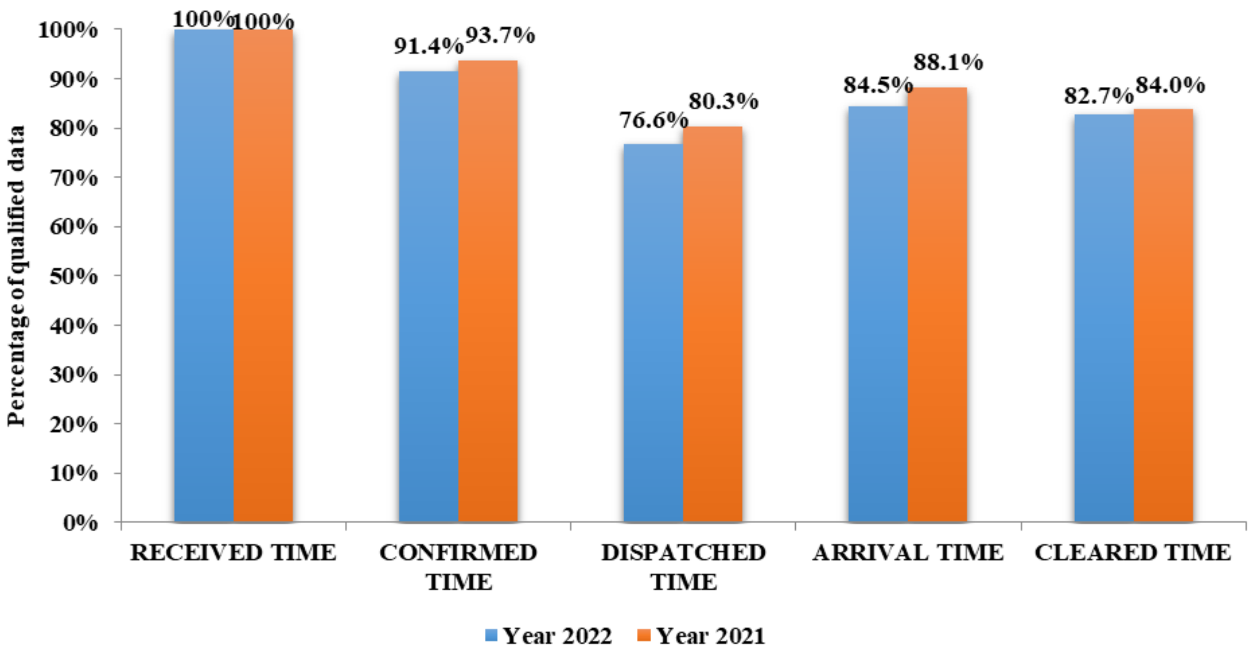


Figure 2.2 Summary of Data Quality for Time Indicators

ANALYSIS OF DATA QUALITY

2.2

Nature of incident/ disabled vehicle

Data were classified based on the nature of the incidents, such as vehicle on fire, collision-personal injury, and collision-fatality. CHART's records for disabled vehicles are also categorized as abandoned vehicles, tire changes, and gas shortage. As shown in Figure 2.1, about 88.3 percent of emergency responses reported in 2022 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 97.0 percent of all emergency responses recorded in 2022 contained the source of detection, which is almost the same as the previous year's data. In 2022, about 94.7 percent of incidents reported and 99.5 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 2022 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 2022 is summarized in Table 2.2. Overall, CHART responded to a total of 38,957 incidents in 2022. Over the same period, the response team also attended to 36,884 disabled vehicle requests.

Table 2.2 Emergency Assistance Reported in 2022

Operation Center	TOC3	TOC4	SOC	TOC7	AOC	OTHER	TOTAL
Incidents	6 (6,106)	6,498 (6,560)	16,683 (10,834)	5,374 (5,232)	10,386 (9,503)	10 (40)	38,957 (38,447)
Disabled Vehicles	12 (10,296)	6,769 (6,994)	14,887 (7,342)	7,026 (7,130)	8,175 (6,625)	15 (60)	36,884 (38,275)
Total	18 (16,402)	13,267 (13,554)	31,570 (18,176)	12,400 (12,362)	18,561 (16,128)	25 (100)	75,841 (76,722)

Note: numbers in each parenthesis the corresponding data from 2021. As of January 2022, TOC-3 has been relocated to the SOC.

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 2022. Note that about 99.98 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	99.32%	99.61%	99.46%
Location	99.98%	99.98%	99.98%
Valid Data for Road & Location	56.97%	60.20%	59.78%

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 2022 shows that up to 65.88 percent of emergency response reports involved lane/shoulder blockage. This value is lower than 69.72 percent in 2021.

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

CHAPTER 3

ANALYSIS OF DATA CHARACTERISTICS

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

3.1 Distribution of Incidents and Disabled Vehicles by Day and Time

3.2 Distribution of Incidents and Disabled Vehicles by Road and Location

3.3 Distribution of Incidents and Disabled Vehicles by Lane Blockage Type

3.4 Distribution of Incidents and Disabled Vehicles by Blockage Duration

3

3.1 Distribution of Incidents and Disabled Vehicles by Day and Time

The research team analyzed the differences between the distribution of incidents/disabled vehicles during weekdays and weekends. As shown in Table 3.1, a large number (about 77 percent) of incidents/disabled vehicles in 2022 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 TOC4 and TOC7 increased while SOC and AOC experience a slight reduction in the percentage of weekend responses.

Table 3.1 Distribution of Incidents/Disabled Vehicles by Day

Center	TOC3		TOC4		TOC7	
Year	2022	2021	2022	2021	2022	2021
Weekdays	100%	83%	78%	84%	78%	86%
Weekends	0%	17%	22%	16%	22%	14%

Center	SOC		AOC		Others		Total	
Year	2022	2021	2022	2021	2022	2021	2022	2021
Weekdays	75%	72%	78%	75%	48%	40%	77%	79%
Weekends	25%	28%	22%	25%	52%	60%	23%	21%

Notes: "Others" includes RAVENS TOC.
As of January 2022, TOC-3 has been relocated to the SOC.

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 25 percent of incidents/disabled vehicles reported in 2022 occurred during peak hours, which is slightly lower than that in 2021.

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

Center	TOC3		TOC4		TOC7	
Year	2022	2021	2022	2021	2022	2021
Peak	28%	31%	30%	31%	28%	31%
Off-Peak	72%	69%	70%	69%	72%	69%

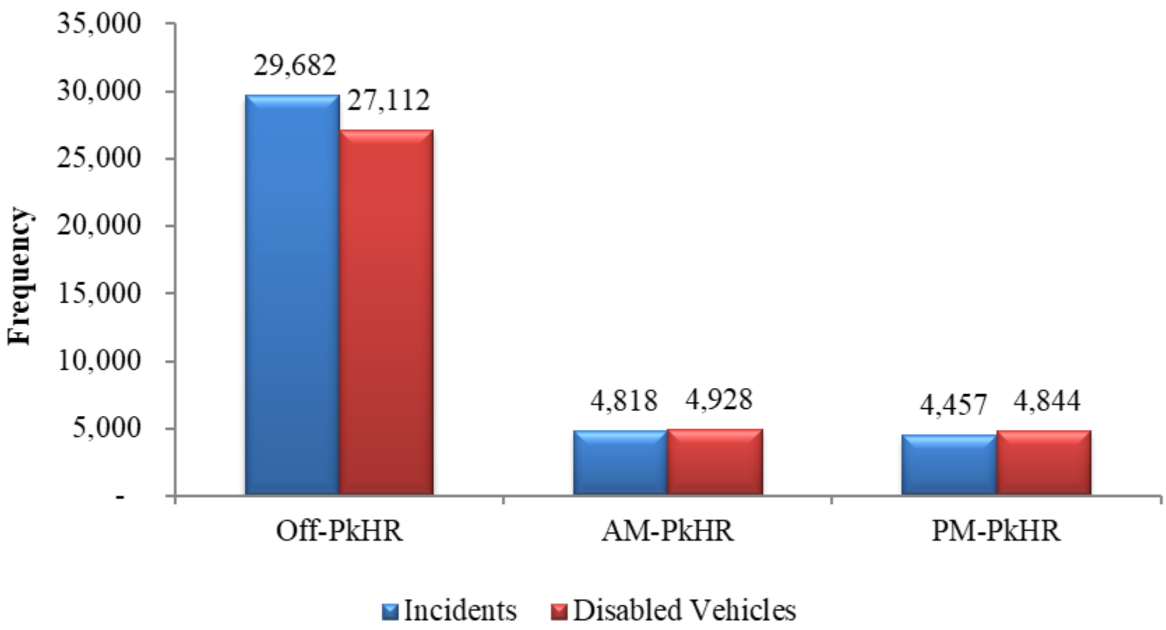
Center	SOC		AOC		Others		Total	
Year	2022	2021	2022	2021	2022	2021	2022	2021
Peak	22%	16%	25%	24%	20%	16%	25%	26%
Off-Peak	78%	84%	75%	76%	80%	84%	75%	74%

Notes: "Others" includes RAVENS TOC.
As of January 2022, TOC-3 has been relocated to the SOC.
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.

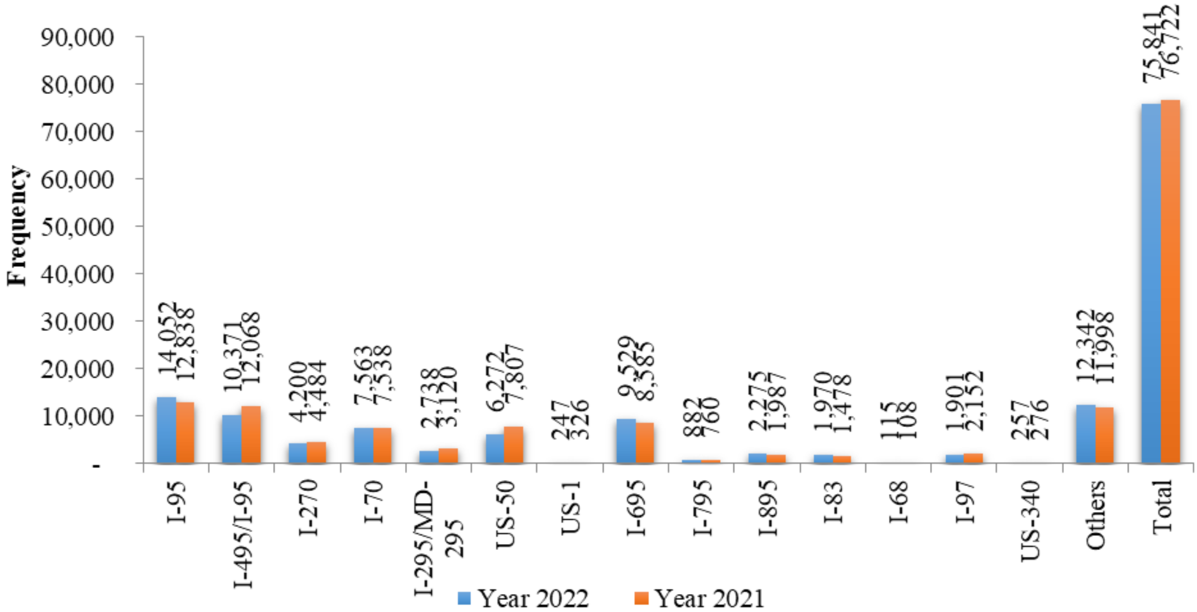


** Off-PkHR, AM-PkHR, and PM-PkHR stand for Off-Peak hours, AM-Peak hours, and PM-Peak hours, respectively.*

Figure 3.1 Distributions of Incidents/Disabled Vehicles by Time of Day in 2022

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

Figure 3.2 compares the frequency distribution among roads between 2022 and 2021, and Figure 3.3 depicts the frequency distribution of incidents and disabled vehicles for 2022.



Note: "Total" includes incomplete data for road name and direction.

Figure 3.2 Distributions of Incidents/Disabled Vehicles by Road in 2022 and 2021

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 2022 were I-95 (from the Delaware border to the Capital Beltway), I-695 (Baltimore Beltway), I-495/95 (Capital Beltway), US-50, I-70 and I-270. I-95 experienced a total of 14,052 incidents/disabled vehicles in 2022, while I-695 had 9,529 incidents/disabled vehicles within the same period. I-495/95, US-50, I-70 and I-270 had 10,371, 6,272 7,563, and 4,200 incidents/disabled vehicles, respectively. Also, notice that the CHART-II database includes 1,127 incidents/disabled vehicles detected by CHART with incomplete information for road names in 2022.

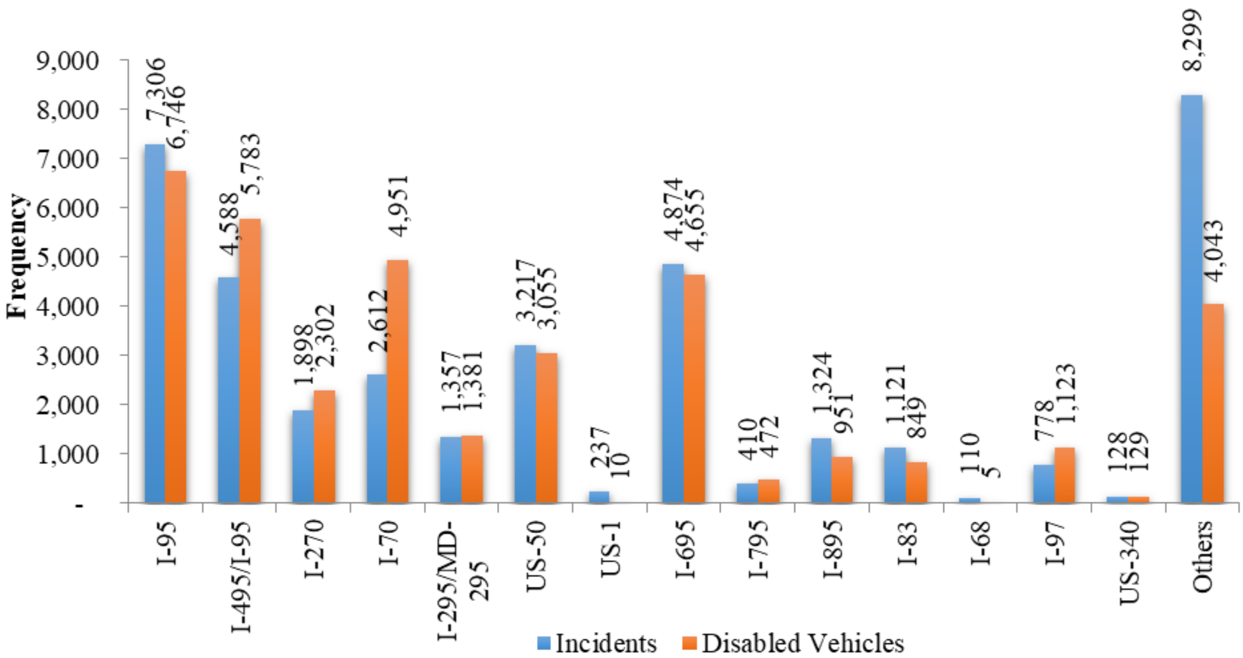


Figure 3.3 Distributions of Incidents/Disabled Vehicles by Road in 2022

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 a.m. peak hours than p.m. peak hours on most major roads.

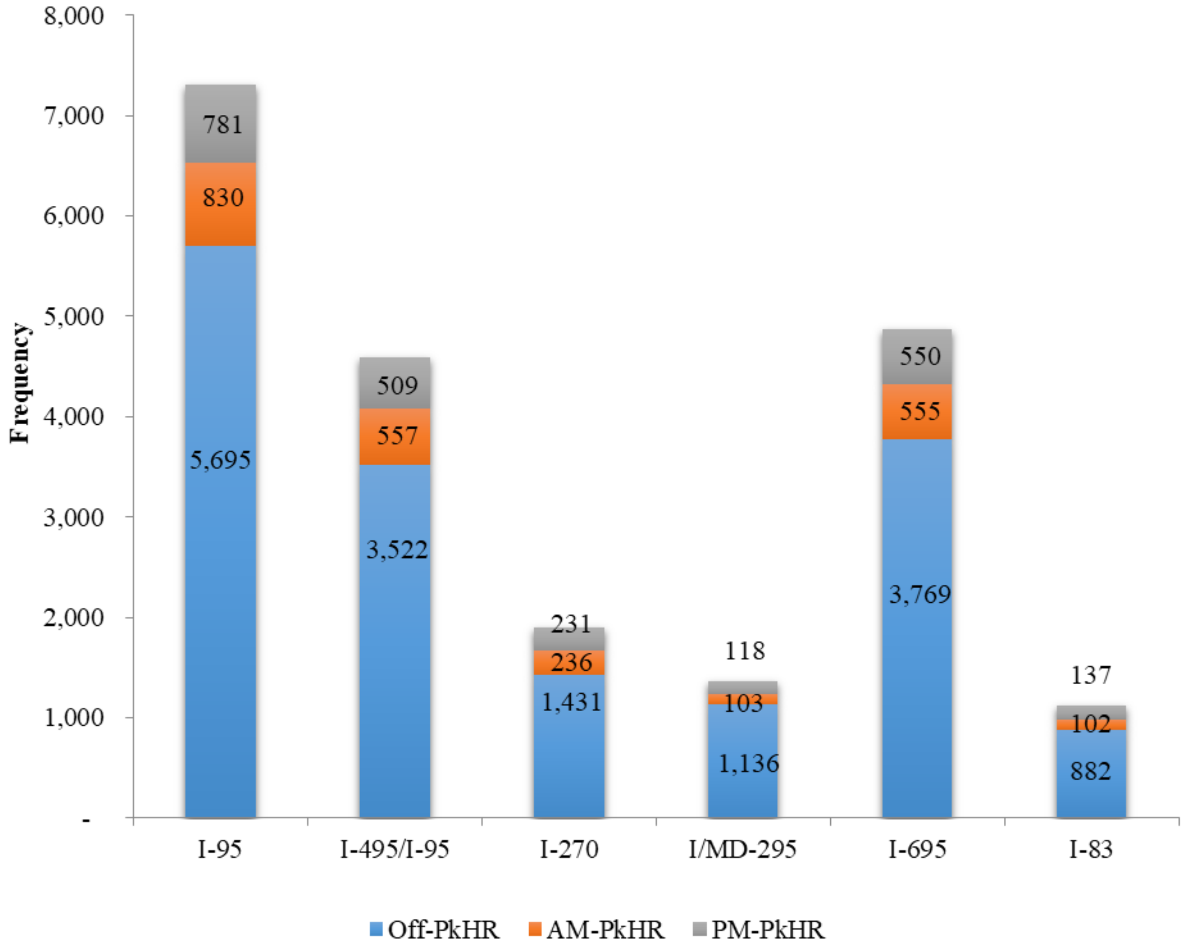


Figure 3.4 Distributions of Incidents by Time of Day on Major Roads in 2022

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

3.2

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

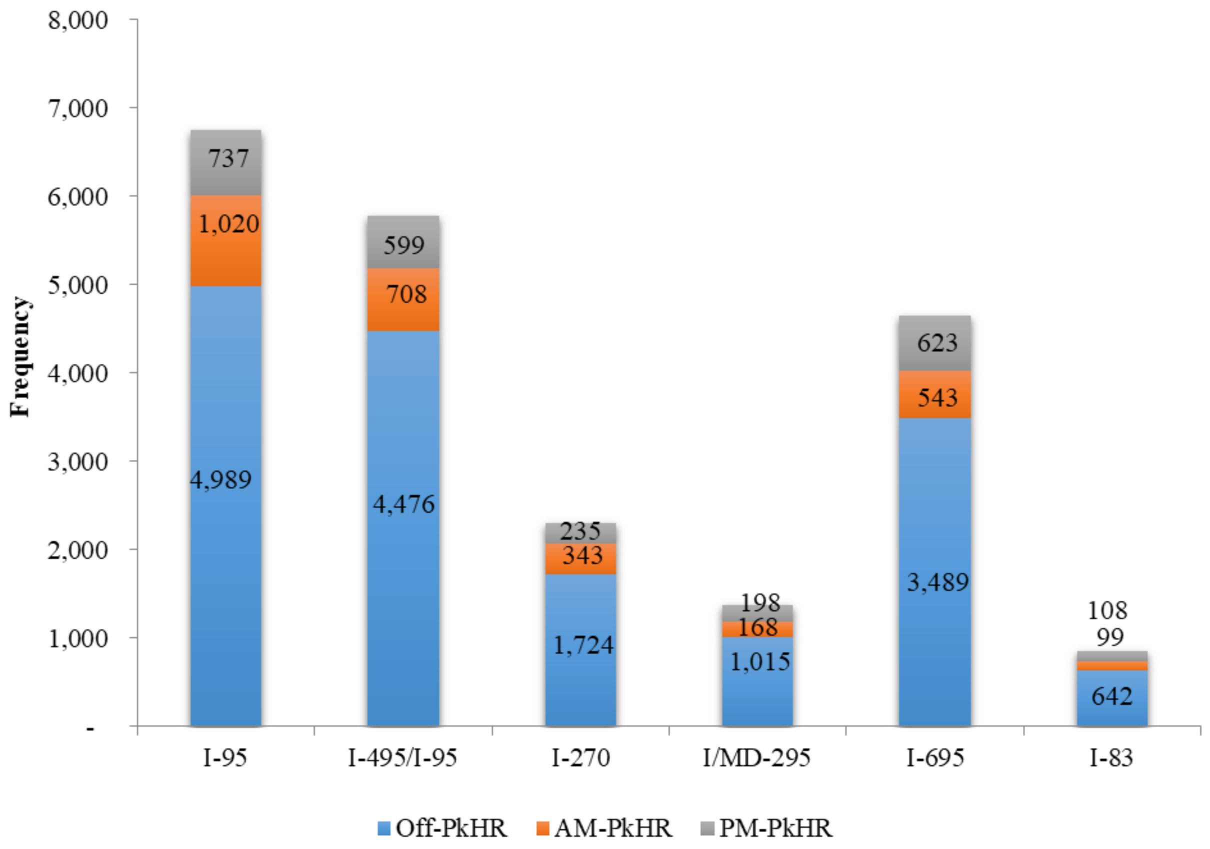


Figure 3.5 Distributions of Disabled Vehicles by Time of Day on Major Roads in 2022

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

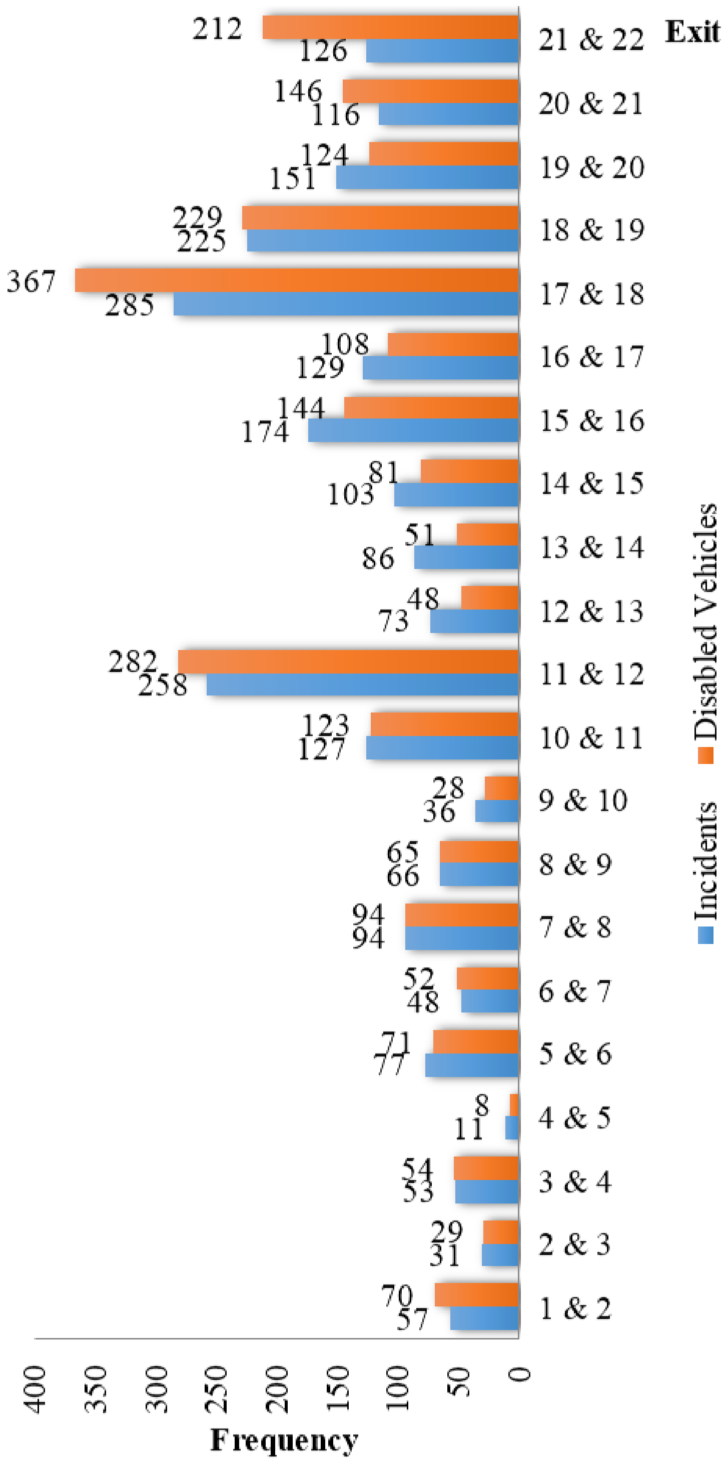


Figure 3.6 Distributions of Incidents/Disabled Vehicles by Location on I-695

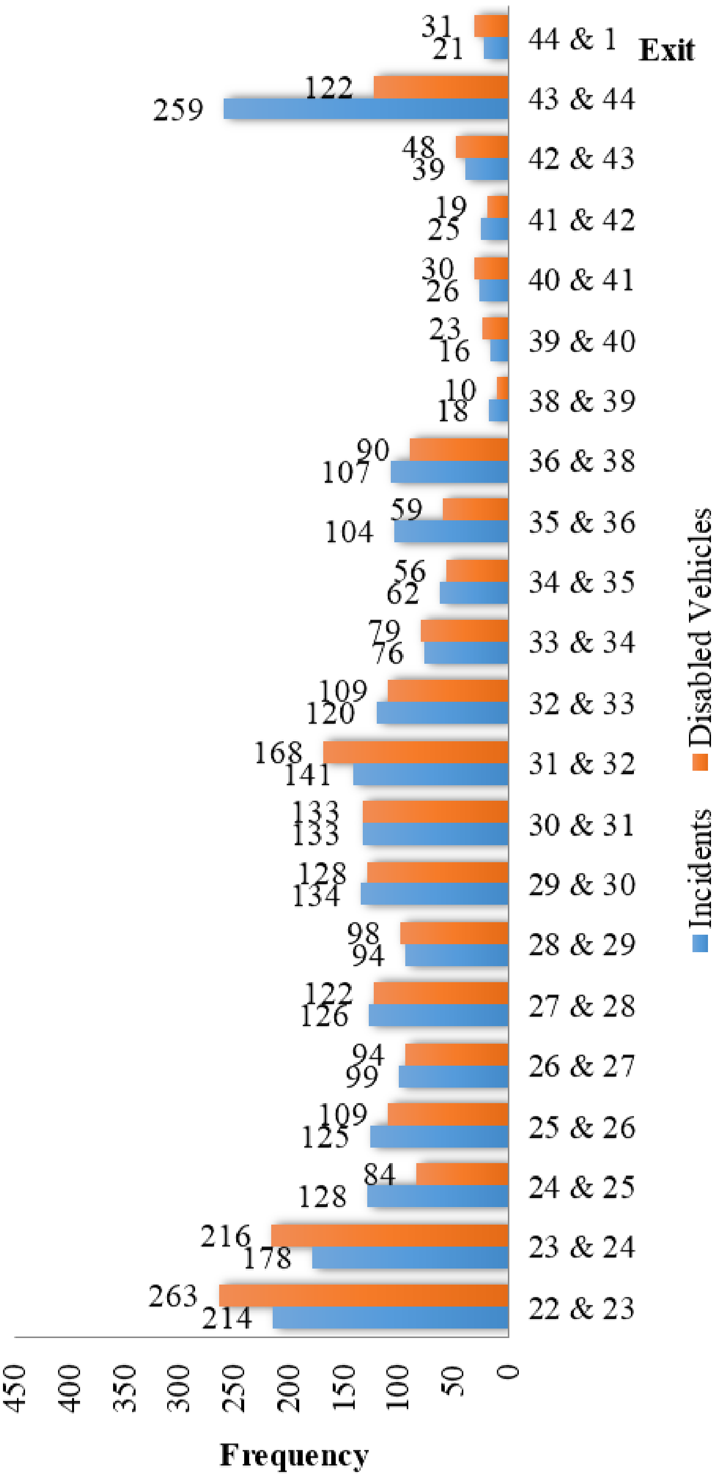


Figure 3.6 Distributions of Incidents/Disabled Vehicles by Location on I-695 (cont.)

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

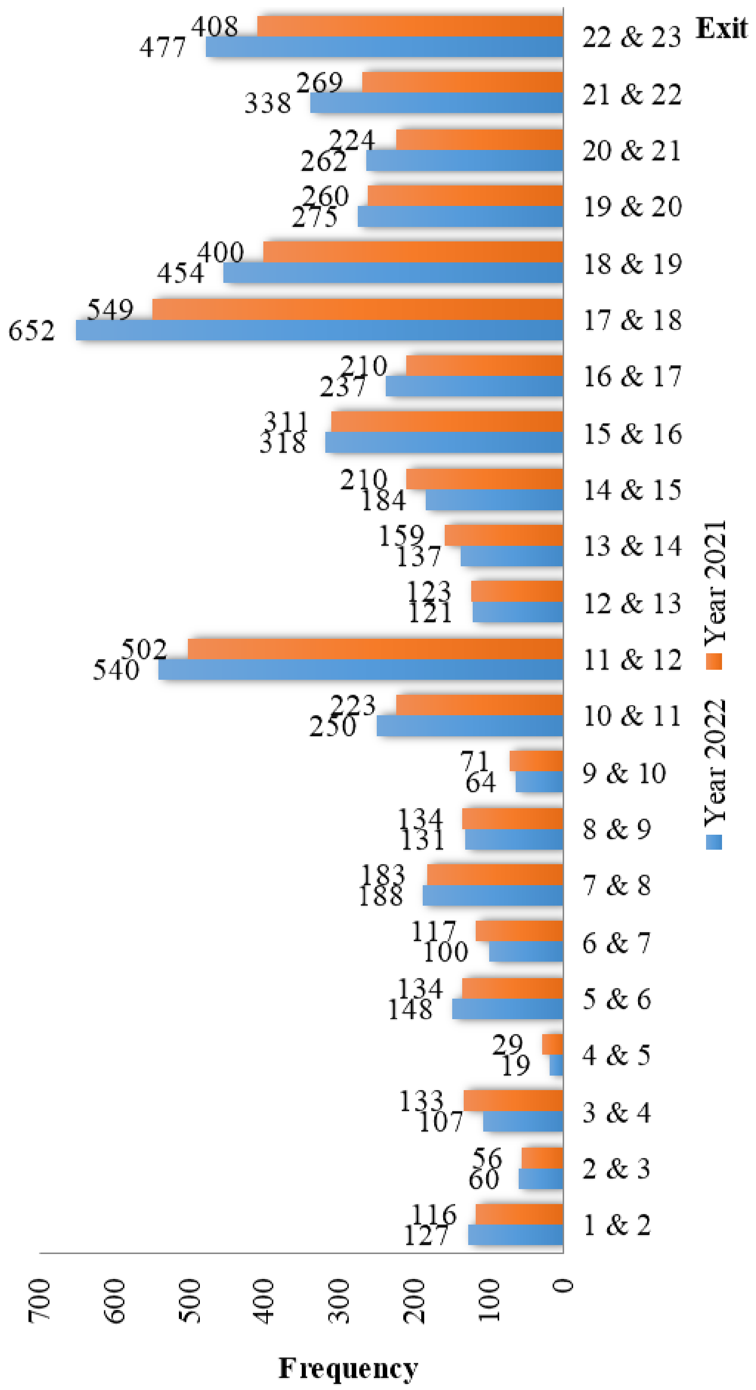


Figure 3.7 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-695

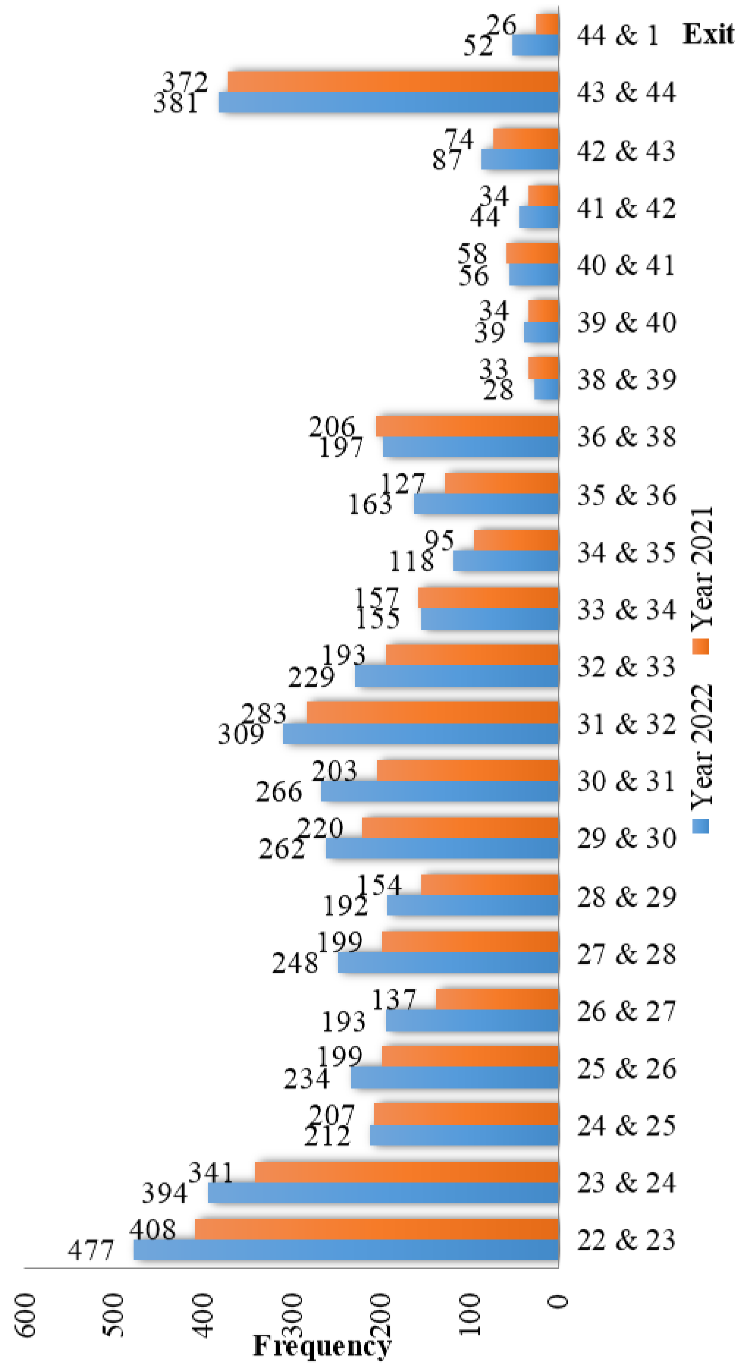


Figure 3.7 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-695 (Cont.)

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

Figure 3.6 shows the distribution of incidents and disabled vehicles by location on I-695 in 2022, while Figure 3.7 compares these values with the results in 2021. The high-incident segments are from Exit 17 to 18, Exit 43 to 44, and Exit 11 to 12 (285, 259 and 258, respectively). The three high frequencies of disabled vehicles (367, 282 and 263 cases) were recorded on the segments between Exits 17 and 18, Exits 11 and 12, and Exits 22 and 23, which are close to the I-70, I-95 and I-83 interchanges, respectively.

The subsequent figures present the comparison between 2022 and 2021 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 (304 cases) occurred between Exits 30 and 31 of I-495. The location with the highest frequency of disabled vehicles (415 cases) occurred between Exits 17 and 19. A comparison with the data in 2021 is illustrated in Figure 3.9.

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

3.2

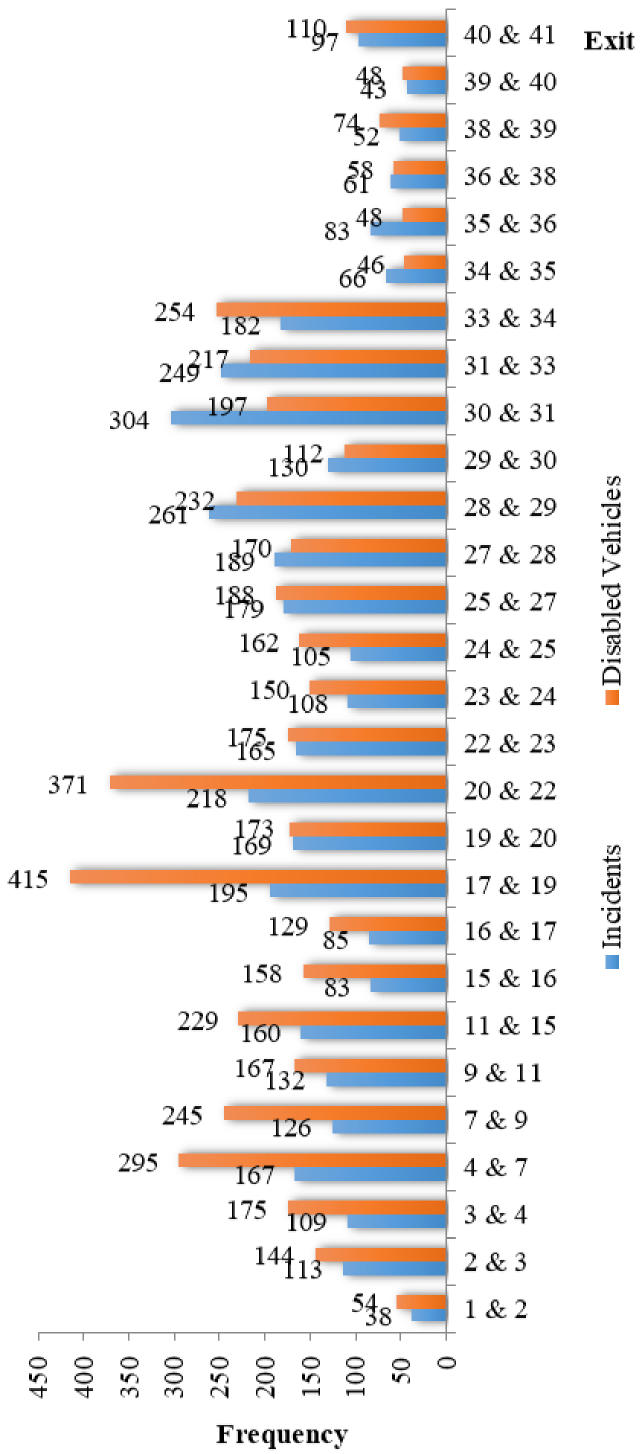


Figure 3.8 Distributions of Incidents/Disabled Vehicles by Location on I-495/I-95

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

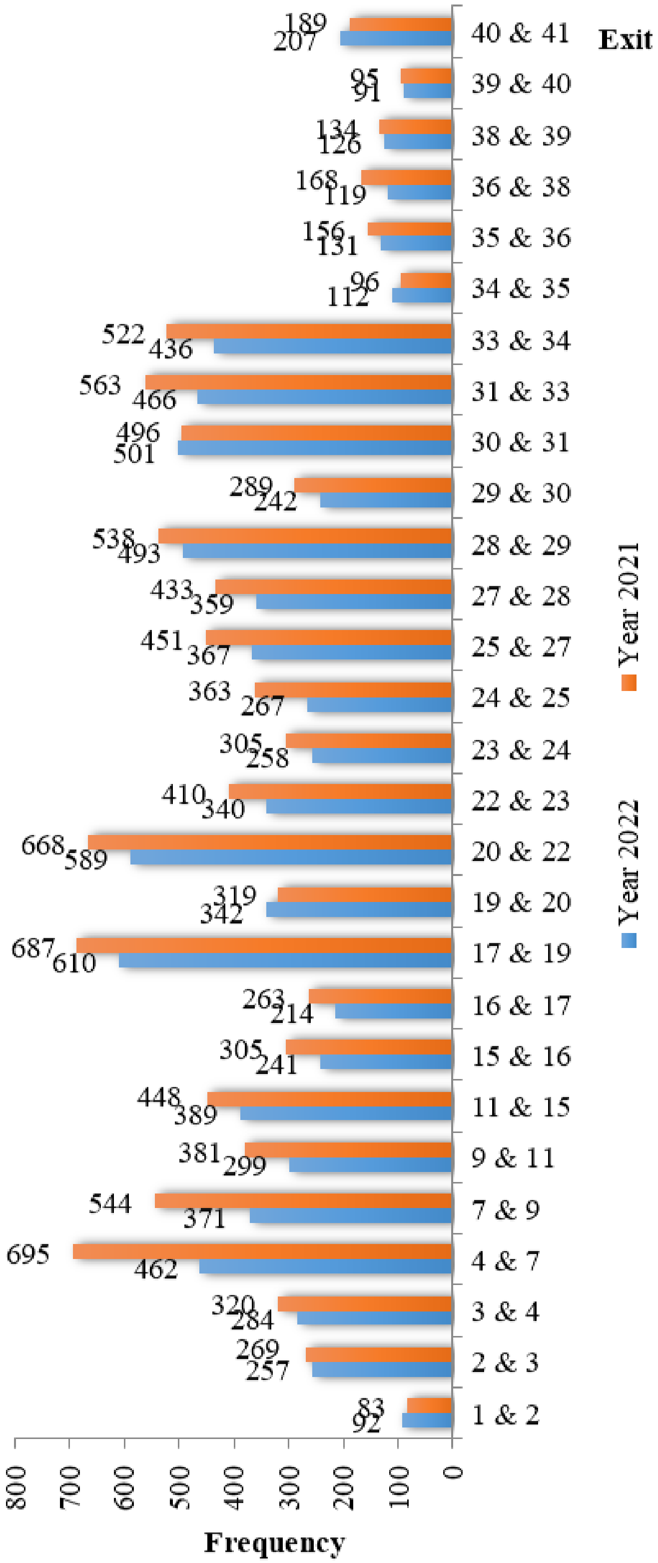


Figure 3.9 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-495/I-95

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 2022 and 2021. As shown in Figure 3.10, the highest number of incidents occurred at the segment between Exits 67 and 74 (931 cases). The same segments experienced a high number of disabled vehicles (602 cases).

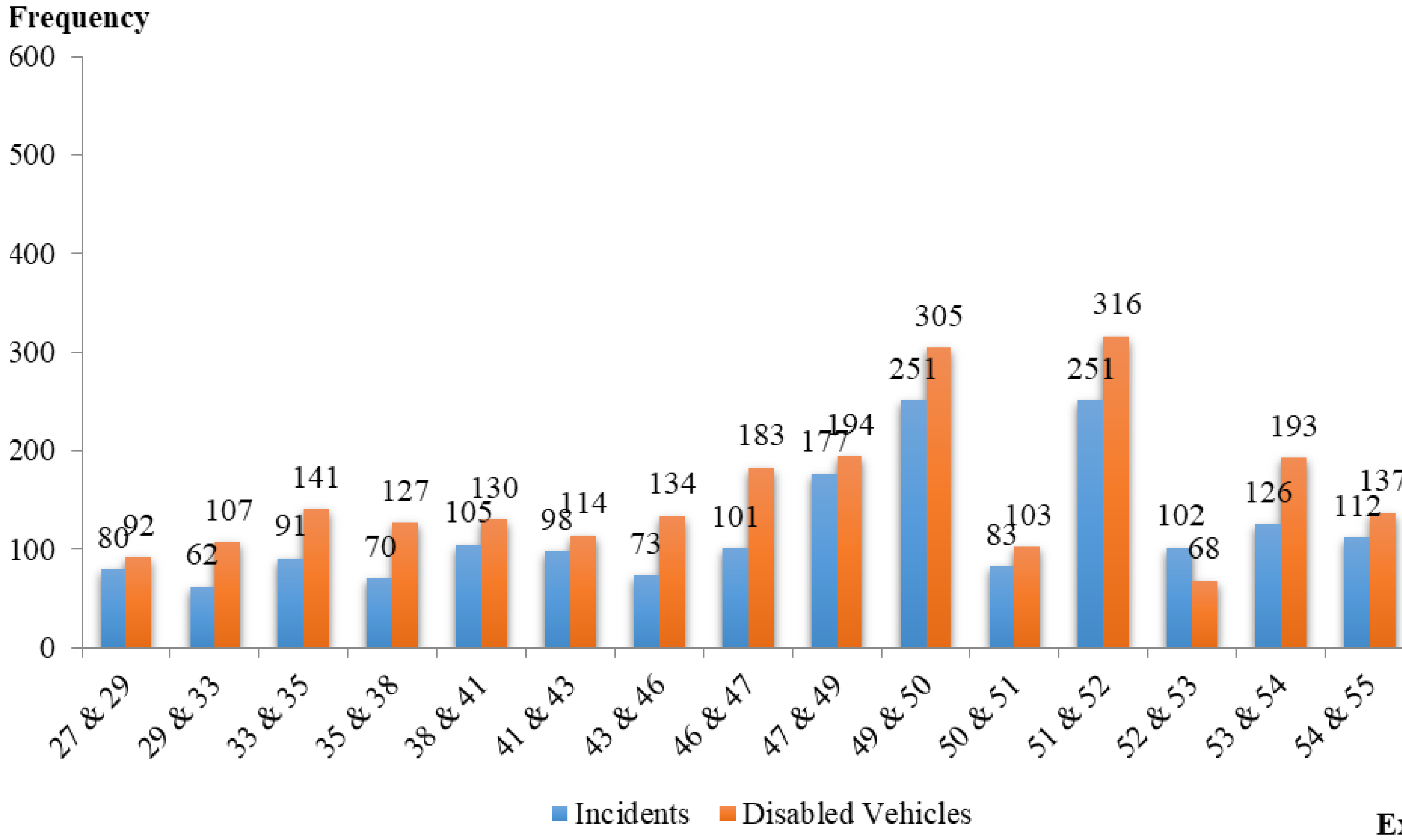


Figure 3.10 Distributions of Incidents/Disabled Vehicles by Location on I-95

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

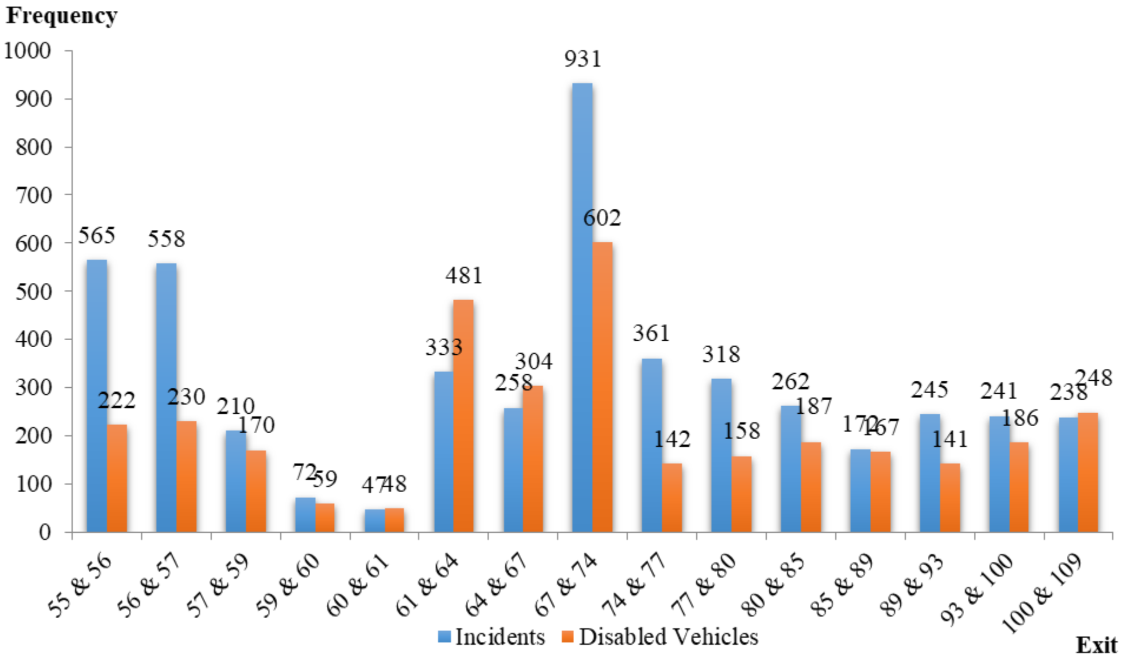


Figure 3.10 Distributions of Incidents/Disabled Vehicles by Location on I-95 (cont.)

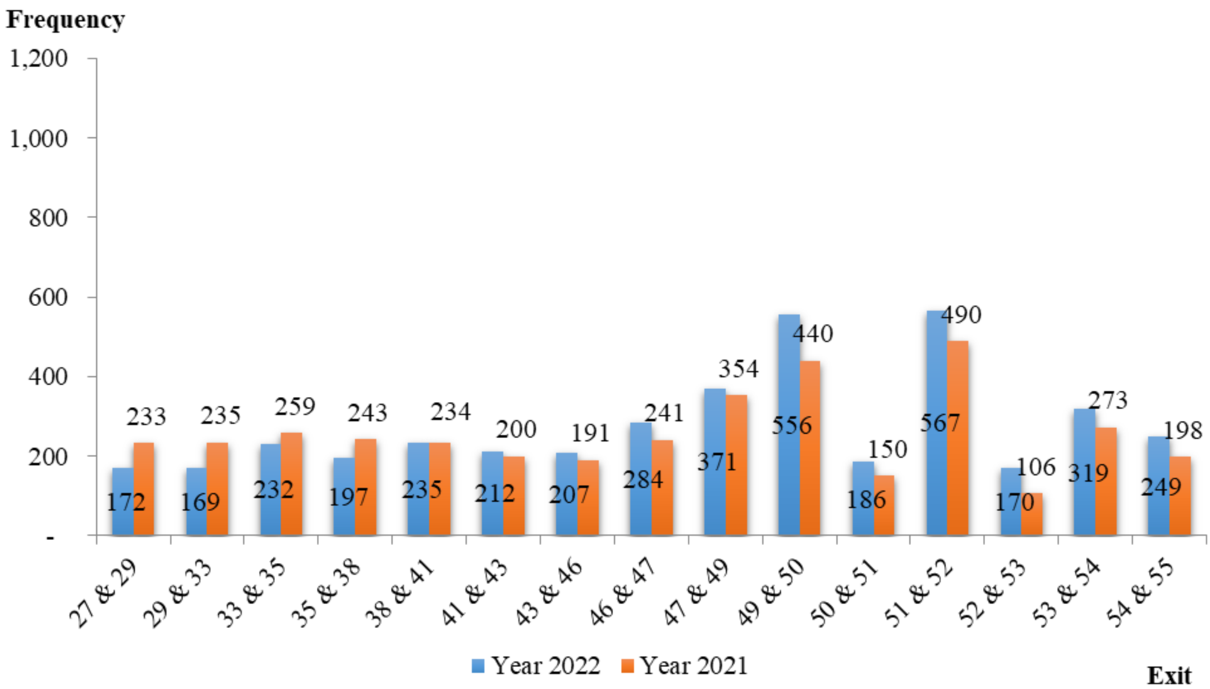


Figure 3.11 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-95

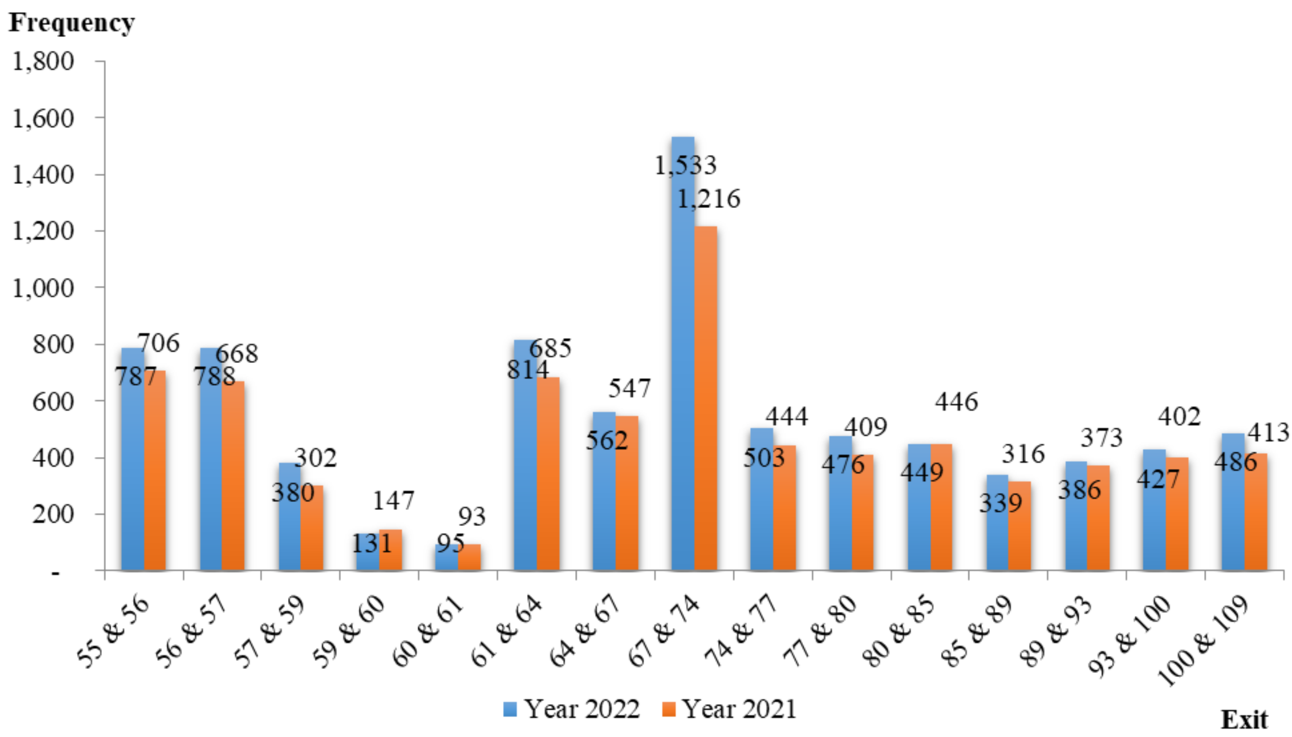


Figure 3.11 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-95 (cont.)

In 2022, the incidents and disabled vehicles recorded for the I-95 segment between Exits 67 and 74 received the highest number of responses, with a total frequency of 1,533 revealing the same patterns as in 2021 (1,216 cases, ranked the 1st). The segment on I-95 between Exits 61 and 64 was the second largest number of incidents/disabled vehicles requests (814 cases) in 2022. Most I-95 segments, especially those between Exits 38 and 59, and Exits 61 and 109, were reported to experience more requests of responding to incident/disabled vehicles than in 2021.

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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 2022. The segment between Exits 26 and 31 on I-270 experienced the highest numbers of incidents (190 cases) and the highest number of disabled vehicles (219 cases).

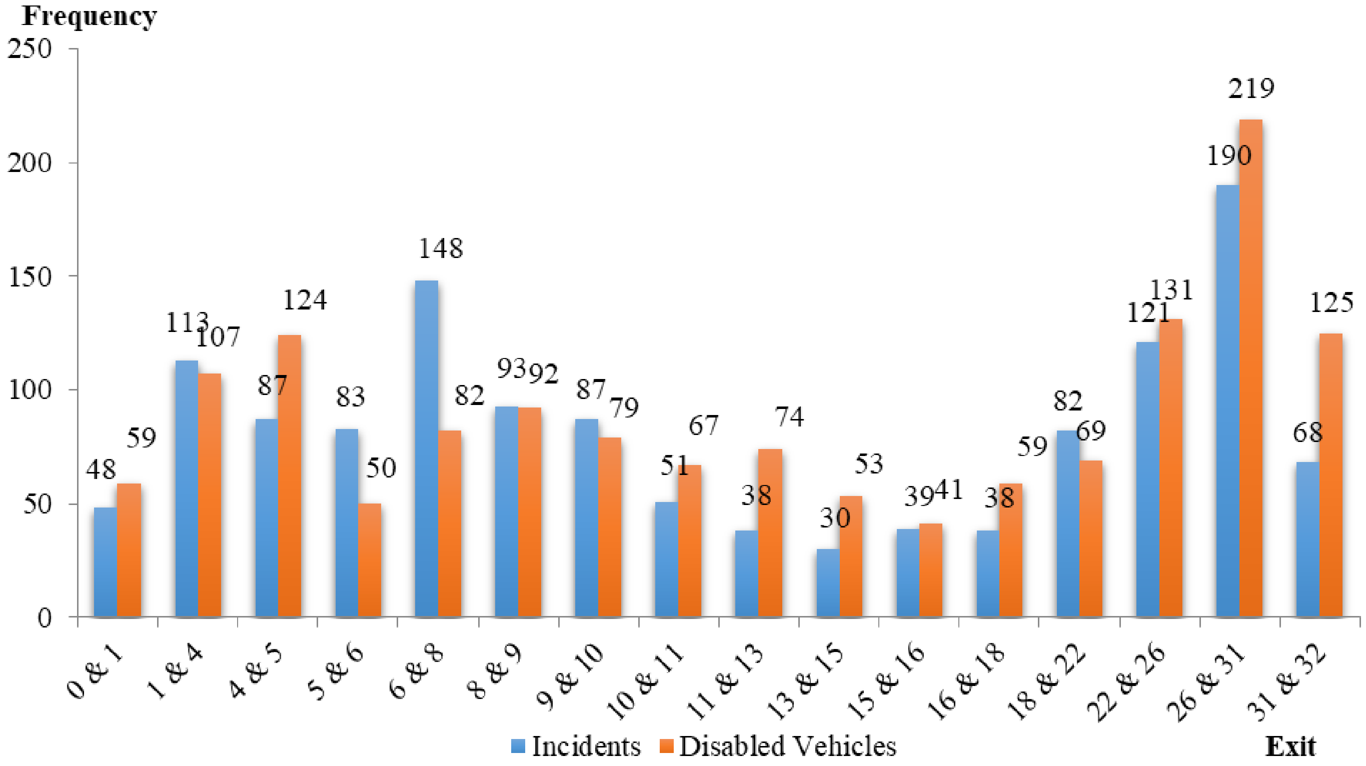


Figure 3.12 Distributions of Incidents/Disabled Vehicles by Location on I-270

Figure 3.13 shows a comparison between 2022 and 2021 data; all I-270 segments from Exit 1 to Exit 8 show fewer incident/disabled vehicles requests than those observed in 2021, as well as the segments from Exit 16 to Exit 32.

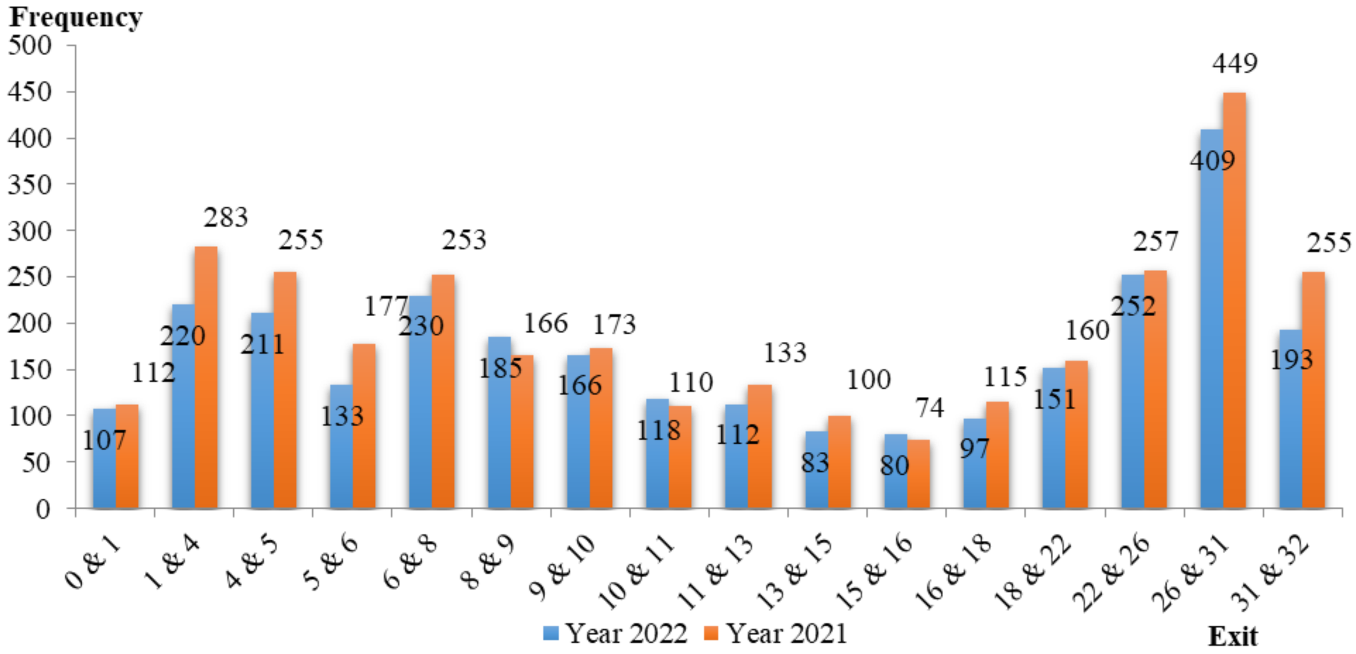
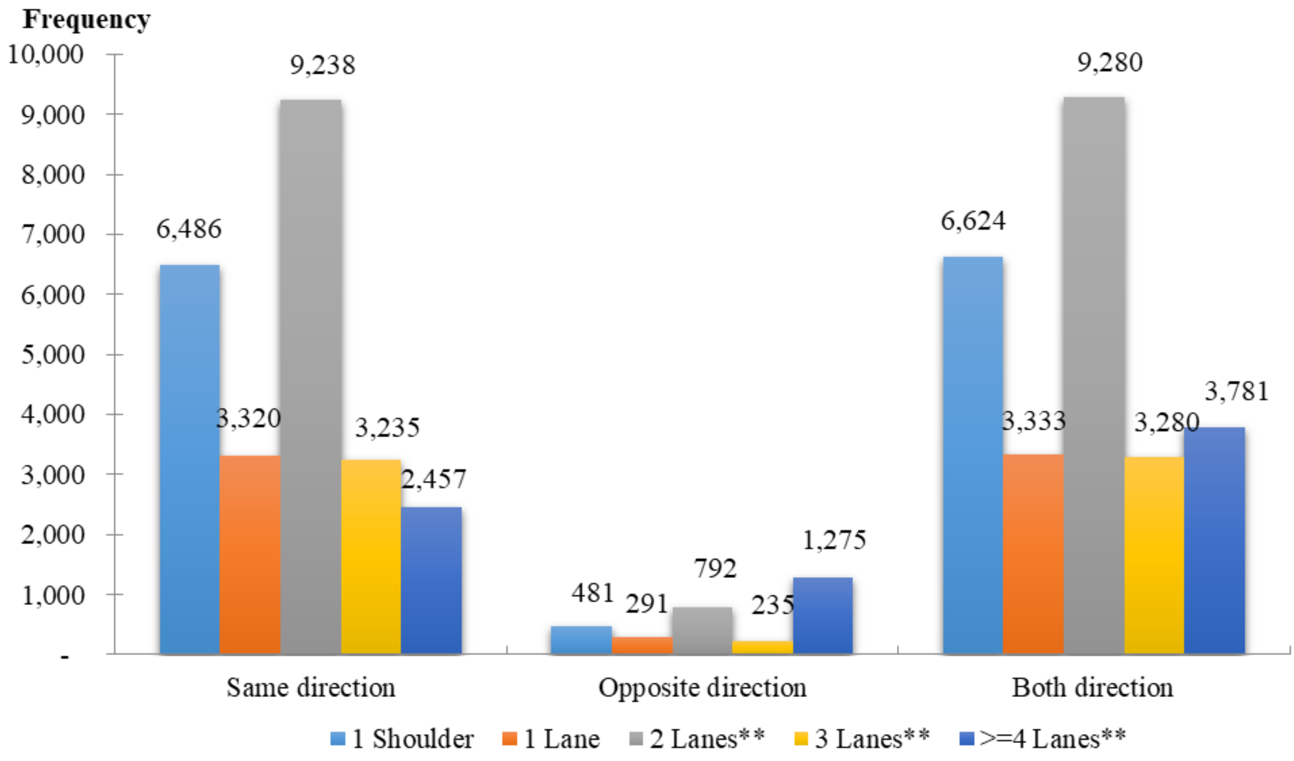


Figure 3.13 Comparisons of Incidents/Disabled Vehicles by Location on I-270

3.3 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY LANE BLOCKAGE TYPE

Figure 3.14 illustrates the distribution of incidents by lane blockage in 2022. A large portion of those incidents involved one-lane or two-lane blockages. The comparison of 2022 incidents/disabled vehicles distribution by lane blockage with 2021 data is illustrated in Figure 3.15. Note that all reported disabled vehicles are classified as shoulder lane blockages in Figure 3.15.

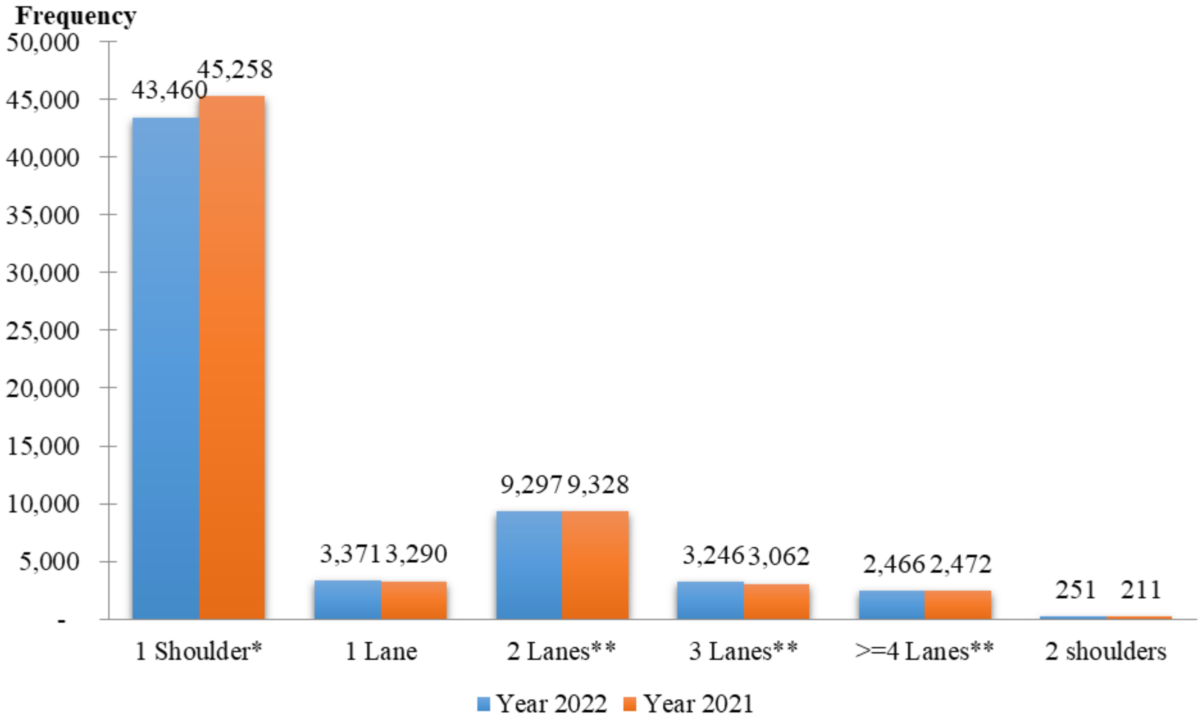


*Note: *This analysis uses only incidents (not including "Disabled Vehicles")*
***Also includes Shoulder Lane Blockages*

Figure 3.14 Distributions of Incidents* by Lane Blockage

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY LANE BLOCKAGE TYPE

3.3

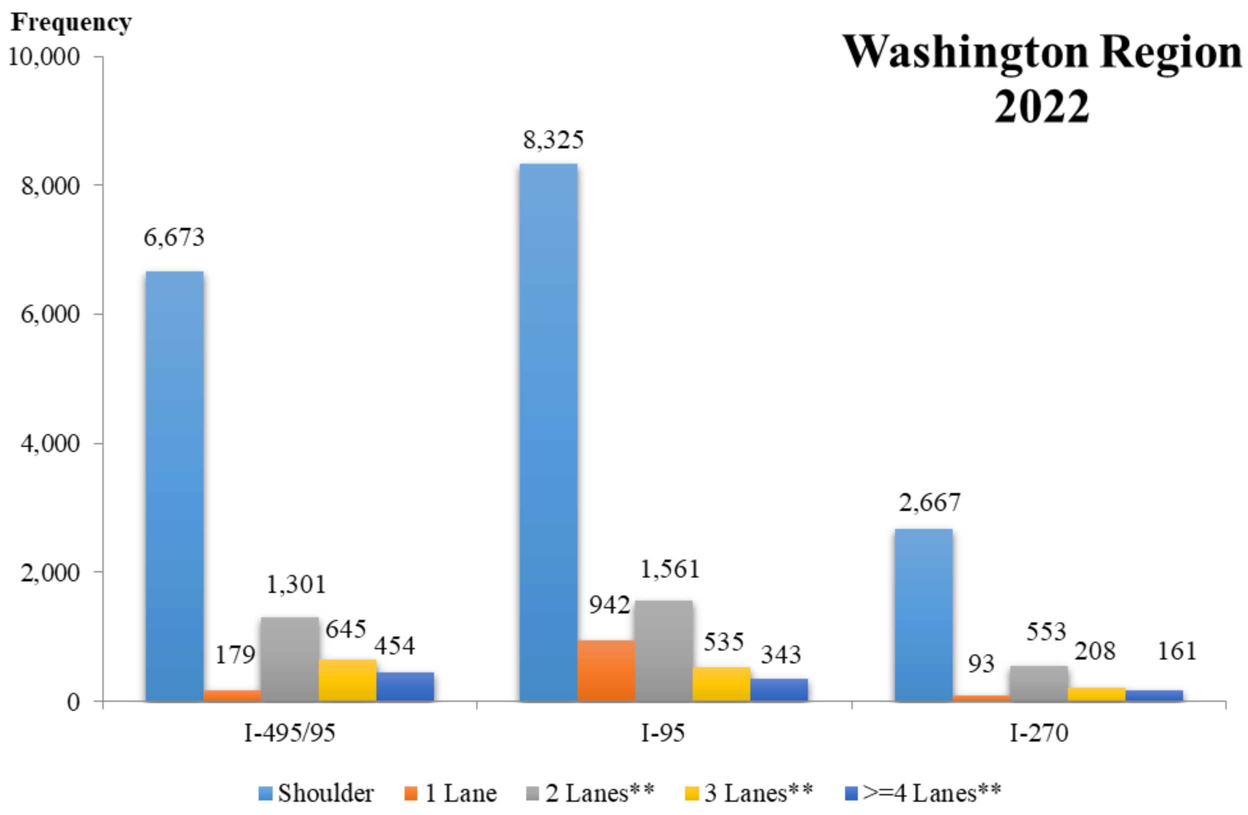


*Note: * Disabled Vehicles are all classified as Shoulder Lane Blockages.*
*** Also includes Shoulder Lane Blockages.*

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

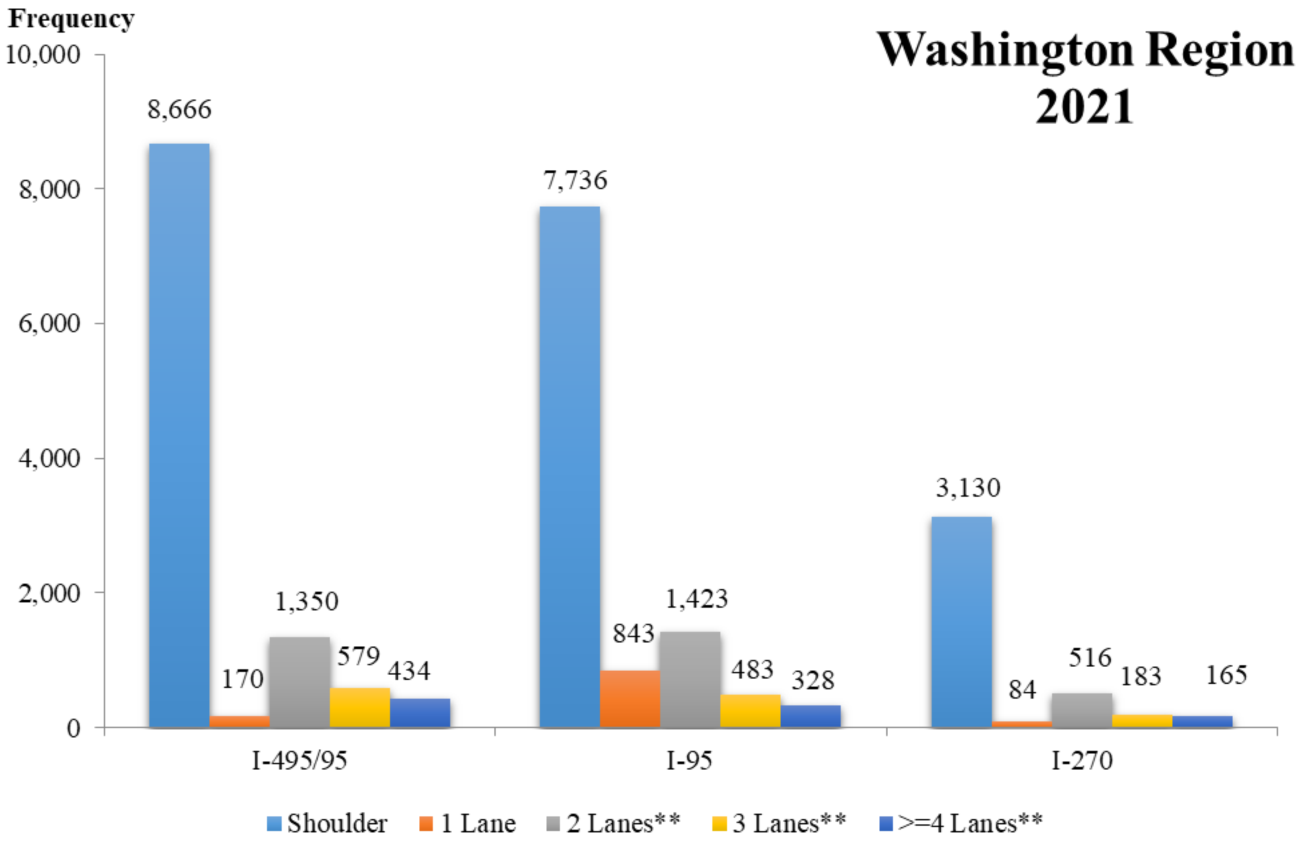
3.3 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY LANE BLOCKAGE TYPE

Figures 3.16 and 3.17 depict a comparison of lane blockage incidents between 2022 and 2021 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*

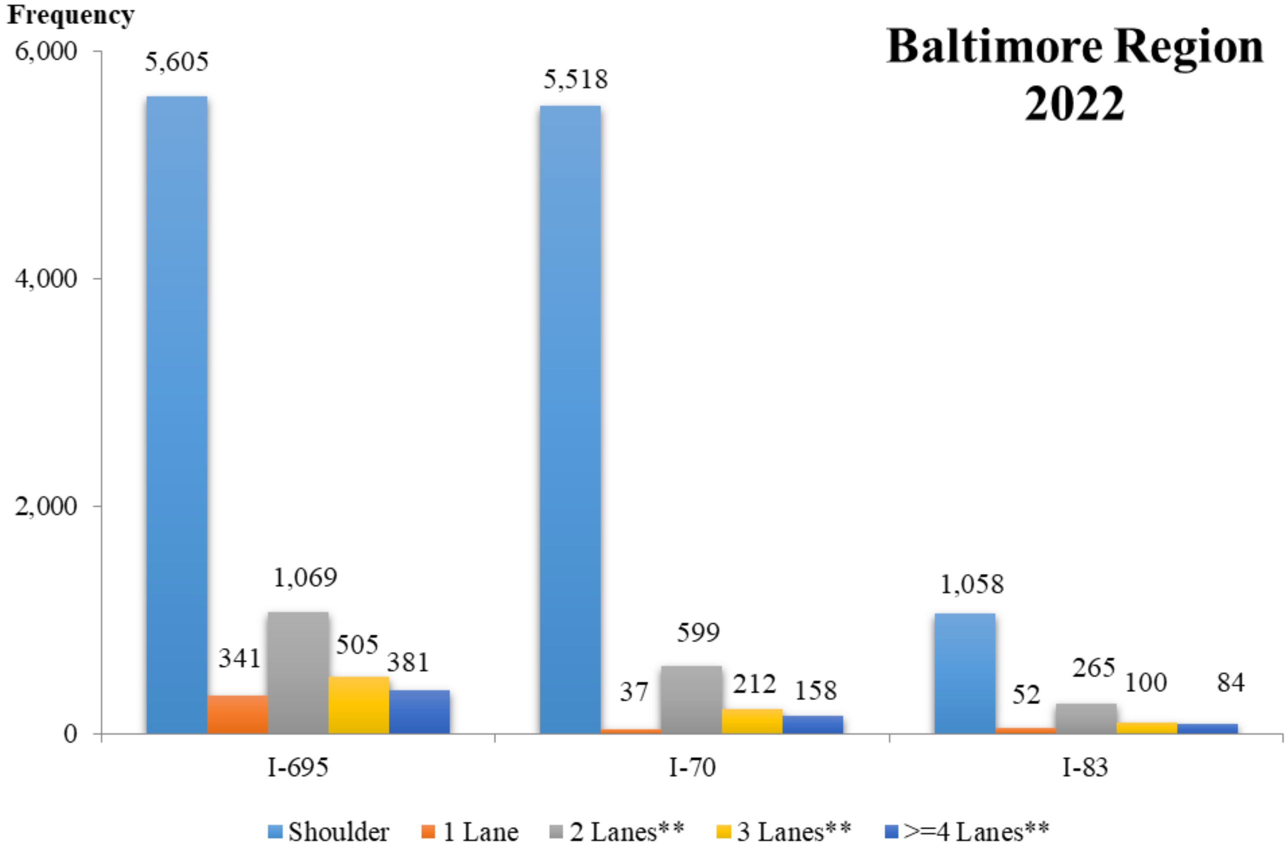
Figure 3.16 Distributions of Lane Blockages Occurring on Major Freeways in the Washington Area



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

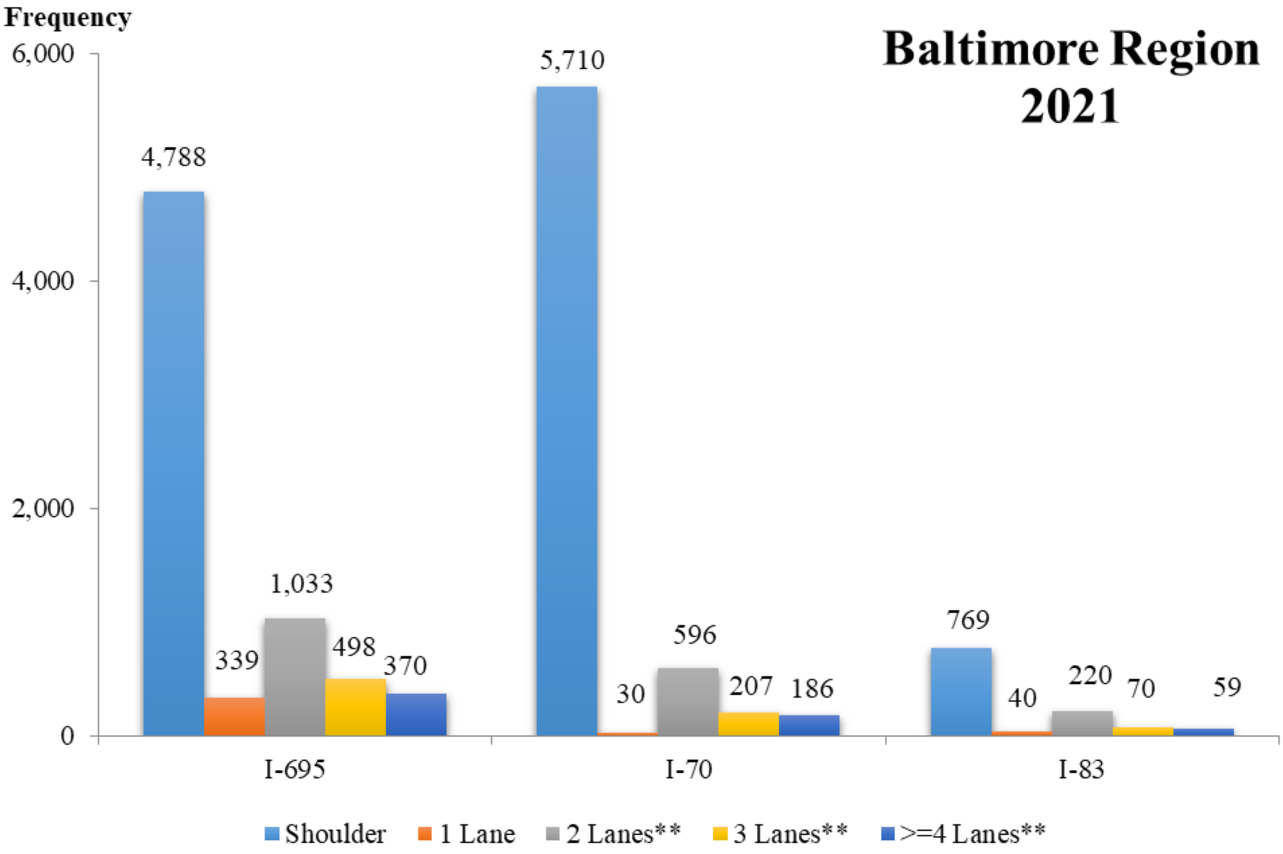
Figure 3.16 Distributions of Lane Blockages Occurring on Major Freeways in the Washington Area (Cont.)

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



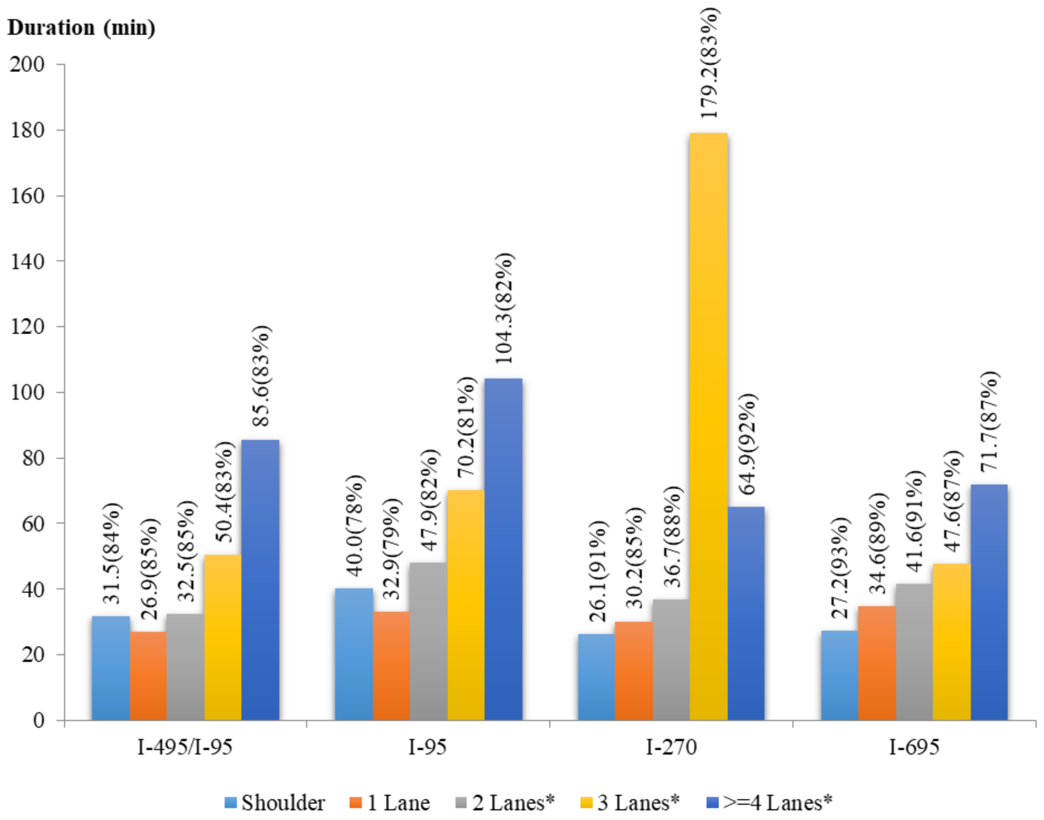
*Note: *Disabled Vehicles are all classified as Shoulder Lane Blockages*
***Also includes Shoulder Lane Blockages*

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.
**The number in each parenthesis shows 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.

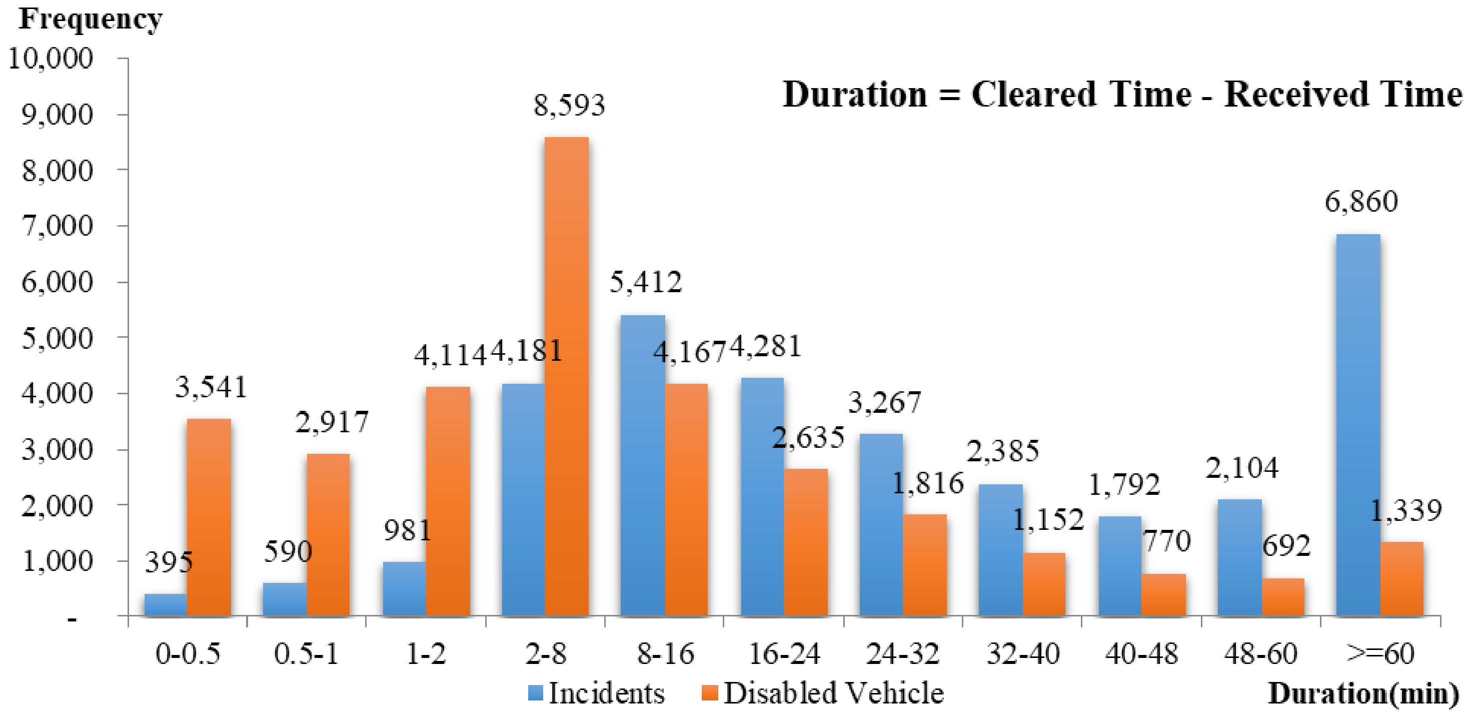
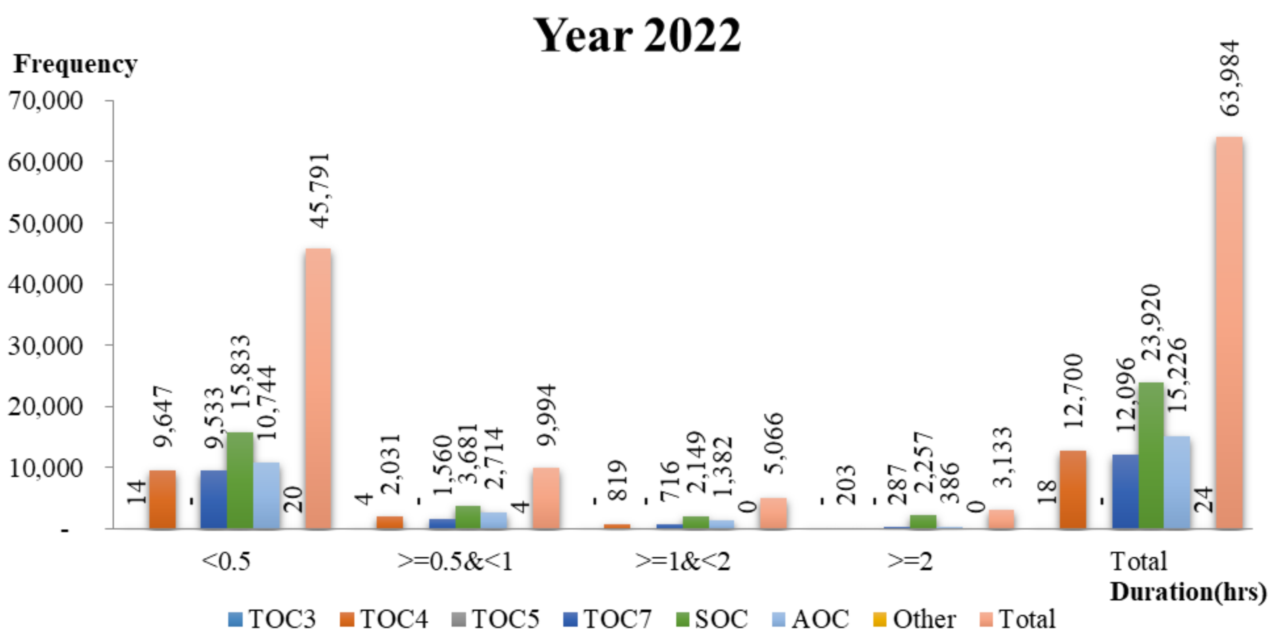


Figure 3.19 Distributions of Incidents/Disabled Vehicles by Duration in 2022

Although most incidents in 2022 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.

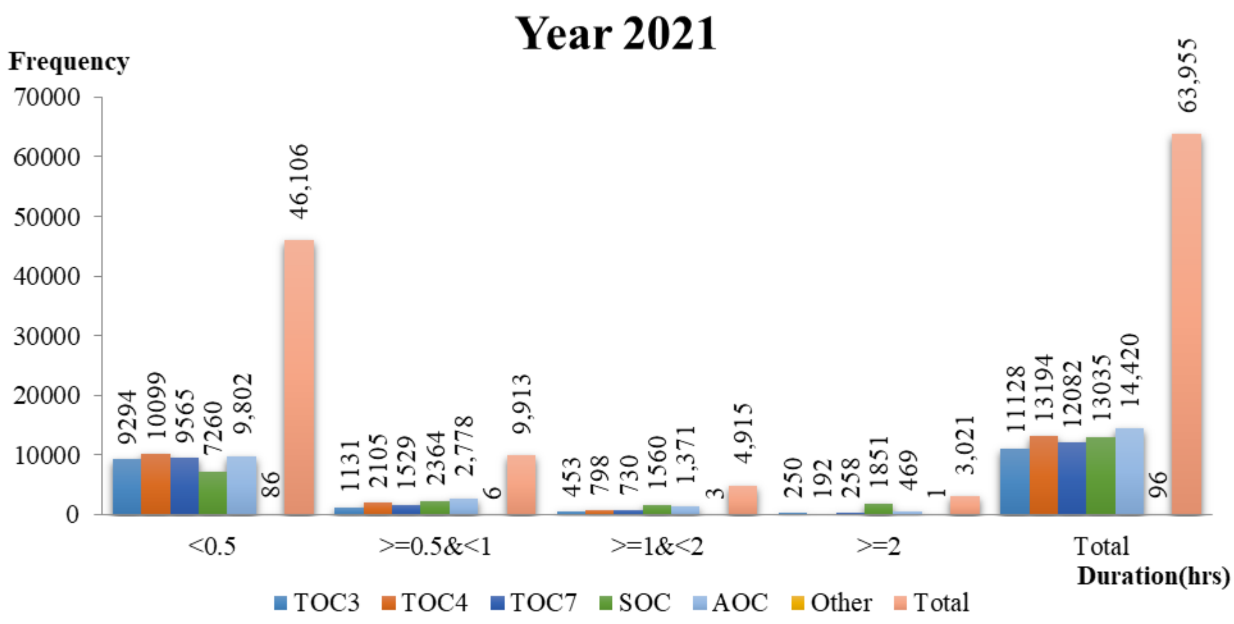
3.4 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY BLOCKAGE DURATION

Figure 3.20 presents the distribution of records in 2022 and its comparison with 2021 data. About 24 percent and 21 percent of reported incidents/disabled vehicles managed by TOC-4 and TOC-7, respectively, had blocked traffic lasting longer than 30 minutes. For SOC, about 34 percent of reported incidents lasted longer than 30 minutes. This implies that only 28 percent of reports to which CHART responded lasted more than 30 minutes in 2022.



Note: As of January 2022, TOC-3 has been relocated to the SOC.

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



Note: As of January 2022, TOC-3 has been relocated to the SOC.

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

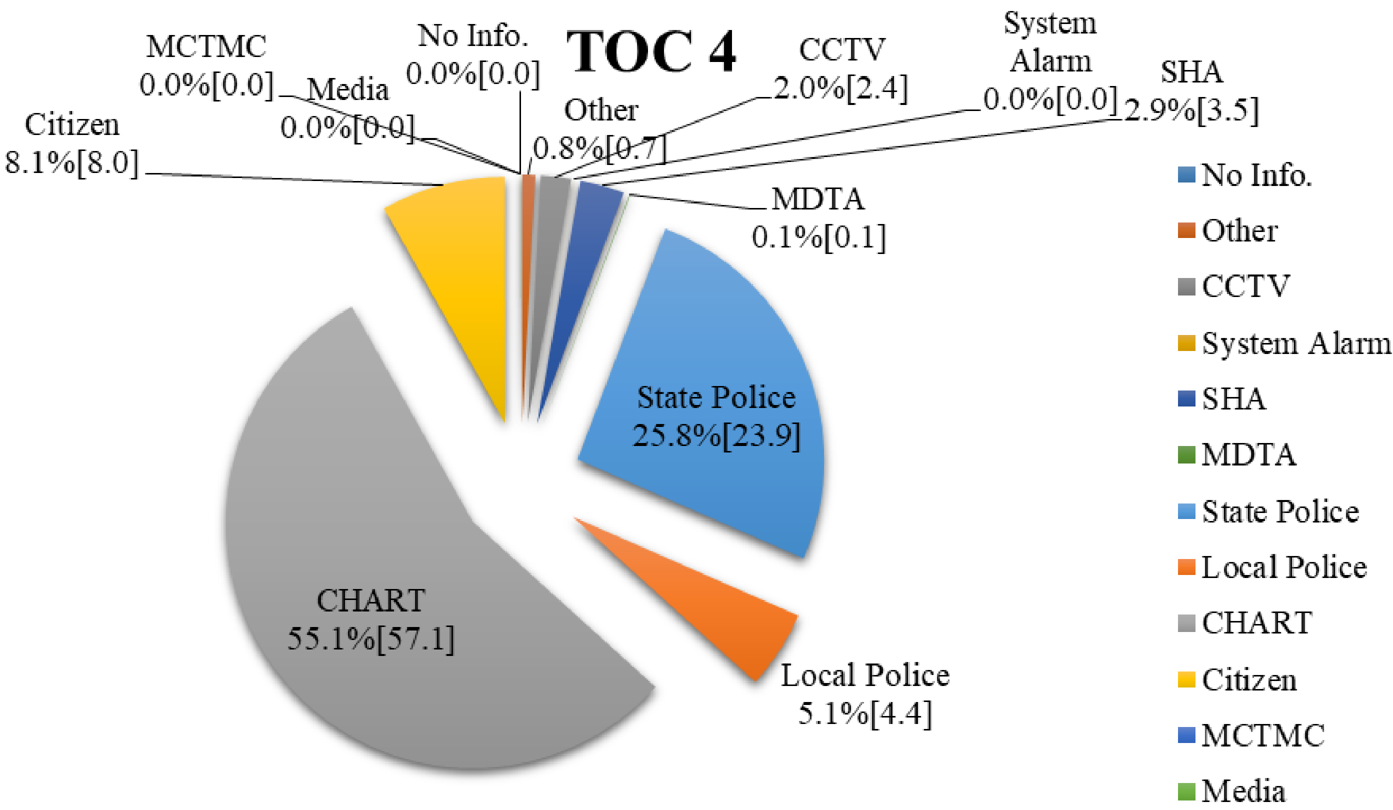
4.1 Evaluation of Detection Efficiency and Effectiveness

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 number of traffic incidents/disabled vehicles managed by the CHART/MSHA emergency response teams to those reported to the CHART control center. Based on 2022 incident/disabled vehicle management records, the overall response rate was 90.9 percent. As in the previous year, existing incident/disabled vehicle 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

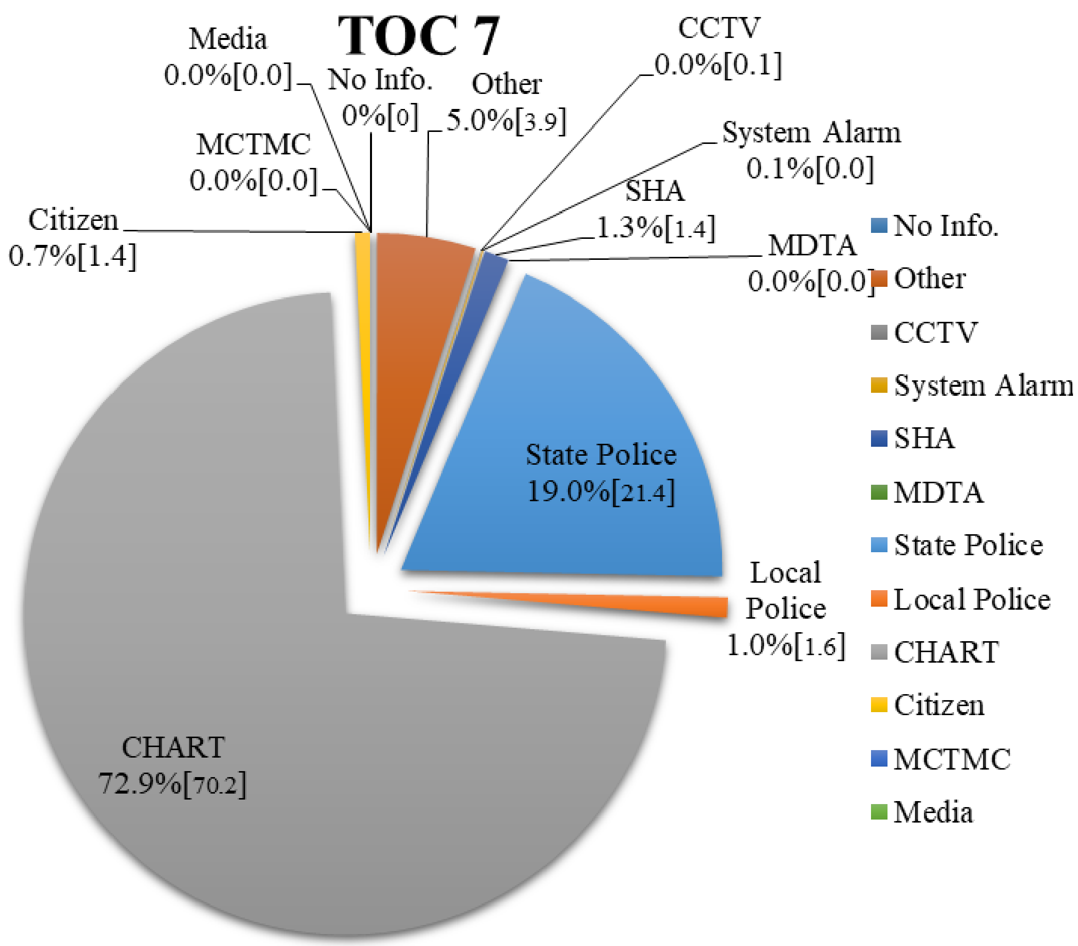
Figures 4.1 and 4.2 illustrate the distributions of incidents/disabled vehicles by detection source for control centers TOC 4 and TOC7, respectively.



Note: Numbers in [ ] show the percentages from Year 2021.

** Actual frequencies for incidents/disabled vehicles detected by system alarm, No info., MCTMC and media are 1, 0, 0, and 3 in the CHART-II database of year 2022.*

Figure 4.1 Distributions of Incidents/Disabled Vehicles by Detection Source for TOC 4



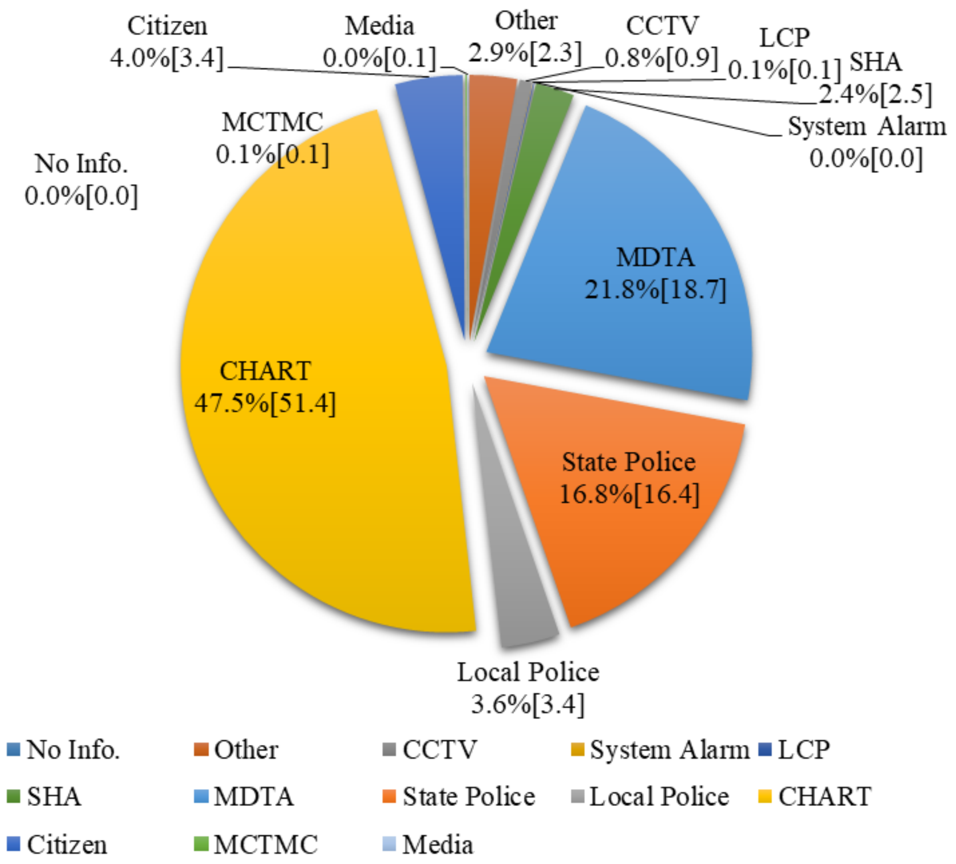
Note: Numbers in [ ] show the percentages from Year 2021

** Actual frequencies for incidents/disabled vehicles detected by No info., CCTV, MDTA, MCTMC, and Media in 2022 are 1, 6, 0, 0 and 1 in the CHART-II database.*

Figure 4.2 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 4.3 clearly show that about 47.5 percent of incidents in 2022 were detected by MSHA/CHART patrols. About 16.8 percent were reported by the MSP, similar to the 16.4 percent figure in 2021. Note that the numbers in parentheses indicate the 2021 statistics.



Note: Numbers in [ ] show the percentages from Year 2021.

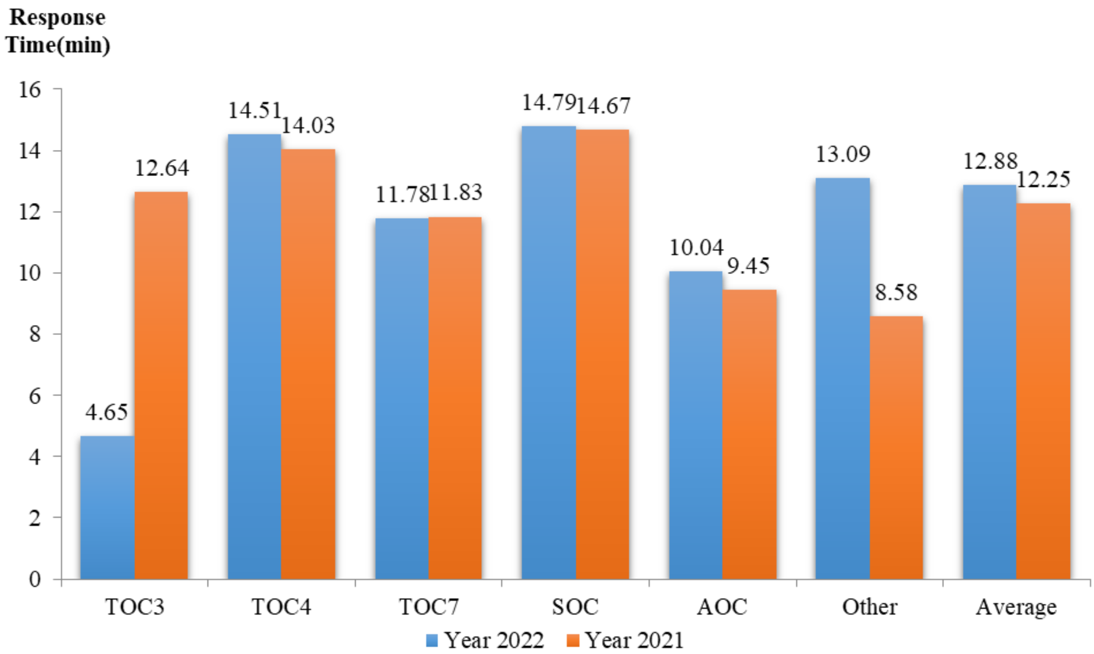
** The actual frequency for incidents/disabled vehicles detected by No info. and System Alarm in 2022 is 0 and 21 in the CHART-II database.*

Figure 4.3 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 2022 is given in Figure 4.4. The average response time in 2022 was 12.88 minutes, slightly lower than that of 2021 (12.25 minutes).

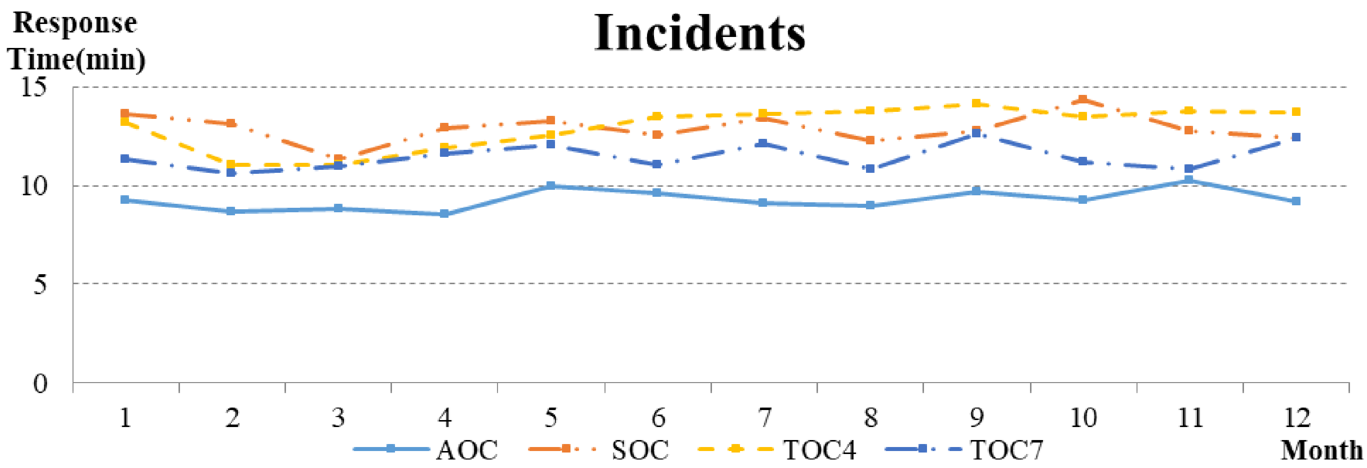


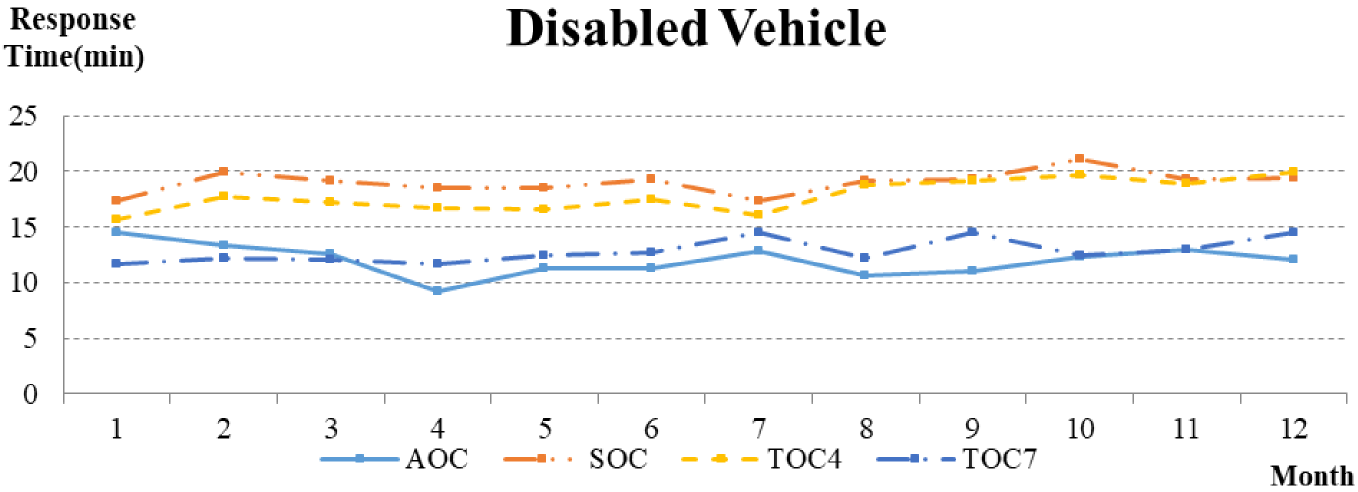
**Note: As of January 2022, TOC-3 has been relocated to the SOC.*

Figure 4.4 Distributions of Average Response Times

4.2 ANALYSIS OF RESPONSE EFFICIENCY

In Figure 4.5 the average response times of incidents by AOC and TOC7 are fairly consistent throughout the year and are mostly below twelve minutes. TOC4 shows relatively fluctuating response times up to 14.4 minutes through year 2022. For disabled vehicles, the response times show significant fluctuations for AOC, which exhibits an reduction in the average response time for disabled vehicles in April, yet an increase in the average response time in July. Overall, the average response times for AOC are relatively shorter than for TOCs in most months, for both incidents and disabled vehicles.



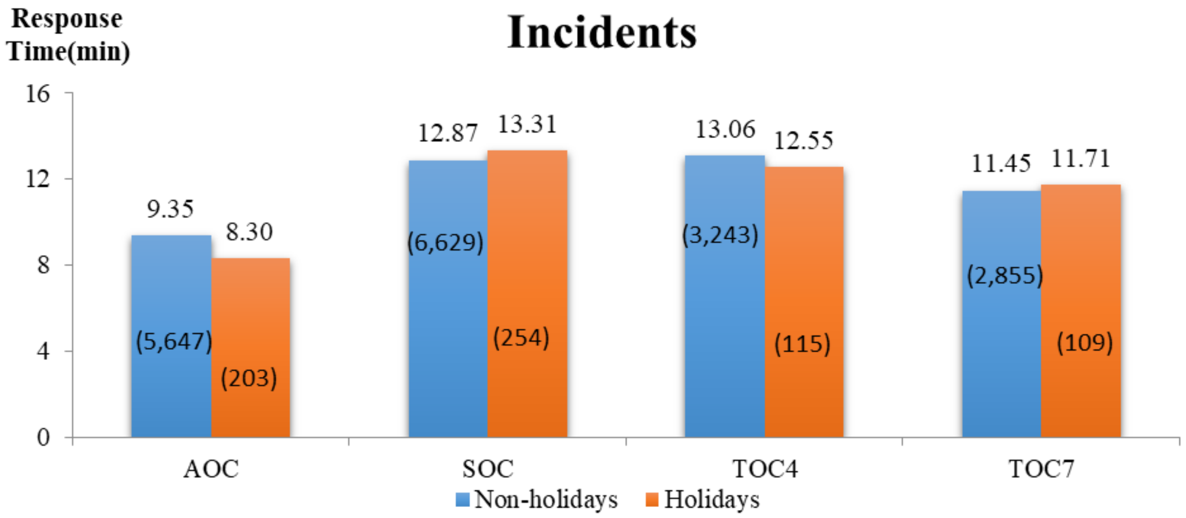


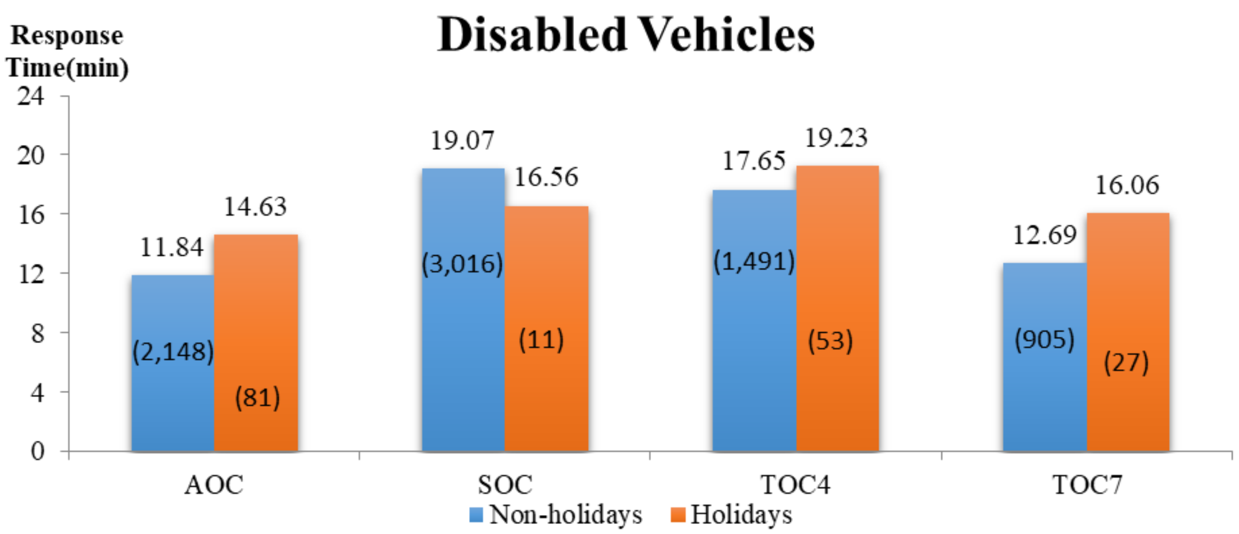
Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. ESTO and TOC 6 were excluded in this analysis, since they operate on a seasonal basis.

Figure 4.5 Average Response Times for Operation Centers by Month in 2022

4.2 ANALYSIS OF RESPONSE EFFICIENCY

Figure 4.6 illustrates the fact that SOC and TOC7 show slightly faster response times for incidents during non-holidays in 2022. The response time for disabled vehicles during non-holidays is shorter than that during holidays for most centers.





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

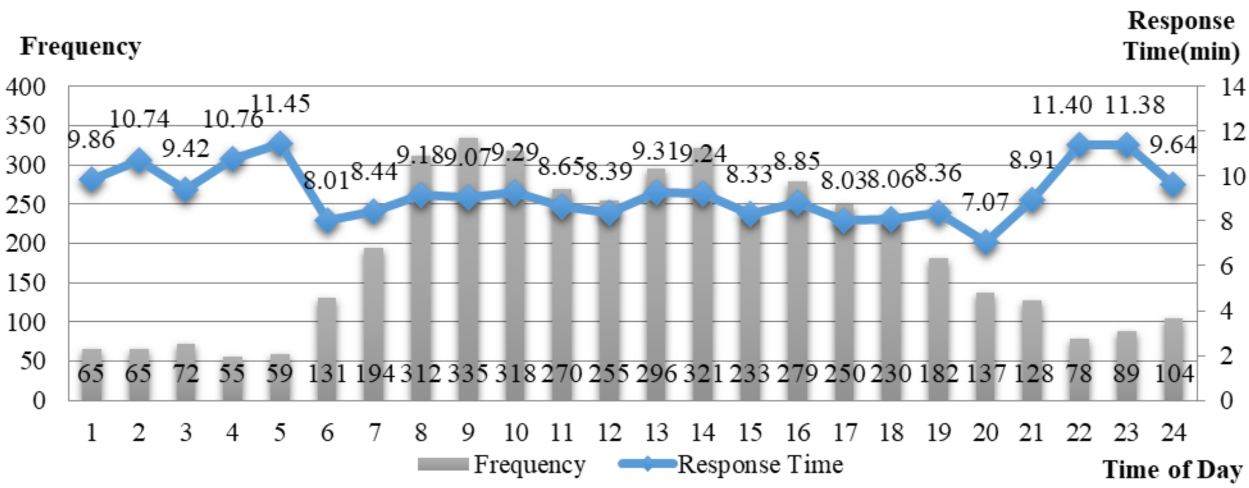
2. Numbers in each parenthesis show the data availability.

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 4.6 Average Response Times for Operation Centers on Holidays and Non-Holidays in 2022

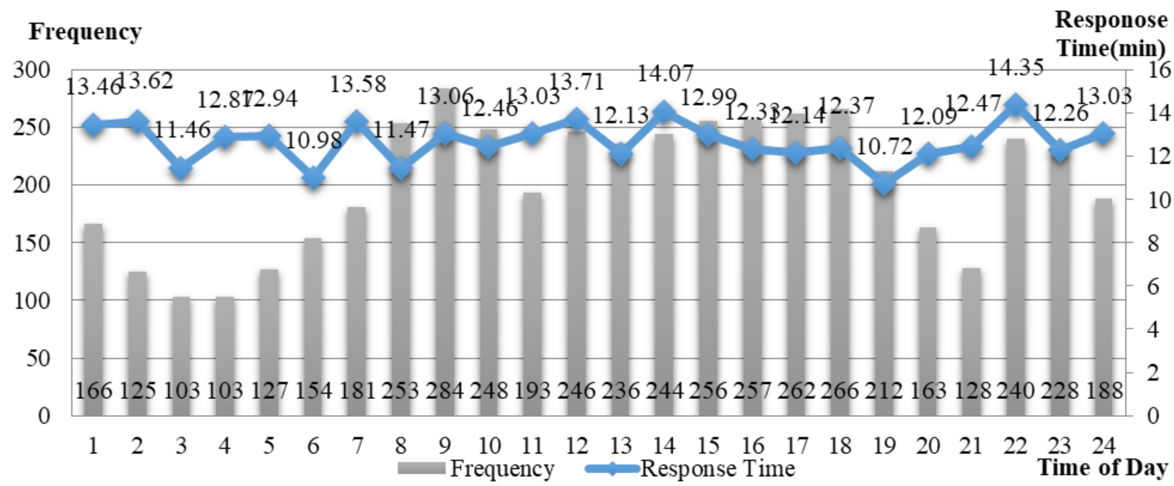
4.2 ANALYSIS OF RESPONSE EFFICIENCY

Figures 4.7 to 4.10 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, SOC shows quite consistent response time through the day. On the other hand, the response times by AOC vary with the operational hours through the day. Since AOC and SOC operate as a backup of TOCs 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.



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

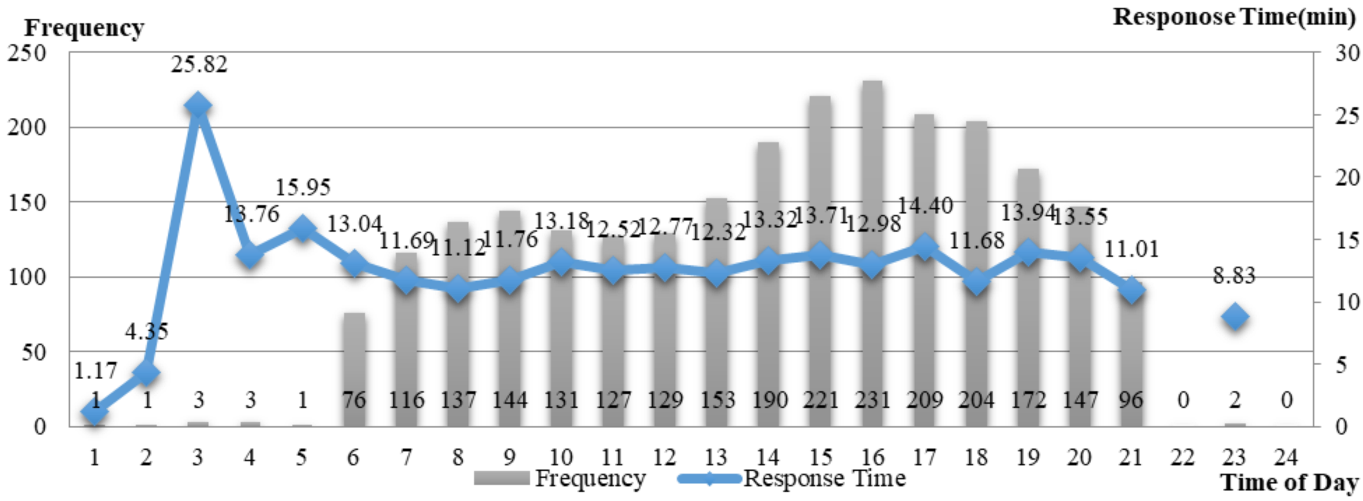
Figure 4.7 Average Response Times for AOC by Time of Day on Weekdays in 2022



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 SOC by Time of Day on Weekdays in 2022

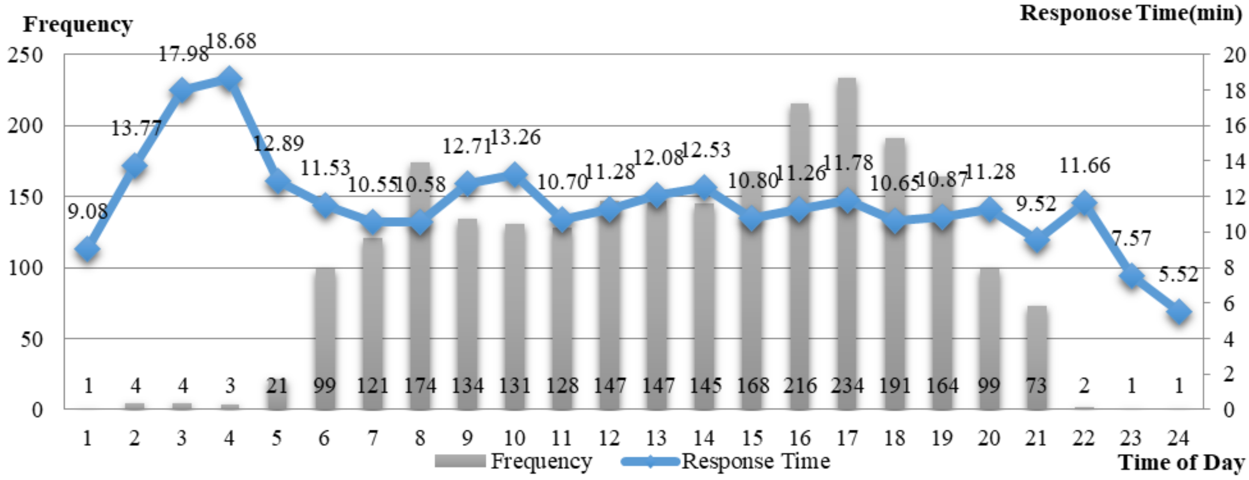
The response times by TOC4 are quite consistent during their operational periods (5 a.m. – 9 p.m.), and the responded incident frequencies also exhibit distinct patterns during peak periods. On the other hand, the response times by TOC4 fluctuate during non-operational hours.



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

Figure 4.9 Average Response Times for TOC4 by Time of Day on Weekdays in 2022

4.2 ANALYSIS OF RESPONSE EFFICIENCY



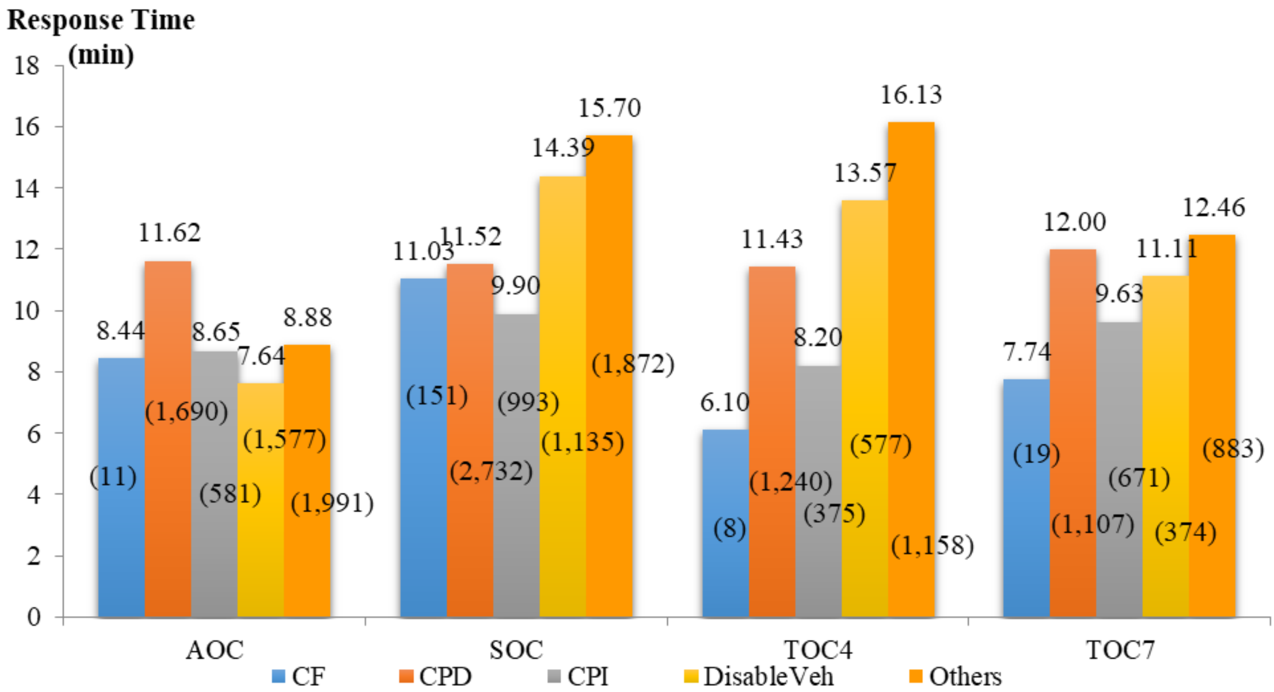
Note: Incident data only for response times between 1 minute and 60 minutes are used for this analysis.

Figure 4.10 Average Response Times for TOC7 by Time of Day on Weekdays in 2022

As shown in Figure 4.10, the highest incident frequency for TOC7 has been exhibited around the PM peak period (4:00 p.m. - 6:30 p.m.), while their average response times are not significantly different compared to those during other operational hours.

ANALYSIS OF RESPONSE EFFICIENCY

Figure 4.11 shows a further analysis of response efficiency, where most operation centers demonstrate relatively faster responses for incidents involving fatalities (CF) and injuries (CPI). On the other hand, SOC 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.

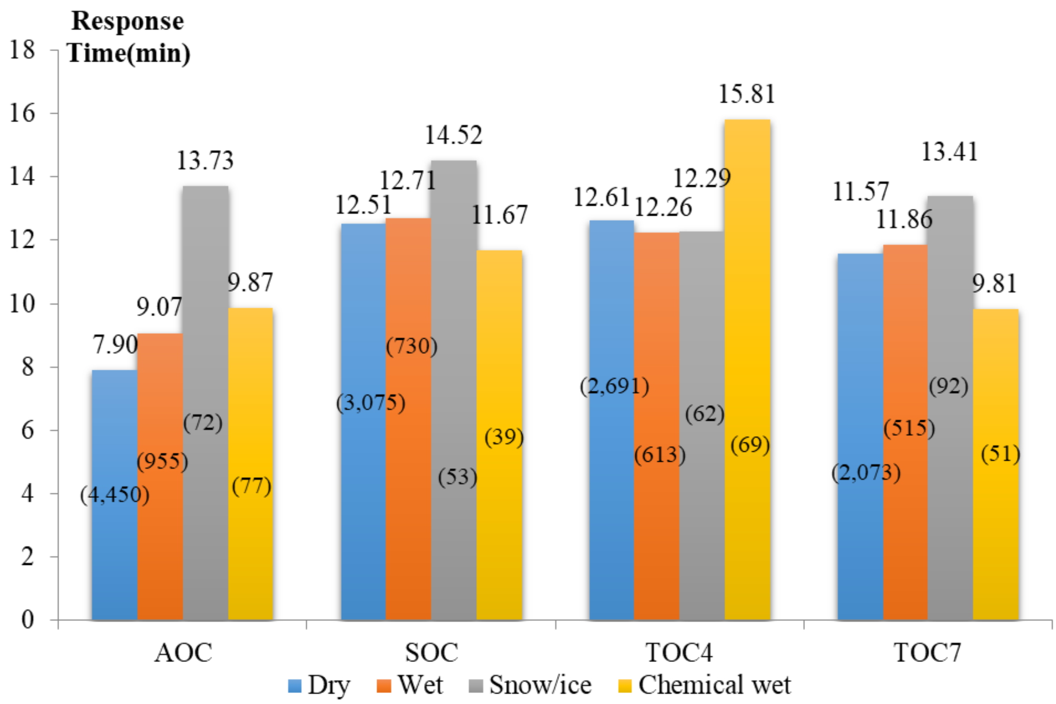
2. Numbers in parentheses show frequencies.

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 4.11 Average Response Times for Operation Centers by Incident Nature in 2022

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 4.12).



Note: 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 4.12 Average Response Times for Operation Centers by Pavement Conditions in 2022

ANALYSIS OF RESPONSE EFFICIENCY

Figures 4.13 through 4.16 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 and CHART units detect the most incidents to which SOC responded. For SOC, on average, the incidents detected by CHART units have relatively fast responses.

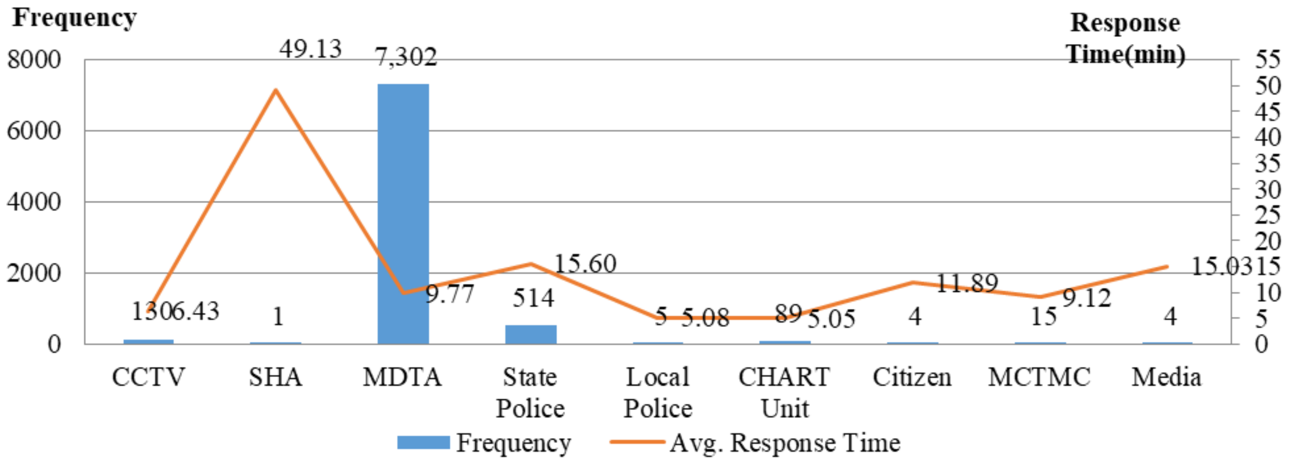


Figure 4.13 Average Response Times for AOC by Detection Source in 2022

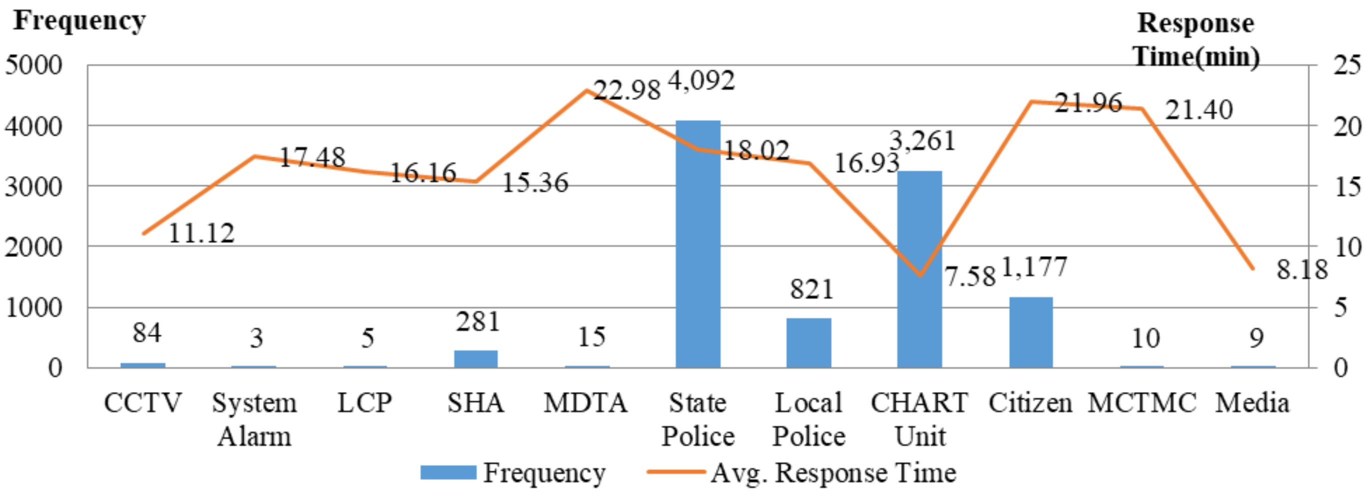


Figure 4.14 Average Response Times for SOC by Detection Source in 2022

For TOC 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 4 and 7.

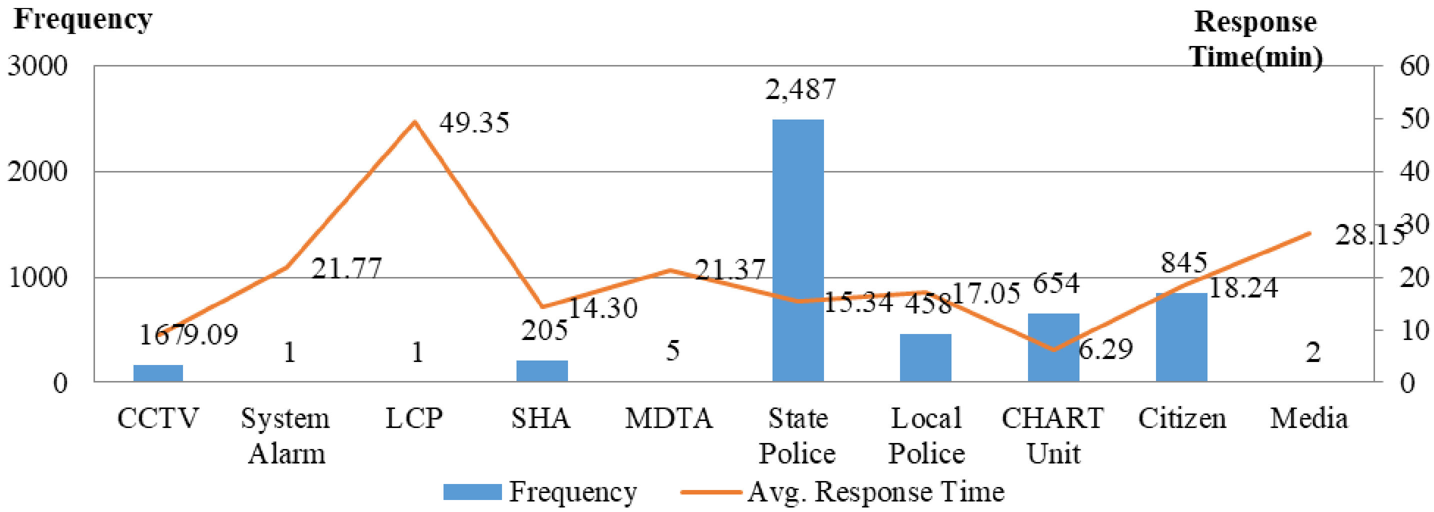


Figure 4.15 Average Response Times for TOC 4 by Detection Source in 2022

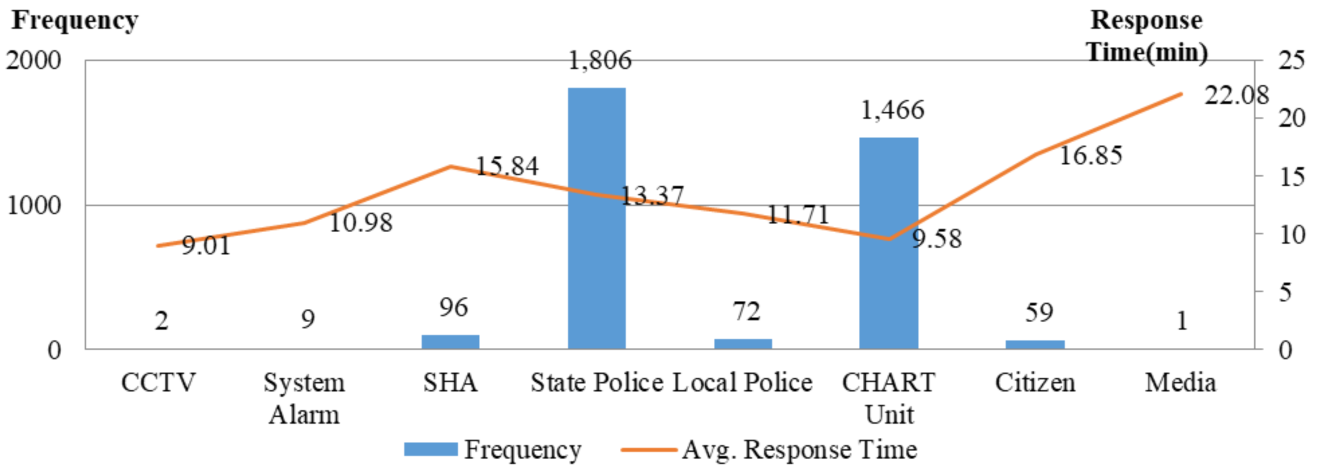
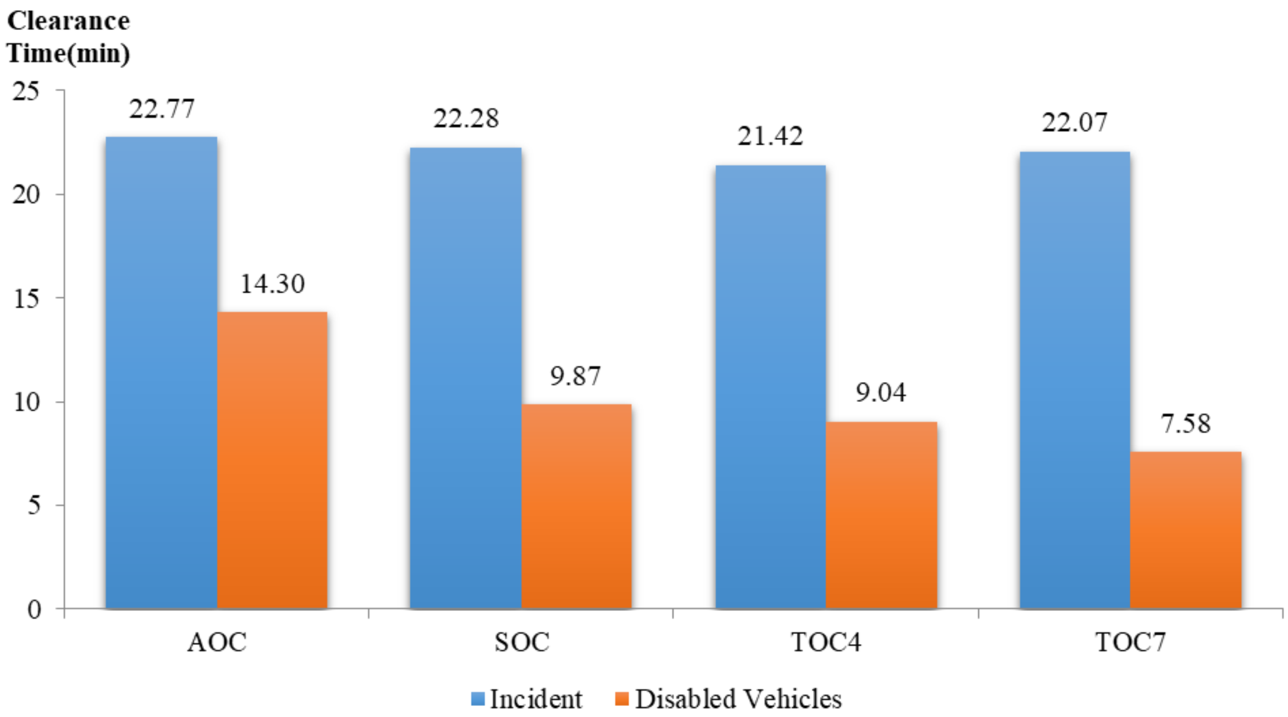


Figure 4.16 Average Response Times for TOC 7 by Detection Source in 2022

4.3 ANALYSIS OF CLEARANCE EFFICIENCY

As is well recognized, the efficiency of incident clearance could vary with many factors. Figure 4.17 summarizes the performance of CHART incident clearance operations by operation center. The average clearance time by AOC is longer than any other response centers for both incidents and disabled vehicles. On the other hand, TOC 4 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 4.17 Average Clearance Times by Operation Center in 2022

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 2022 for non-responded incidents and those to which CHART responded. Since CHART's incident management team responded to most incidents in 2022, the data for non-CHART incidents are very limited.

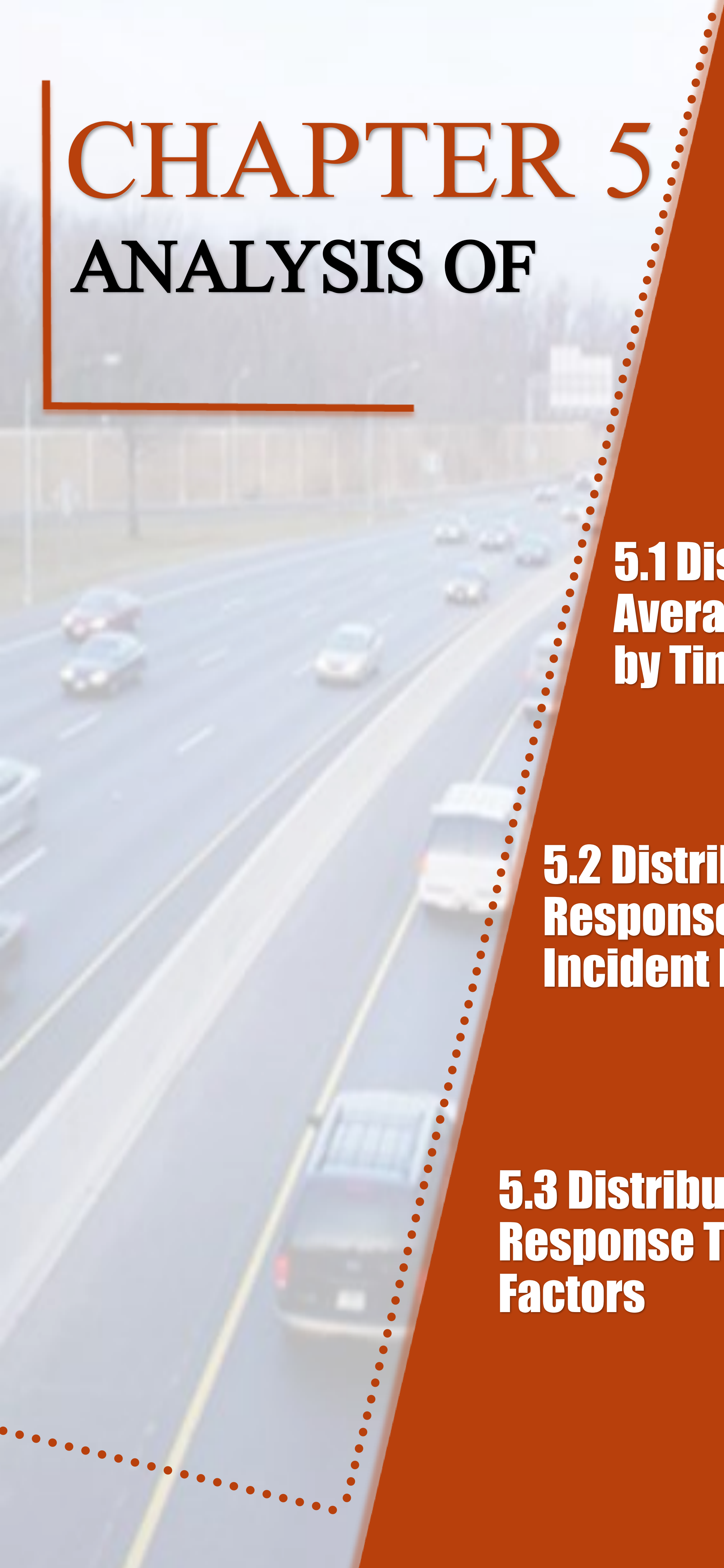
As shown in Table 4.1, the average durations for clearing an incident with and without the assistance of CHART were, respectively, about 26.02 minutes and 37.54 minutes in 2022. Note that incidents with durations of less than one minute were excluded from the analysis and incidents of "Unknown Lane Blockage" 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 2022 contributed to a reduction in blockage duration of about 30.69 percent, which has certainly contributed significantly to savings in travel times, fuel consumption, and related socioeconomic costs. Note that only about 83 percent of incident reports contain all the required information (i.e., received time and cleared time) for incident duration computation.

Table 4.1 Comparisons of Incident Durations for Various Types of Lane Blockages in 2022 (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	21.62	59,58	34.17	469	1,348	22.62%
1 lane	23.54	12,130	33.85	815	3,090	25.48%
2 lanes	39.01	26,42	49.30	156	388	14.69%
3 lanes	44.20	7,11	67.38	50	138	19.41%
>=4 lanes	51.19	3,59	76.92	32	62	17.27%
Weighted Average	**26.02 (26.31)**	**21,800 (21,678)**	**37.54 (37.82)**	**1,522 (1,379)**		
Unknown	16.49	6,326	30.92	646		

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 2021

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

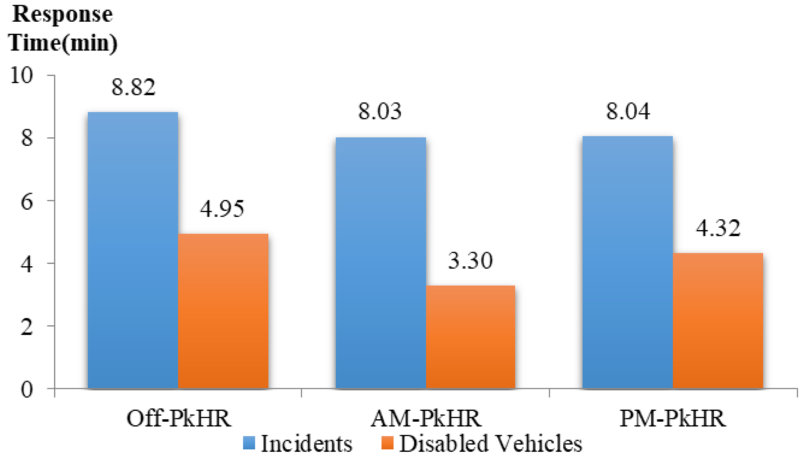
5.3 Distribution of Average Response Times by Various Factors

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).

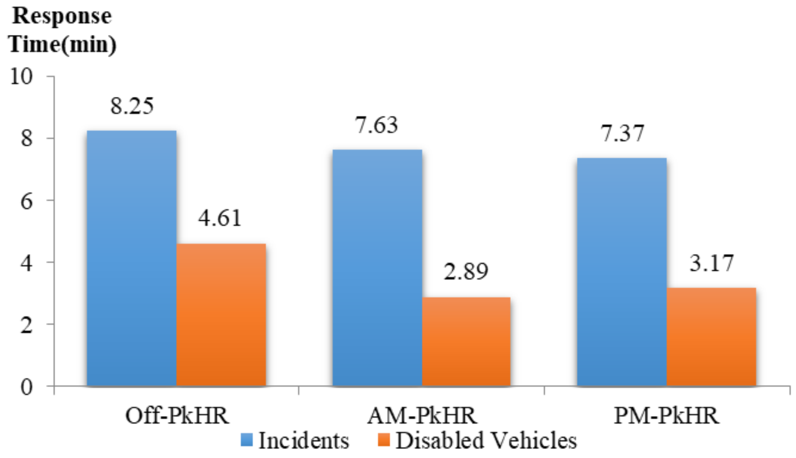
For these reasons, this chapter presents the results from the statistical analysis of incident response times; this analysis provides a fundamental insight into the characteristics of incident response times under various conditions.

5.1 DISTRIBUTION OF AVERAGE RESPONSE TIMES BY TIME OF DAY



Year 2022

Year 2021

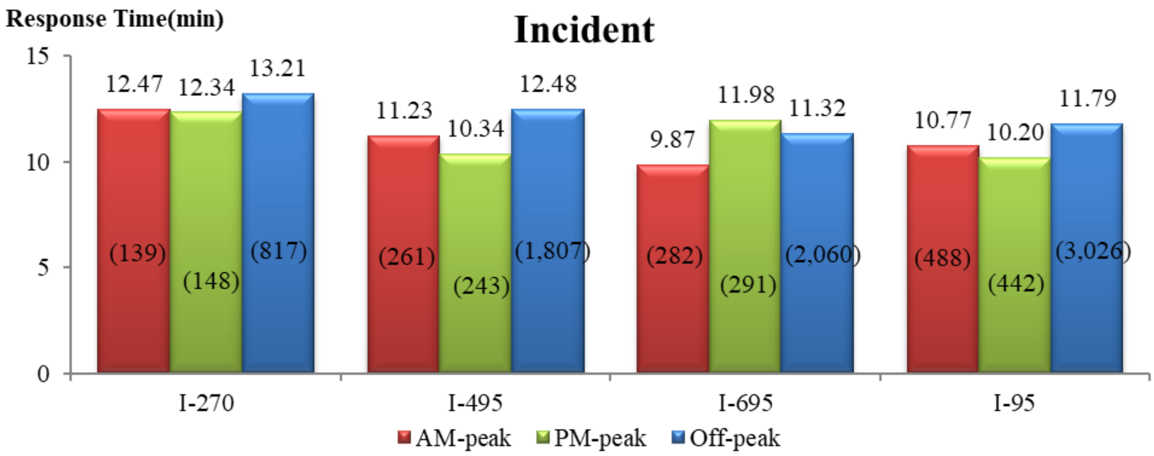


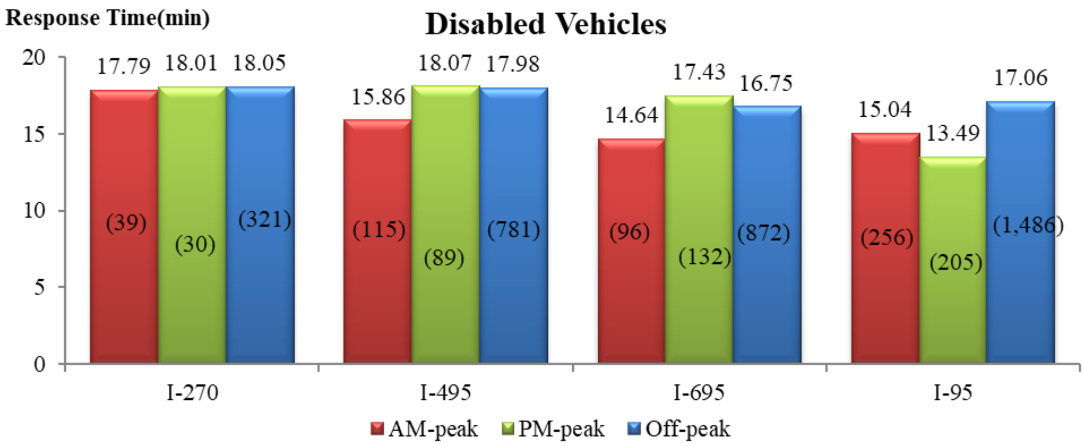
Note: Off-peak Hours include night times.

Figure 5.1 Distributions of Average Response Times by Time of Day in 2022 and 2021

Figure 5.1 compares response times by time of day in 2022 and 2021. In 2022, the average response time during a.m. peak hours was 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 2022.

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 2022

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, compared to those on other major roads. For disabled vehicles, the response times on I-270 during a.m. peak hours were longest, whereas disabled vehicles on I-495 had a longer response time during p.m. peak hours.

5.2 DISTRIBUTION OF AVERAGE RESPONSE TIMES BY INCIDENT NATURE

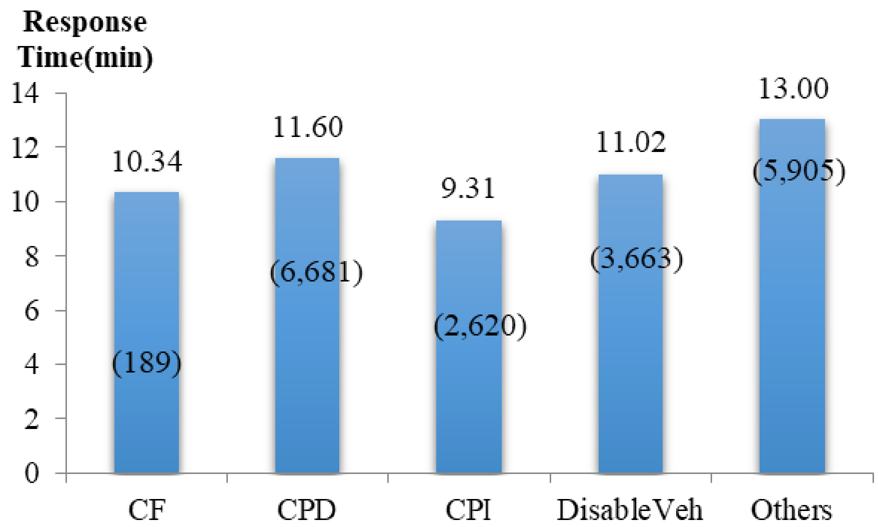
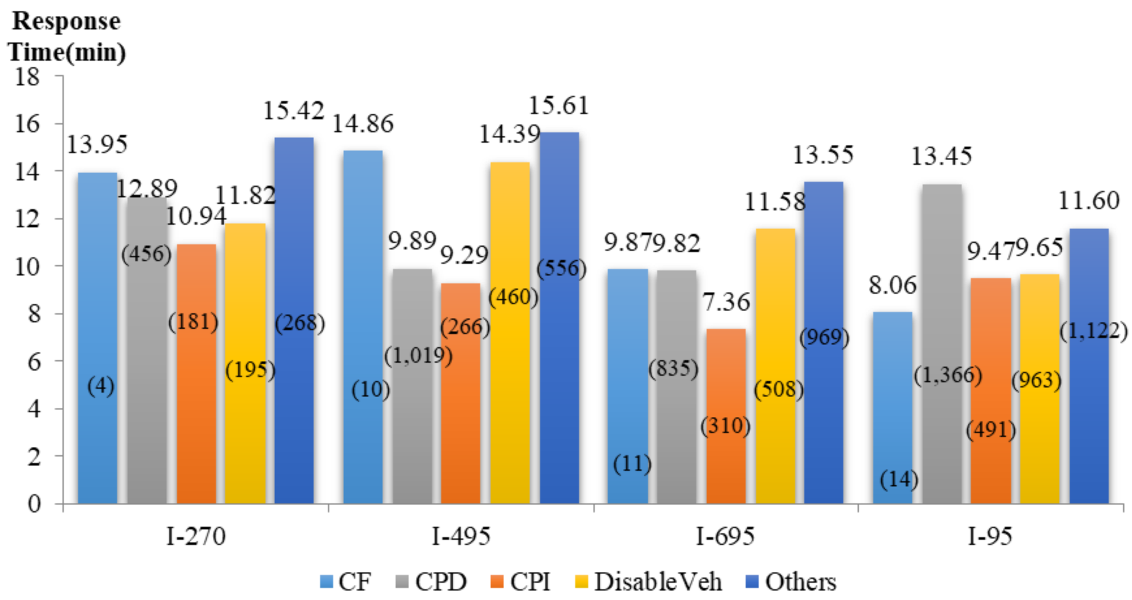


Figure 5.3 shows that the response times are likely to decrease as a detected incident becomes severe. For instance, the collision types of incidents, causing any fatality and injuries (CF and CPI), usually lead to quicker responses than other types of incidents.

Figure 5.3 Average Response Time by Incident Nature in 2022

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 2022

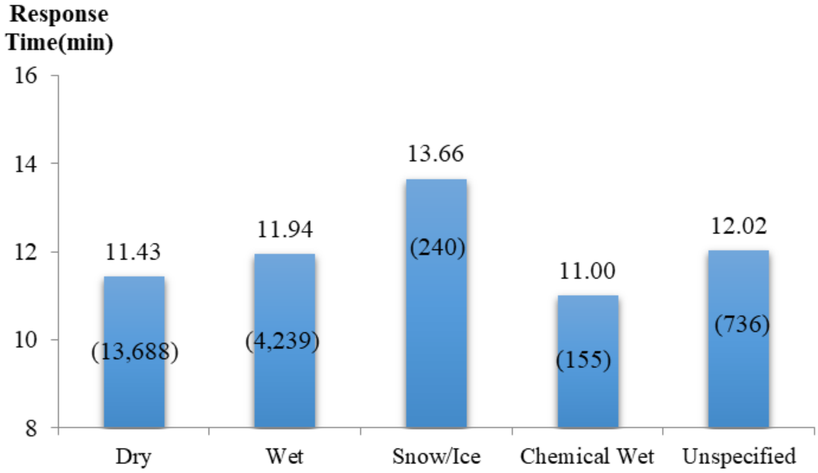
A similar pattern of decreased response times as the incident becomes severe appears on four major corridors, especially on I-695 and I-95, as shown in Figure 5.4.

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 other conditions. When the pavement is chemically wet, the response time is likely to be shorter. This factor reflects the weather conditions that are usually unavailable in most incident databases.



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 2022

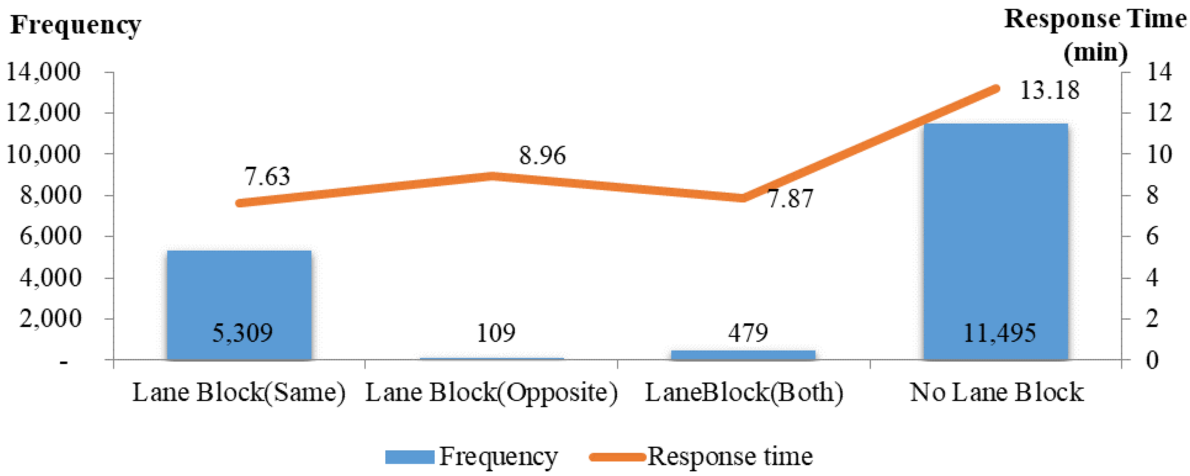
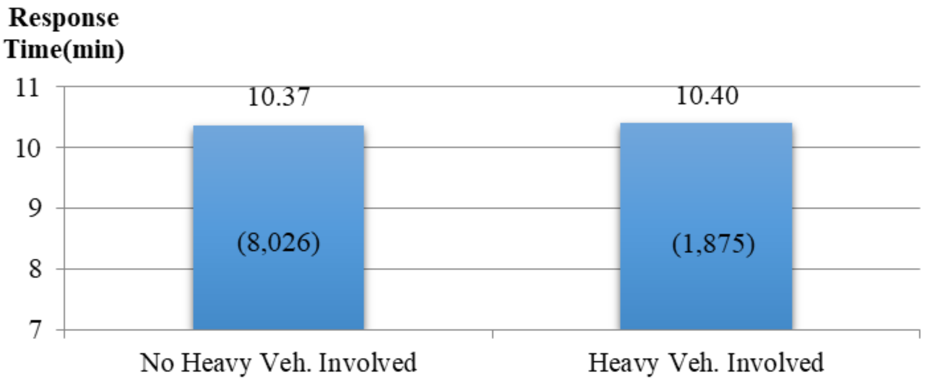


Figure 5.6 Average Response Time by Lane Blockage in 2022

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

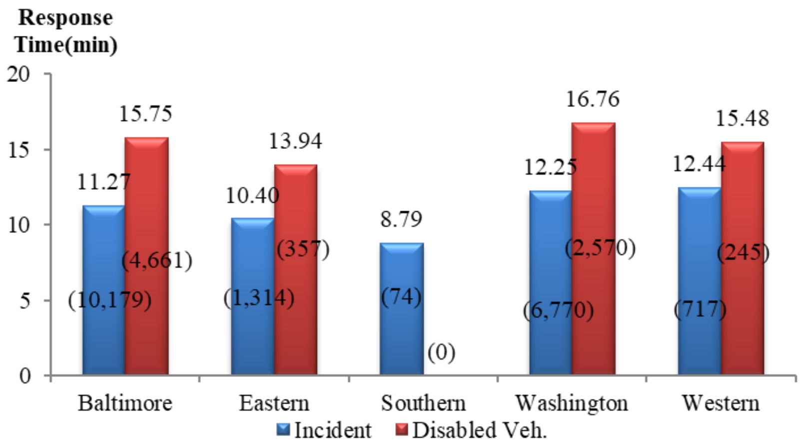
When a detected incident is involved with any heavy vehicles such as vans, SUVs, pick-up trucks, single-unit trucks, or tractor-trailers, the response is similar to the incidents which heavy vehicles are not involved in, as shown in Figure 5.7.



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 2022

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 Southern 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. The Western region also experiences the similar response times. 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 2022

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 2022, about 40 percent of incidents without collisions were caused by Disabled Vehicles. A similar pattern was also observed in 2021, when about 38 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.

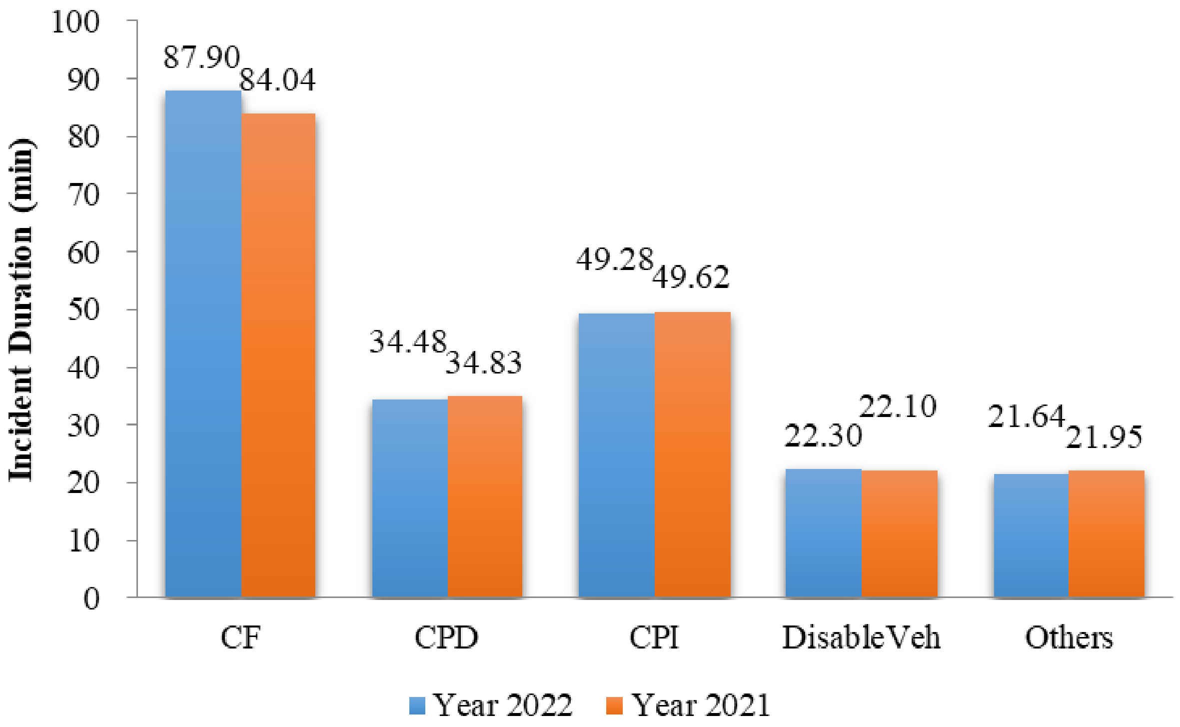
Table 6.1 Categories of Incident Nature

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 2022. 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.

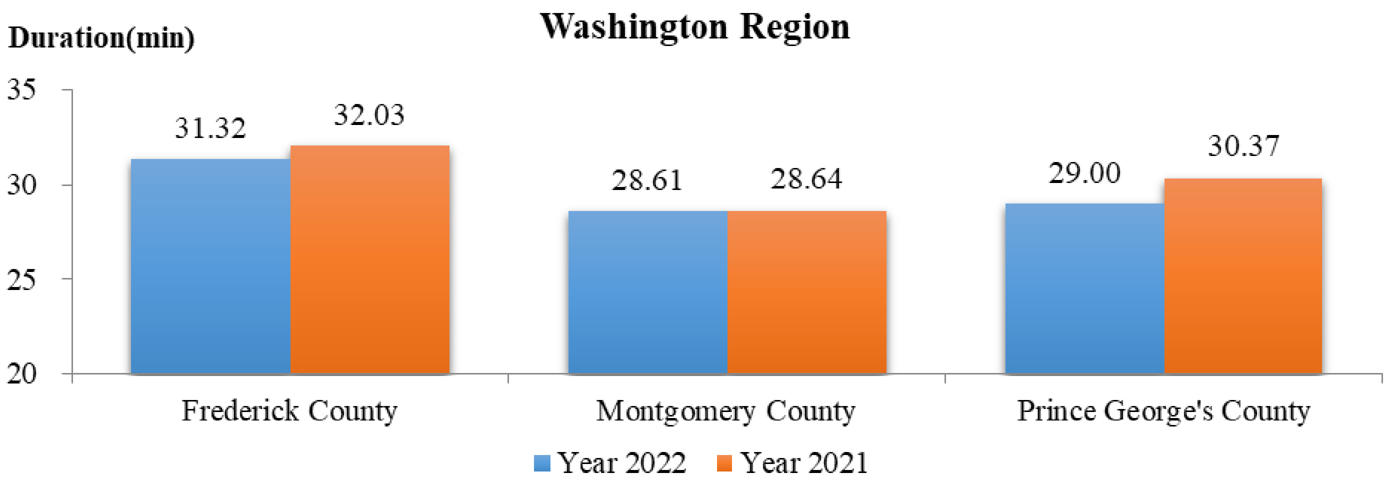


Note: 1. Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis
2. CF, CPD, and CPI represent collision-fatality, collision-property damage, and collision-personal injury, respectively.

Figure 6.1 Distribution of Average Incident Duration by Nature in 2022 and 2021

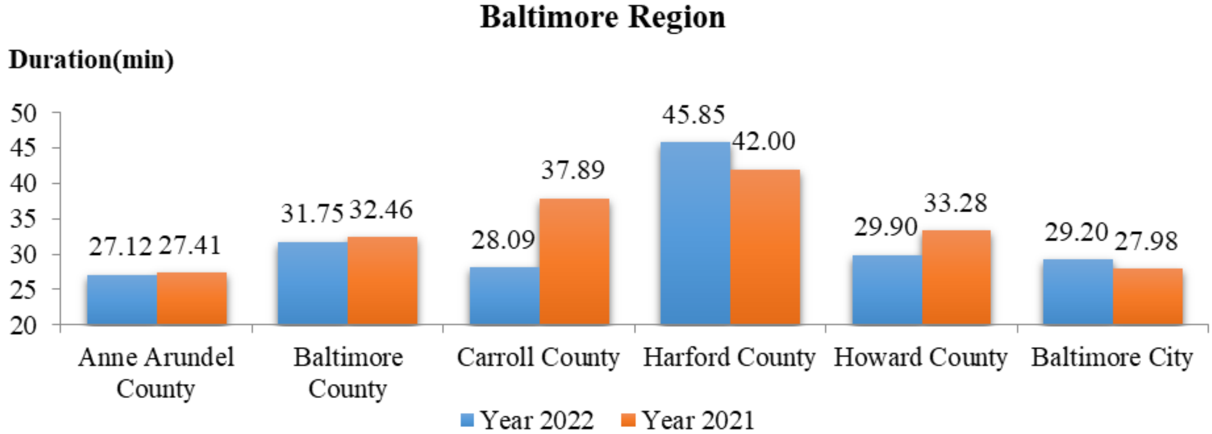
6.2 DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY COUNTY AND REGION

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 Baltimore and Harford Counties had longer durations, (i.e., longer than 30 minutes) 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 2022 and 2021



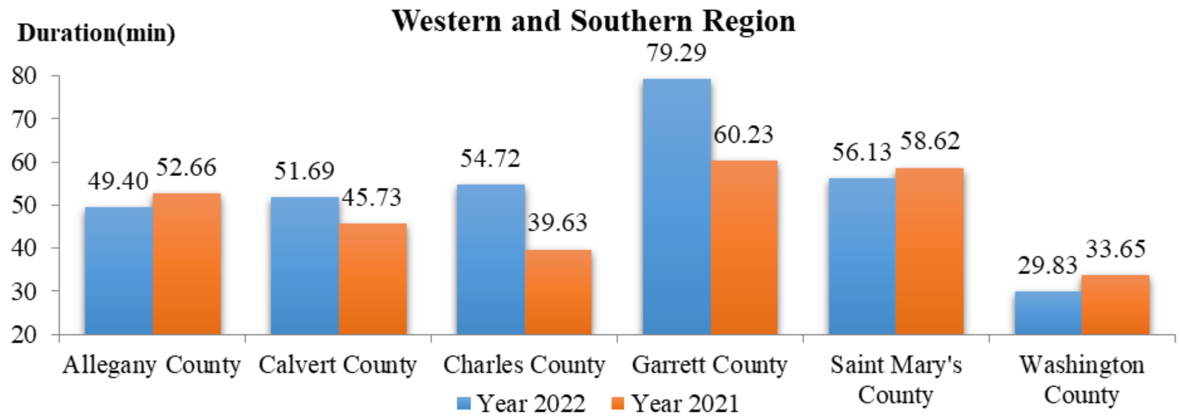
Note: Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis.

Figure 6.3 Distribution of Average Incident Duration by County in Baltimore Region in 2022 and 2021

DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY COUNTY AND REGION

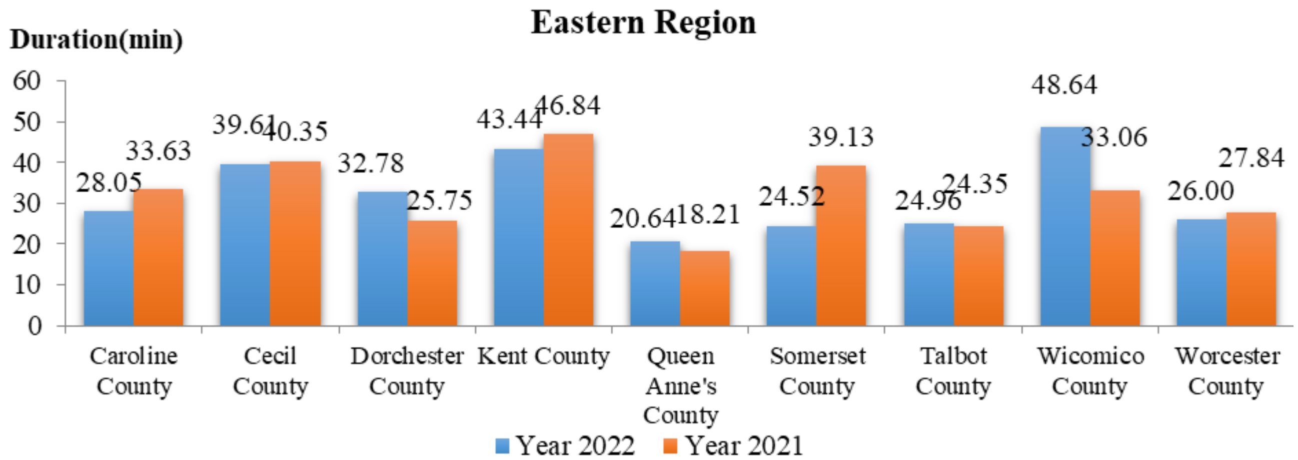
6.2

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 or even higher than one hour. Washington County had the shortest average incident duration in western and southern Maryland in the year 2022. The incidents occurring in Wicomico 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 21 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 2022 and 2021



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 2022 and 2021

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 that for most other areas in Maryland in 2022.

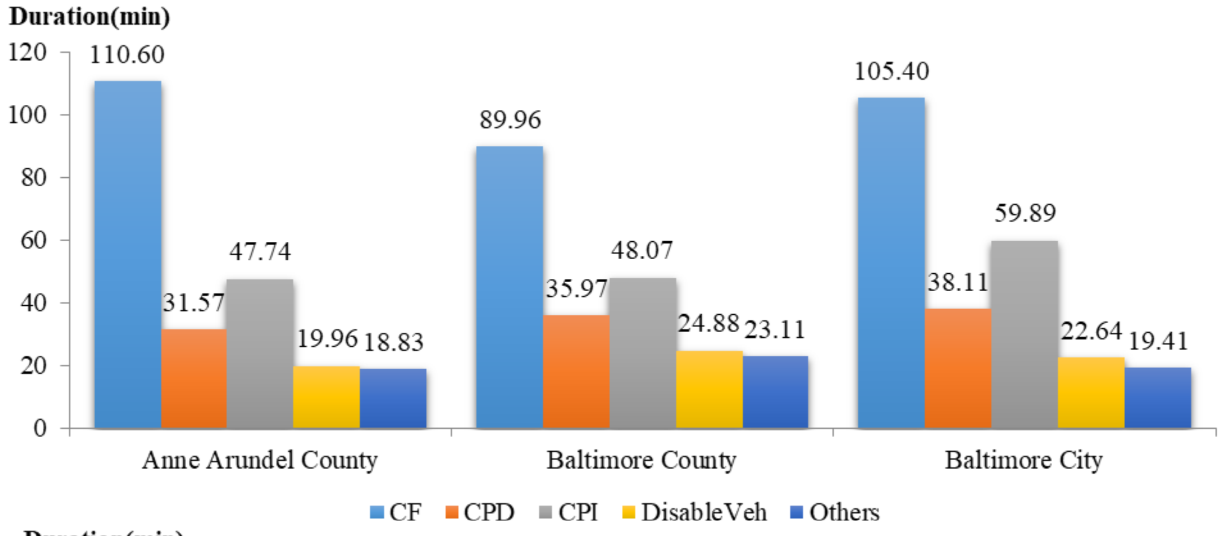
Table 6.2 Summary of Incident Duration Components by Region

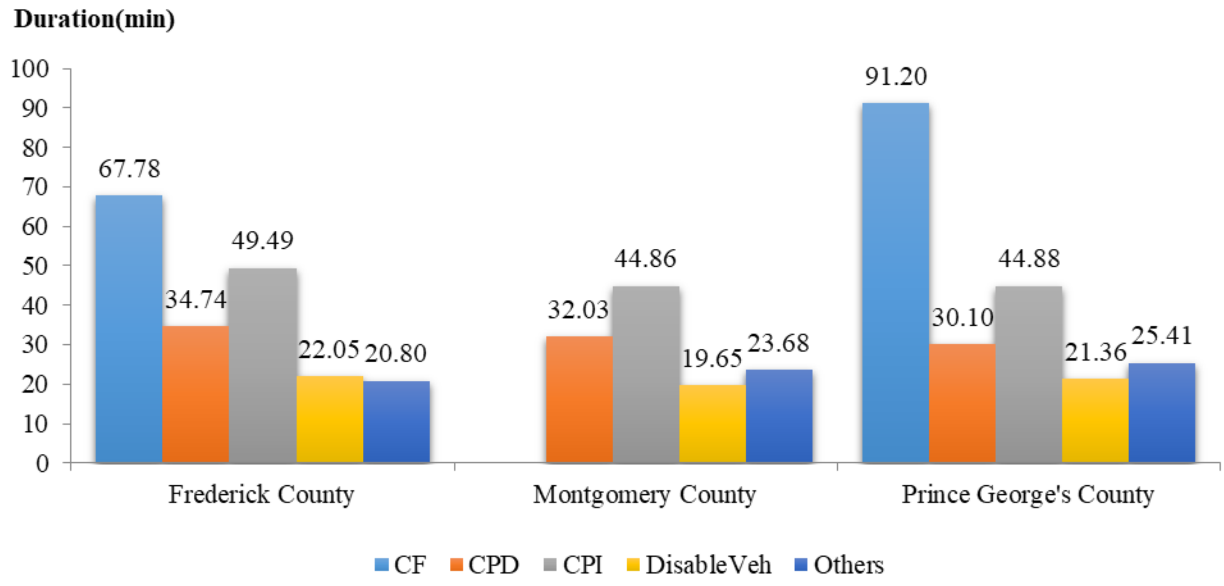
Region	Sample Frequency*	Avg. Response Time (mins)	Avg. Clearance Time (mins)	Avg. Incident Duration (mins)
Baltimore	11,920	8.01	22.80	30.80
Eastern	1,543	6.46	19.91	26.36
Southern	54	9.02	45.84	54.86
Washington	8,408	8.14	21.48	29.63
Western	950	7.85	23.01	30.86

** 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 Frederick County was shorter than in any other area. On the other hand, CF-related incidents in Anne Arundel County resulted in relatively long durations.

In all those counties, 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 2022 have about 82 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	2022	17,444	7.62	21.65	29.28
	2021	17,950	7.36	22.42	29.78
Weekends	2022	5,435	8.98	23.88	32.86
	2021	4,988	8.19	24.61	32.79

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

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

	Year	Sample* Frequency	Avg. Response Time (min)	Avg. Clearance Time (min)	Avg. Incident Duration (min)
Off-Peak	2022	17,224	8.16	22.43	30.59
	2021	17,322	7.72	23.36	31.08
Peak	2022	5,655	7.30	21.42	28.72
	2021	5,616	6.98	21.47	28.45

**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. Peak hours: 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.

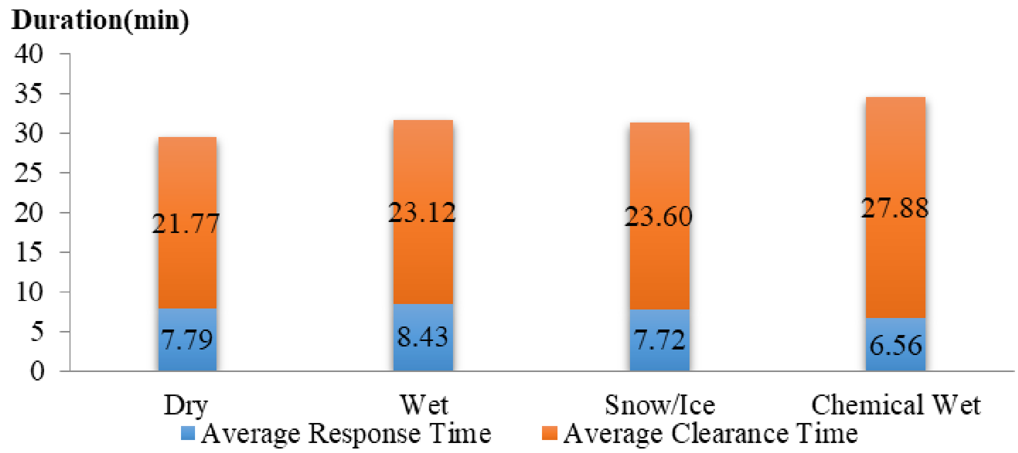
Table 6.5 Distribution of Average Incident Duration without and with CHART

	Year	Sample* Frequency	Avg. Response Time (min)	Avg. Clearance Time (min)	Avg. Incident Duration (min)
w/o CHART	2022	959	19.18	31.51	50.69
	2021	919	16.34	31.73	48.07
w/ CHART	2022	21,920	7.46	21.77	29.23
	2021	22,019	7.17	22.53	29.70

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.

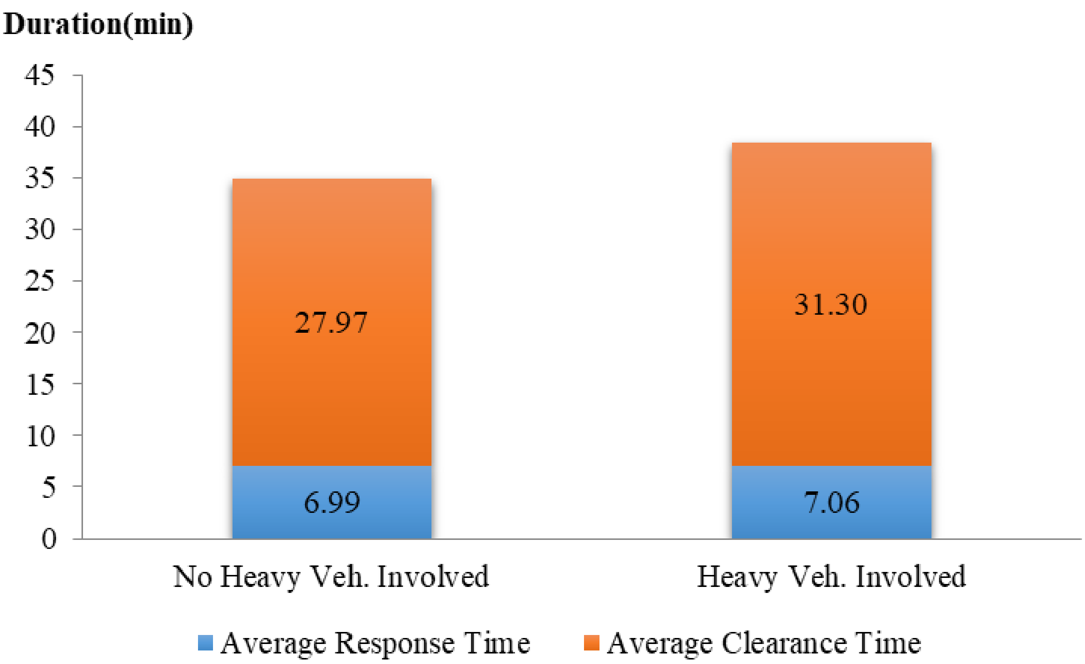
The response time and clearance time of incidents could vary with the pavement conditions, based on the pavement conditions. Figure 6.7 shows that chemical wet conditions (e.g., oil spill) may result in a faster response , but its average clearance time is likely to be longer.



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

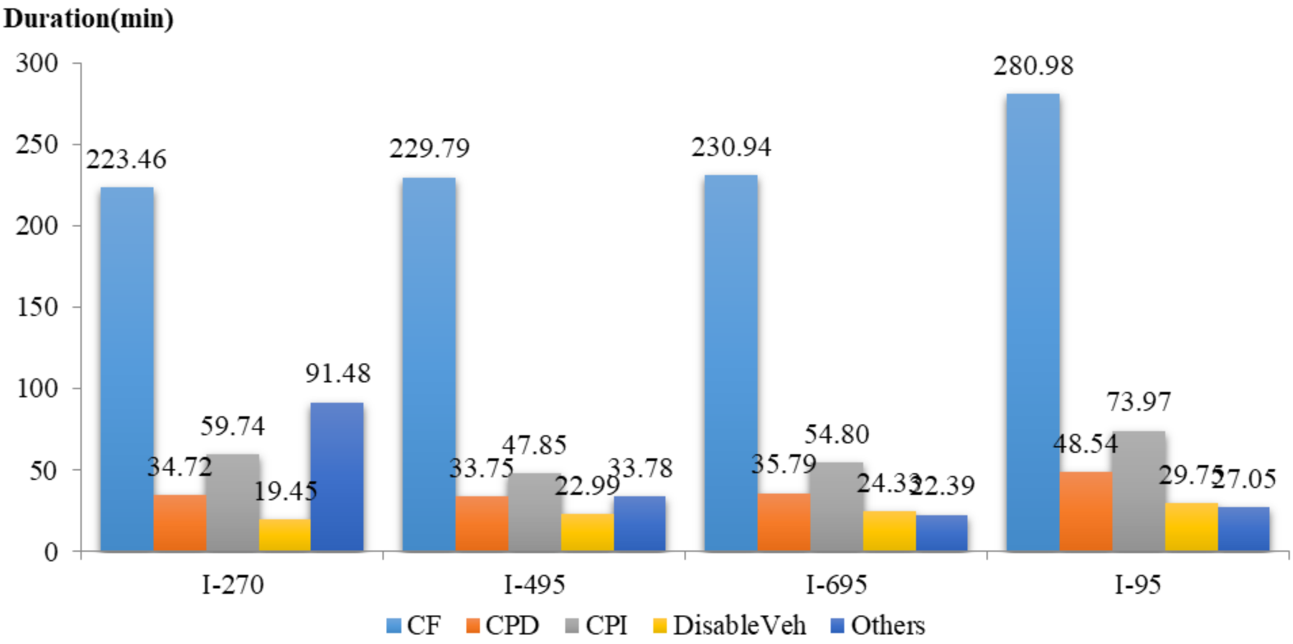
Figure 6.8 illustrates how a heavy vehicle influences the incident durations. In 2022, the response and clearance times for incidents involved with a heavy vehicle were likely to be longer than those without a heavy vehicle due to their incident severity.



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., 281 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 2022 and Year 2021 are depicted in Figure 7.1. Those assists offered by TOC 4, TOC 7 and AOC are illustrated in Figure 7.2, Figure 7.3 and Figure 7.4, respectively.

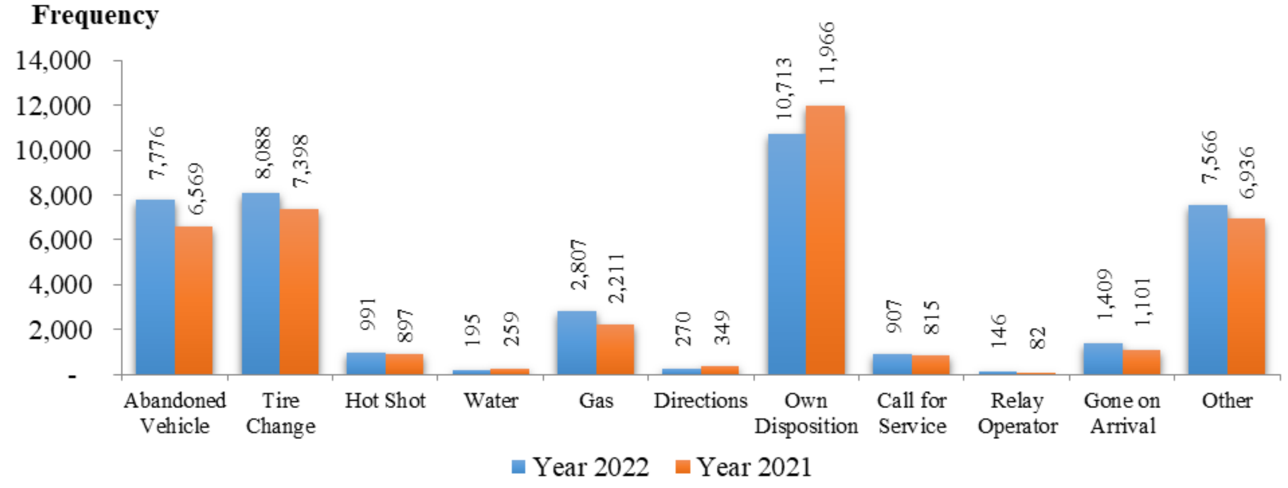


Figure 7.1 Classification of Driver Assistance Requests by Nature in 2022 and 2021

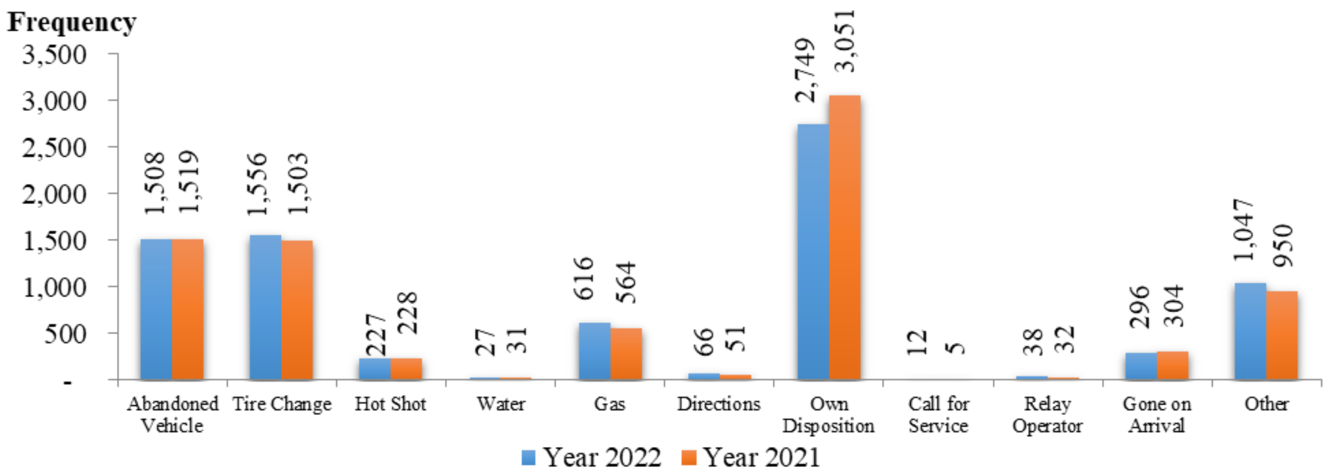


Figure 7.2 Classification of Driver Assistance Requests by Nature for TOC 4

ASSISTANCE TO DRIVERS

7.1

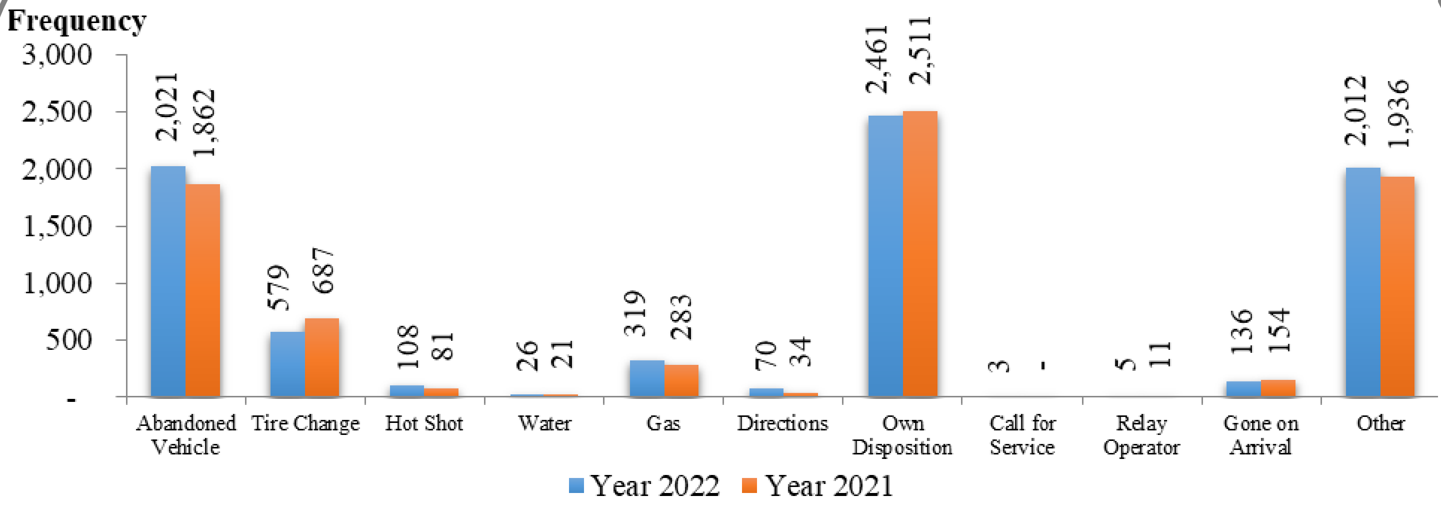


Figure 7.3 Classification of Driver Assistance Requests by Nature for TOC 7

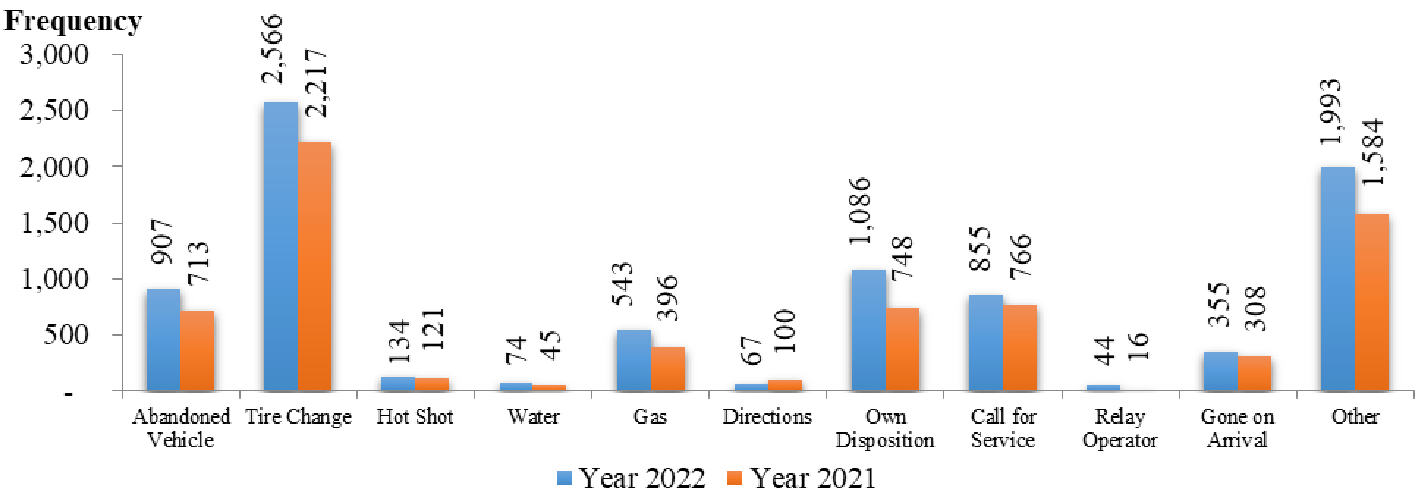


Figure 7.4 Classification of Driver Assistance Requests by Nature for AOC

These types of driver assistance in 2022 include flat tires, shortages of gas, or mechanical problems. Out of the 36,884 assistance requests, 10,784 assists were related to “out of gas” or “tire changes,”, more than the number in 2021 (10,394 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 2022. Notably, 1,150 secondary incidents occurred in 2022. 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: 1,150
- Estimated number of secondary incidents without CHART, which reduced incident duration by 29.12 percent, calculated as: 1,150/(1-0.2912) = 1,622 incidents
- The number of incidents potentially reduced due to CHART/MSHA operations: 1,622-1,150 = 472 secondary incidents .

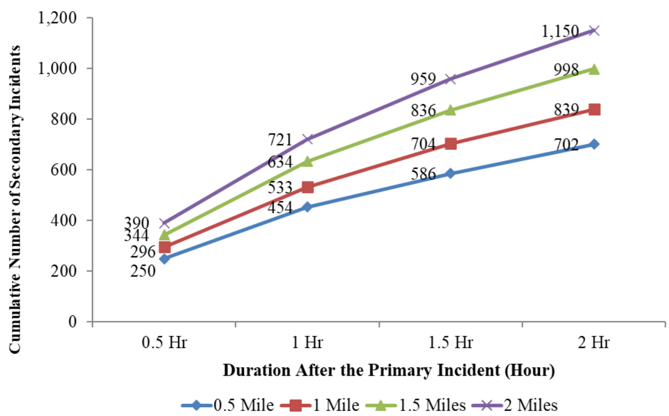


Figure 7.5 Distributions of Reported Secondary Incidents

Note that the 472 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.

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	2022	199	401	56	173	105	46	39	65	1,084
	2021	186	333	53	171	96	36	42	67	984
	2020	170	264	49	137	71	26	30	53	800
	2019	175	286	62	156	73	30	21	57	860
	2018	173	231	58	184	74	33	28	69	850

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

7.4 DIRECT BENEFITS TO HIGHWAY USERS

The benefits obtained as a result of reduced delays and fuel consumption are summarized in Table 7.2, where the monetized benefit conversion from delay reduction was based on the unit rates from the U.S Census Bureau (2022) and the Energy Information Administration (2022). Figure 7.6 also shows the difference in benefits between 2021 and 2022.

The evaluation for 2022 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 33.19 million dollars. Thus, CHART operations in Year 2022 generated a total savings of 2,030.56 million dollars.

DIRECT BENEFITS TO HIGHWAY USERS

7.4

Table 7.2 Total Direct Benefits to Highway Users in 2022

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	**Truck**	1.99 (2.10)	Driver *$23.41/hour (23.30)* [1]	46.68 (48.83)
			Cargo $45.40/hour	90.54 (95.14)
	Car	39.00 (37.64)	*$46.50/hour (44.15)* [2]	1,813.33 (1,661.87)
Fuel Consumption (M gallon)		7.78 [4] (7.65)	Gasoline *$4.06/gal (3.09)* [3]	33.19 (24.01)
			Diesel *$5.00/gal (3.28)* [3]	
Emissions	**HC (ton)**	535.87 (519.47)	$6,700/ton	46.81 (45.41)
	CO (ton)	6,018.68 (5,834.48)	$6,360/ton	
	NO (ton)	256.64 (248.79)	$12,875/ton	
	CO_2 (metric ton)	71,201.40 (70,198.61)	$23/metric ton [5]	
Total		**$ 2,030.56 (1,875.25)**		

<Note>
** The number in each parenthesis is the estimate in year 2021.*
** 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, 994, 218.40… veh-hr * $23.41hr = $46,684,652.72…*
<Source>

1. *The truck driver's unit cost is based on the information from the Bureau of Labor Statistics in year 2022*
2. *The car driver's unit cost is based on household income by the U.S. Census Bureau (2022).*
3. *The gasoline and diesel unit costs are from the Energy Information Administration in year 2022.*
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

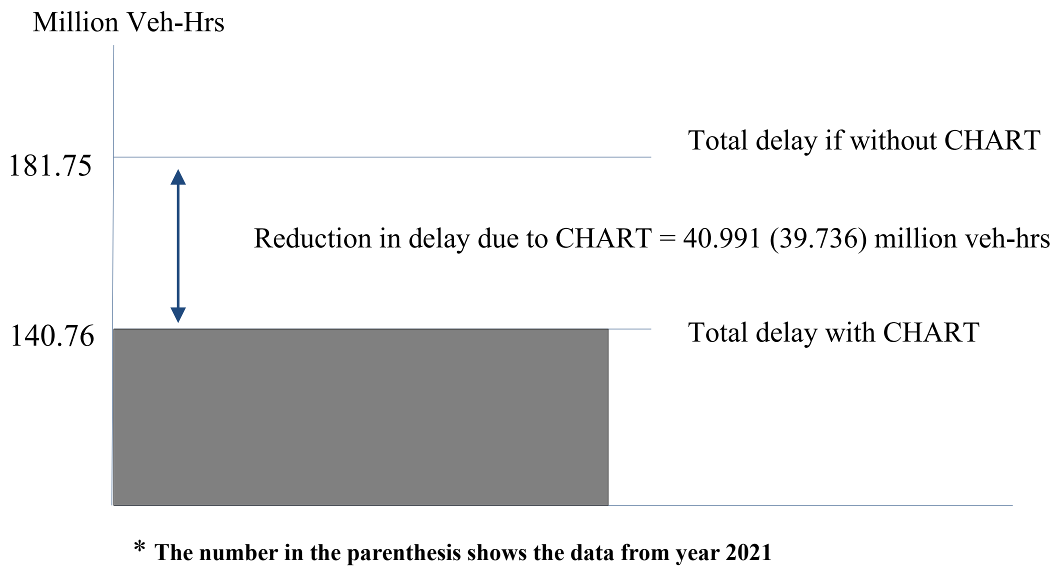


Figure 7.6 Reduction in Delay due to CHART in Year 2022

The total benefits increased from 1,875.25 million dollars in 2021 to 2,030.80 million dollars in 2022. The main factors contributing to the increase in benefits are listed and tabulated below:

- The total number of incidents used for the benefit estimate increased by about 2.81 percent from year 2021 to year 2022, as shown in Table 7.3.
- The ratio, reflecting the difference between incident durations with CHART and those without CHART, increased from 28.04 percent in 2021 to 29.12 percent in 2022, as shown in Table 7.4.
- Table 7.5 shows that the adjusted AADT in 2022 decreased by 0.13 percent on the major roads in Maryland compared to 2021.
- Table 7.6 shows that average truck percentage decreased in year 2022 over all major roads in Maryland, by 20.28 percent on average.

Table 7.3 Total Number of Incidents Eligible for the Benefit Estimate

	2021	2022	Δ(' 21 ~ '22) [2]
No. of Incidents	31,253	32,130	2.81%

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 2021 to Year 2022 is calculated as follows: $\Delta X(\%)=(X_{2022}-X_{2021})/X_{2021}*100$

Table 7.4 Comparison of Incident Duration Reduction between 2021 and 2022

	With CHART (mins)	Without CHART (mins)	Difference (mins)	Ratio in Difference
2021	27.99	38.89	10.90	28.04%
2022	27.67	39.04	11.37	29.12%
Δ(21 ~ '22) [2]	-1.13%	0.39%	4.27%	3.87%

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

2.The percentage change in incident duration (X) from Year 2021 to Year 2022 is calculated as follows: $\Delta X(\%)=(X_{2022}-X_{2021})/X_{2021}*100$

7.4 DIRECT BENEFITS TO HIGHWAY USERS

Table 7.5 Changes in adjusted AADT (with peak hour factor) for Major Roads from 2021 to 2022

	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	**2021**	11,912	7,981	6,987	10,586	4,087	2,342	4,746	2,434	3,162	54,237
	2022	11,836	7,927	7,076	10,529	4,112	2,356	4,655	2,457	3,220	54,167
Δ(21 ~ '22)		-0.64%	-0.68%	1.28%	-0.54%	0.60%	0.59%	-1.92%	0.95%	1.83%	-0.13%

Note: The percentage change in the adjusted AADT(X) from Year 2021 to Year 2022 is calculated as follows: $\Delta X(\%)=(X_{2022}-X_{2021})/X_{2021}*100$

Table 7.6 Changes in Truck Percentage for Major Roads from 2021 to 2022

	Year	I-495	I-95	I-270	I-695	MD 295	US 50	US 1	I-83	I-70	Average
Truck Percentage (%)	**2021**	7.76	11.98	5.41	7.57	2.72	11.30	4.84	13.25	10.47	8.37
	2022	6.15	9.91	4.26	5.88	1.83	8.09	2.77	12.93	8.19	6.67
Δ(21 ~ '22)		-20.79	-17.27	-21.22	-22.31	-32.48	-28.37	-42.76	-2.42	-21.75	-20.28

Note: The percentage change in the truck percentage from Year 2021 to Year 2022 is calculated as follows: $\Delta X(\%)=(X_{2022}-X_{2021})/X_{2021}*100$

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 (2021)			1,875.25
Key Factor		**Δ('21~ '22)[1]**	**Estimated Benefits[2]**
Sensitivity Analysis	Adjusted AADT	▼ 0.13%	1,873.10 (▼0.11%)
	Number of Incidents	▲ 2.81%	1,915.10 (▲2.13%)
	Incident duration percentage difference between w/ and w/o CHART	▲ 3.87%	1,947.77 (▲3.87%)
	Truck percentage	▼ 20.28%	1,863.61 (▼0.62%)
	Monetary unit of gas price	▲ 41.86%	1,884.01 (▲0.47%)
	Monetary unit of time value	▲ 2.90%	1,963.89 (▲4.73%)
Benefit of the Current Year (2022)			**2,030.56** (▲8.29%)

Note:1. This field is showing the difference in percentage between 2021 and 2022.
2. The numbers in each parenthesis show the percentage of the benefit change from year 2021.

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 2022 value, but setting all other factors identical to those in 2021; and

• Following the same procedures to analyze the sensitivity of the total 2021 benefits with respect to each key factor.

The decrease in the average adjusted AADT by 0.13 percent in 2022 contributed to a decrease of 0.11 percent in the total benefit. The number of lane-blockage incidents increased by 2.81 percent in 2022, resulting in the benefit increase of 2.13 percent. Note that the ratio with respect to the performance difference between incident durations with and without CHART involvement increased by 3.87 percent, and thus directly resulted in a 3.87 percent increase in the total benefit. An increase of 4.73 percent in the total benefit is due solely to the average raise of 2.90 percent in the MD driving populations' 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 2022 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 49.79, 4.20, 1.43, 5.30, 2.97, and 0.99 million vehicle-hours, respectively, in 2022.

The total benefits produced from the reduction in delays, fuel consumption, and emissions for each major road in 2022 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 2022 are $495.60M, $209.38M, $70.23M, $262.55M, $150.24M, and $51.05M, respectively. Note that the benefits for those six major corridors account for 61.02% of the total CHART benefits of $2,030.56M.

Table 7.8 Number of Incidents Used for Benefit Estimate for the Six Major Corridors in 2022

Corridors	Number of Incidents	Reduction in Delay due to CHART (M vehicle-hours)
I-95	5,858	9.79
I-95/495	3,479	4.20
I-270	1,049	1.43
I-695	3,588	5.30
I-70	1,745	2.97
I-83	927	0.99
Others	15,484	16.31

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 2022

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	Truck	0.89	Driver *$23.41/hour*	20.86
			Cargo *$45.40/hour*	40.46
	Car	8.89	*$46.50/hour*	413.61
Fuel Consumption (M gallon)		2.15	Gasoline *$4.06/gal*	9.42
			Diesel *$5.00/gal*	
Emissions	HC (ton)	127.93	$6,700/ton	11.24
	CO (ton)	1,436.88	$6,360/ton	
	NO (ton)	61.27	$12,875/ton	
	CO_2 (metric ton)	20,006.11	$23/metric ton [5]	
Total		**$495.60 M**		

Table 7.9(b) Total Direct Benefits for I-95/495 in 2022

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	Truck	0.25	Driver *$23.41/hour*	5.88
			Cargo *$45.40/hour*	11.41
	Car	3.95	*$46.50/hour*	183.71
Fuel Consumption (M gallon)		0.83	Gasoline *$4.06/gal*	3.57
			Diesel *$5.00/gal*	
Emissions	HC (ton)	54.93	$6,700/ton	4.81
	CO (ton)	616.99	$6,360/ton	
	NO (ton)	26.31	$12,875/ton	
	CO_2 (metric ton)	7,638.28	$23/metric ton [5]	
Total		**$209.38 M**		

Table 7.9(c) Total Direct Benefits for I-270 in 2022

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	**Truck**	0.05	Driver *$23.41/hour*	1.09
			Cargo *$45.40/hour*	2.11
	Car	1.38	*$46.50/hour*	64.32
Fuel Consumption (M gallon)		0.26	Gasoline *$4.06/gal*	1.07
			Diesel *$5.00/gal*	
Emissions	**HC (ton)**	18.69	$6,700/ton	1.63
	CO (ton)	209.95	$6,360/ton	
	NO (ton)	8.95	$12,875/ton	
	CO_2 (metric ton)	2,317.18	$23/metric ton [5]	
Total		**$70.23 M**		

Table 7.9(d) Total Direct Benefits for I-695 in 2022

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	**Truck**	0.27	Driver *$23.41/hour*	6.24
			Cargo *$45.40/hour*	12.10
	Car	5.03	*$46.50/hour*	233.84
Fuel Consumption (M gallon)		1.01	Gasoline *$4.06/gal*	4.32
			Diesel *$5.00/gal*	
Emissions	**HC (ton)**	69.23	$6,700/ton	6.05
	CO (ton)	777.52	$6,360/ton	
	NO (ton)	33.15	$12,875/ton	
	CO_2 (metric ton)	9,263.05	$23/metric ton [5]	
Total		**$262.55 M**		

Table 7.9(e) Total Direct Benefits for I-70 in 2022

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	Truck	0.26	Driver *$23.41/hour*	5.99
			Cargo *$45.40/hour*	11.62
	Car	2.72	*$46.50/hour*	126.41
Fuel Consumption (M gallon)		0.64	Gasoline *$4.06/gal*	2.81
			Diesel *$5.00/gal*	
Emissions	HC (ton)	38.88	$6,700/ton	3.42
	CO (ton)	436.72	$6,360/ton	
	NO (ton)	18.62	$12,875/ton	
	CO_2 (metric ton)	5,971.97	$23/metric ton [5]	
Total		**$70.56 M**		

Table 7.9(f) Total Direct Benefits for I-83 in 2022

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	Truck	0.12	Driver *$23.41/hour*	2.89
			Cargo *$45.40/hour*	5.60
	Car	0.87	*$46.50/hour*	40.34
Fuel Consumption (M gallon)		0.24	Gasoline *$4.06/gal*	1.07
			Diesel *$5.00/gal*	
Emissions	HC (ton)	12.95	$6,700/ton	1.14
	CO (ton)	145.49	$6,360/ton	
	NO (ton)	6.20	$12,875/ton	
	CO_2 (metric ton)	2,265.65	$23/metric ton [5]	
Total		**$51.05 M**		

DIRECT BENEFITS TO HIGHWAY USERS

In addition to the above benefit analysis, a reduction in emissions due to reduced travel time in the Baltimore and Washington regions has also been computed. The results are summarized in Tables 7.10(a) and 7.10(b), where the daily delay reductions for the Washington region in 2022 were 1,650.56 hours/day and 44,934.61 hours/day for trucks and cars, respectively, compared with the 2,181.31 hours/day for trucks and 47,364.74 hours/day for cars in 2021. The delay reduction for trucks in the Baltimore region increased from 5,878.37 hours/day in 2021 to 6,019.51 hours/day in 2022, and increased from 97,406.40 hours/day in 2021 to 105,051.31 hours/day in 2022 for passenger cars. The overall reductions in emissions (i.e., by cars and trucks) for the entire region were \$180,043/day and \$174,636/day for the years 2022 and 2021, 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	
		2022	2021	2022	2021	2022	2021
Annual Delay Reduction	hour	1,994,218	2,095,517	429,147	567,141	1,565,072	1,528,377
Daily Delay Reduction	hour	7,670	8,060	1,651	2,181	6,020	5,878
Emission Reduction							
HC reduction	ton/day	0.100	0.105	0.035	0.038	0.065	0.067
	$/day	671.81	705.94	234.02	256.86	437.80	449.08
CO reduction	ton/day	1.126	1.183	0.392	0.431	0.734	0.753
	$/day	7,162.66	7,526.50	2,495.02	2,738.52	4,667.64	4,787.97
NO reduction	ton/day	0.048	0.050	0.017	0.018	0.031	0.032
	$/day	618.29	649.69	215.37	236.39	402.92	413.30
CO2 reduction	metric ton/day	66.20	69.56	23.06	25.31	43.14	44.25
	$/day	1,522.63	1,599.97	530.39	582.15	992.24	1,017.82
Total	$/day	9,975.39	10,482.10	3,474.79	3,813.92	6,500.60	6,668.18

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	
		2022	2021	2022	2021	2022	2021
Annual Delay Reduction	hour	37,640,498	22,025,139	12,314,833	7,914,609	25,325,665	14,110,530
Daily Delay Reduction	hour	144,771	84,712	47,365	30,441	97,406	54,271
Emission Reduction							
HC reduction	ton/day	1.961	1.893	0.683	0.689	1.278	1.204
	$/day	13,137.13	12,680.37	4,576.15	4,613.77	8,560.99	8,066.61
CO reduction	ton/day	22.023	21.257	7.671	7.734	14.351	13.523
	$/day	140,063.63	135,193.83	48,789.30	49,190.40	91,274.33	86,003.44
NO reduction	ton/day	0.939	0.906	0.327	0.330	0.612	0.577
	$/day	12,090.42	11,670.06	4,211.54	4,246.16	7,878.88	7,423.90
CO2 reduction	metric ton/day	207.65	200.43	72.33	72.93	135.32	127.50
	$/day	4,775.95	4,609.90	1,663.64	1,677.32	3,112.31	2,932.59
Total	$/day	170,067.14	164,154.16	59,240.63	59,727.64	110,826.52	104,426.52

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 2022 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 2022 was 12.88 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 2022 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 2022, 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

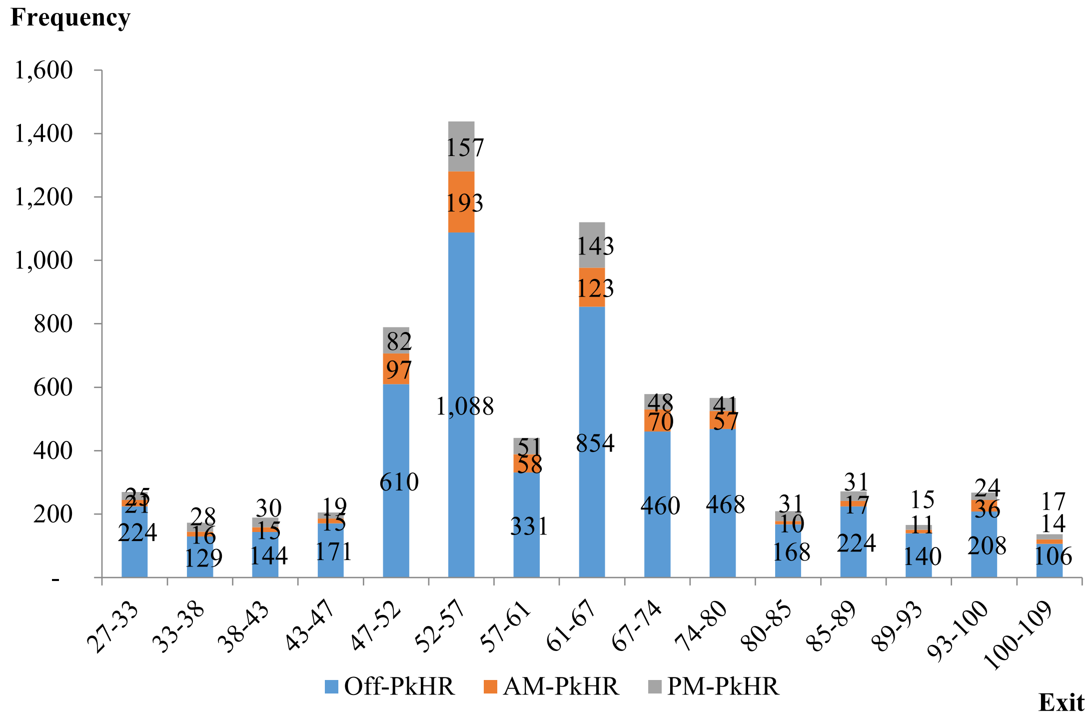


Figure A.1 Distribution of Incidents by Time of Day on I-95 in Year 2022

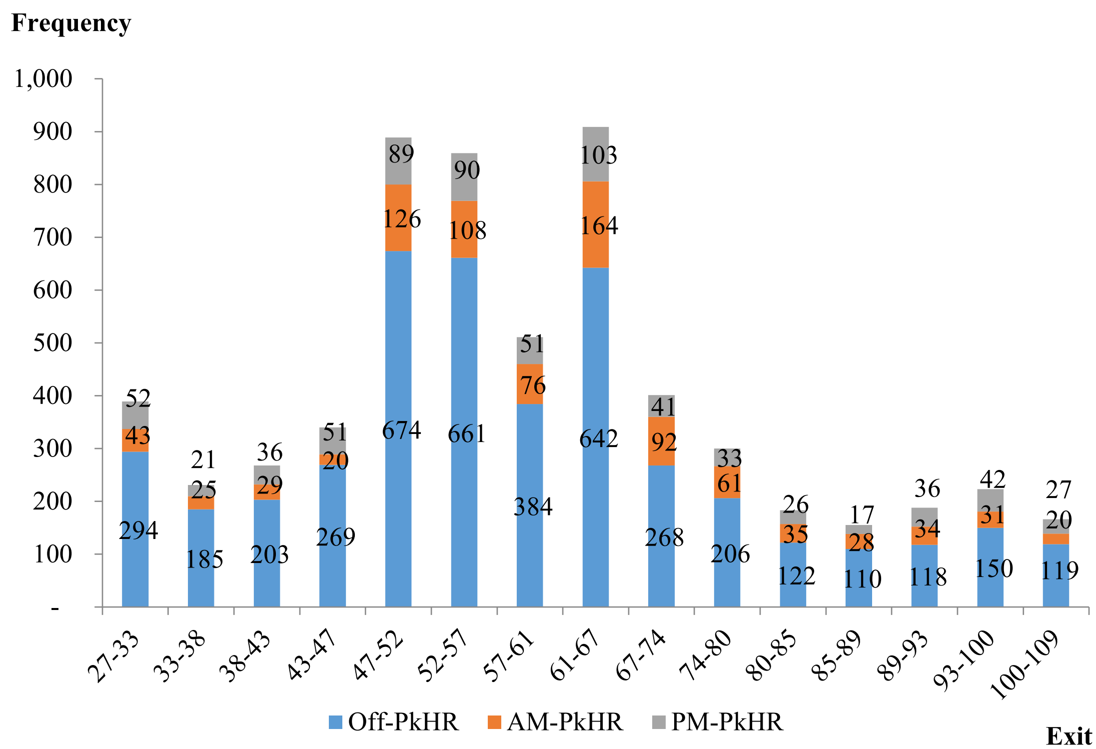


Figure A.2 Distribution of Disabled Vehicles by Time of Day on I-95 in Year 2022

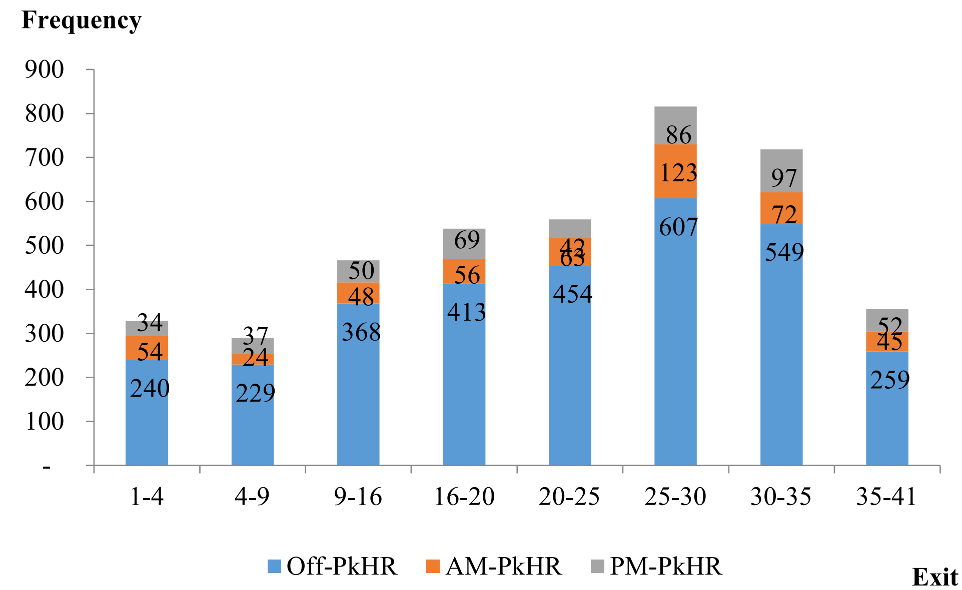


Figure A.3 Distribution of Incidents by Time of Day on I-495 in Year 2022

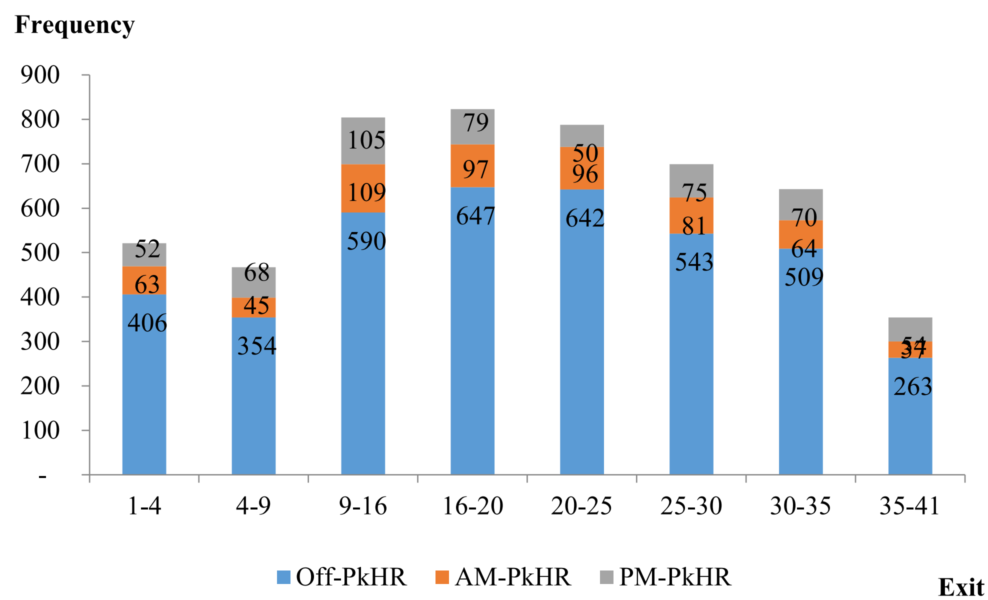


Figure A.4 Distribution of Disabled Vehicles by Time of Day on I-495 in Year 2022

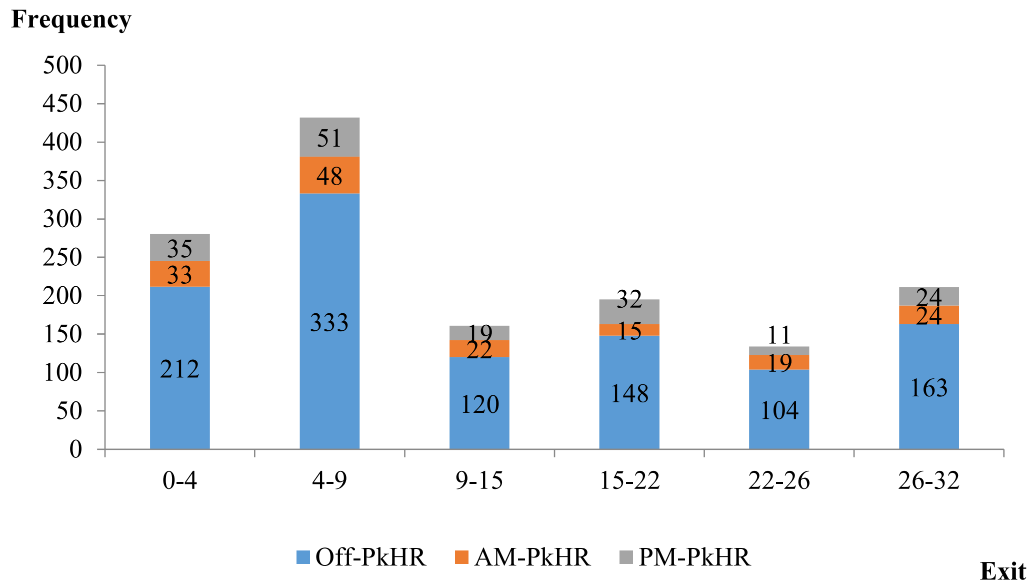


Figure A.5 Distribution of Incidents by Time of Day on I-270 in Year 2022

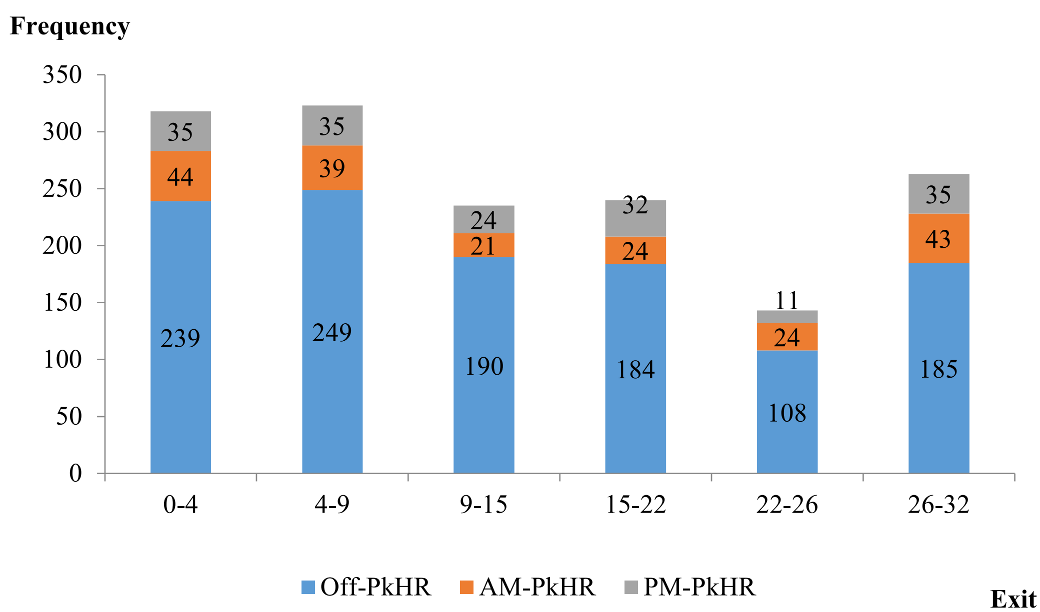


Figure A.6 Distribution of Disabled Vehicles by Time of Day on I-270 in Year 2022

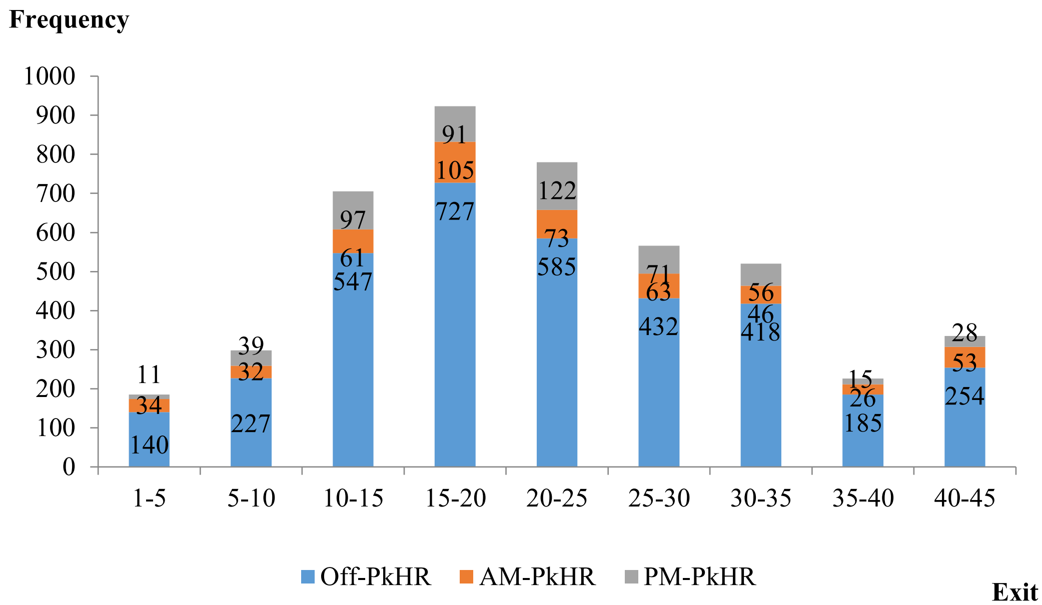


Figure A.7 Distribution of Incidents by Time of Day on I-695 in Year 2022

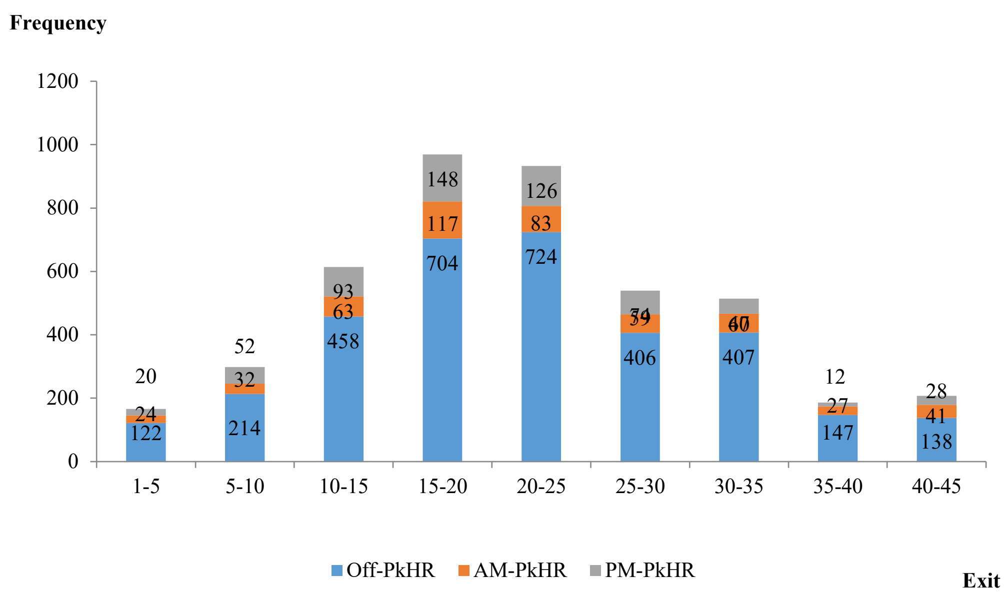


Figure A.8 Distribution of Disabled Vehicles by Time of Day on I-695 in Year 2022

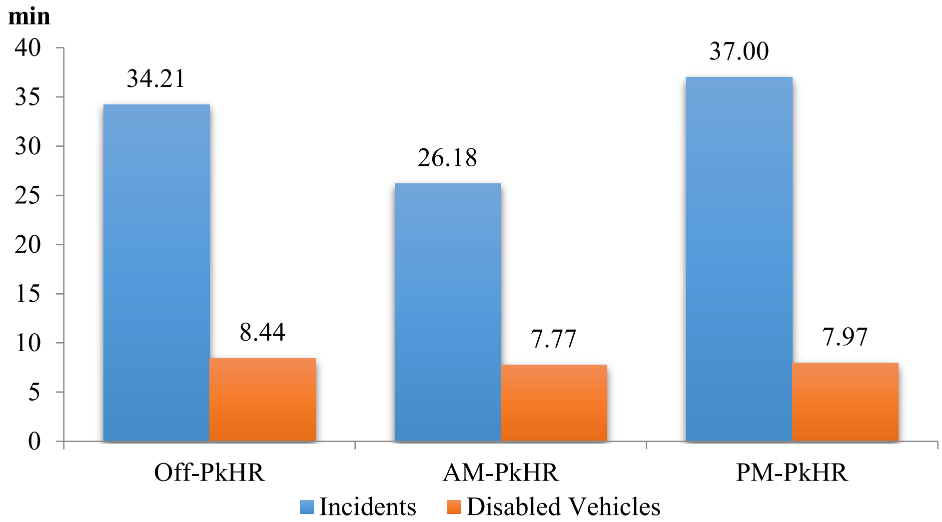


Figure A.9 Distribution of Clearance Time by Time of Day in Year 2022

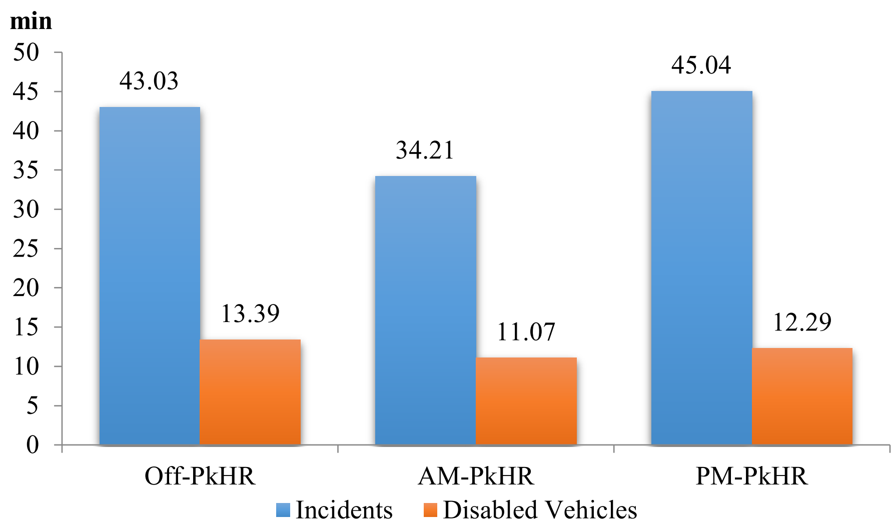


Figure A.10 Distribution of Incident Duration by Time of Day in Year 2022

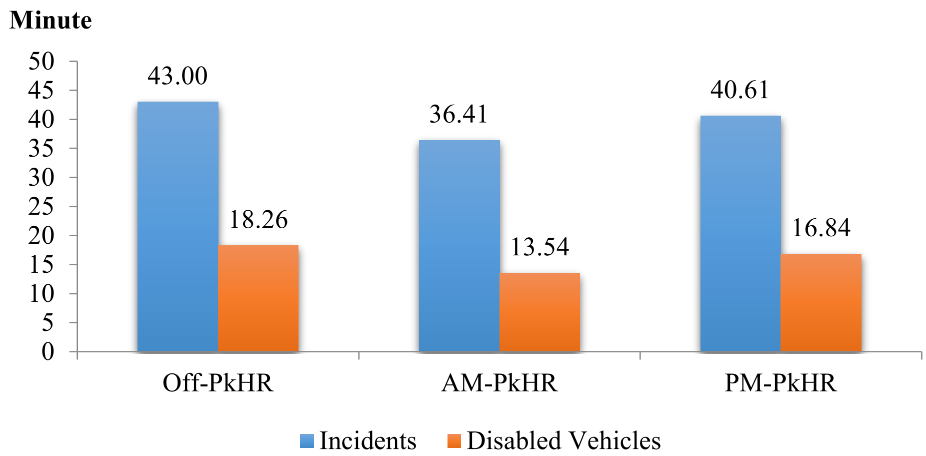


Figure A.11 Distribution of Incident Duration by Time of Day on I-95 in Year 2022

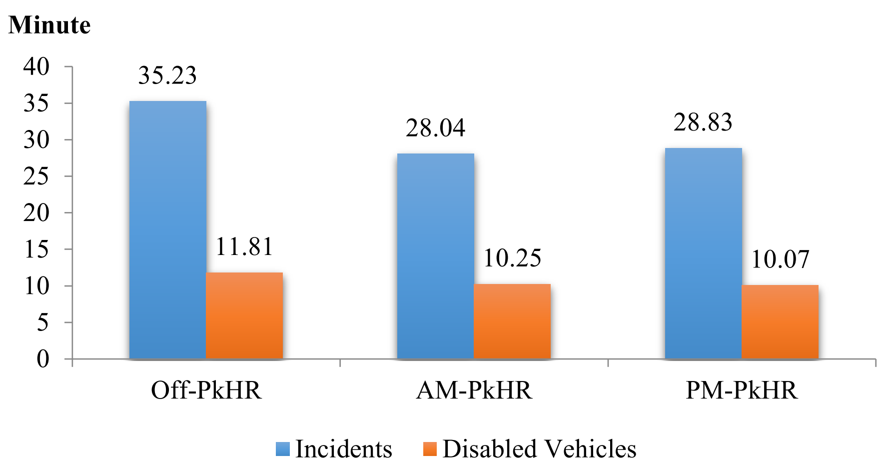


Figure A.12 Distribution of Incident Duration by Time of Day on I-495 in Year 2022

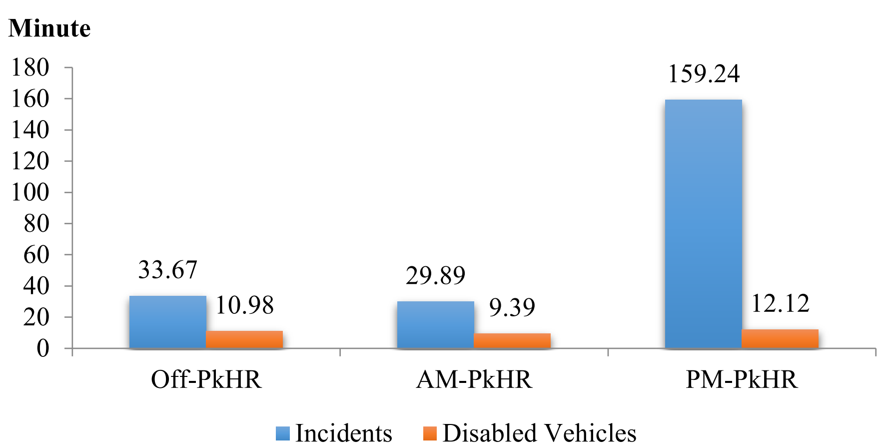


Figure A.13 Distribution of Incident Duration by Time of Day on I-270 in Year 2022

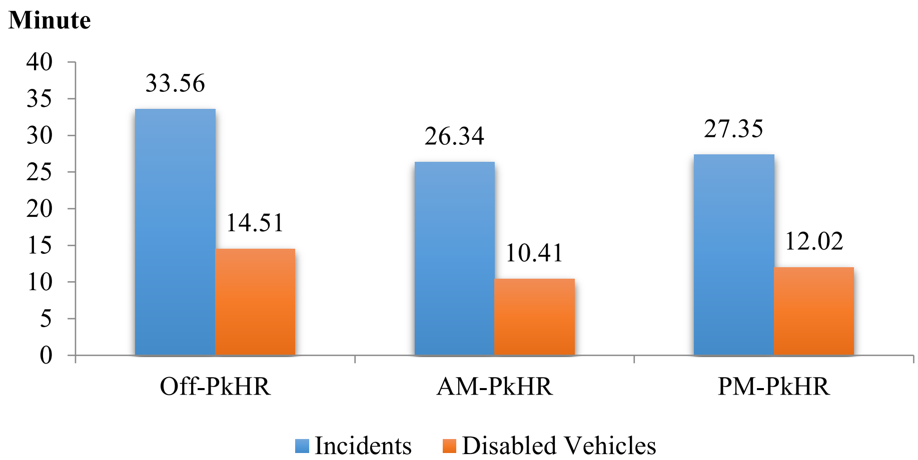


Figure A.14 Distribution of Incident Duration by Time of Day on I-695 in Year 2022

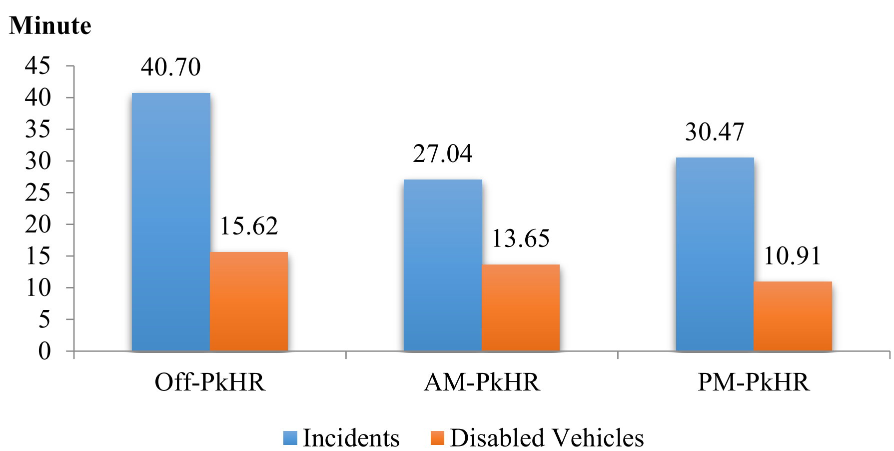


Figure A.15 Distribution of Incident Duration by Time of Day on I/MD-295 in Year 2022

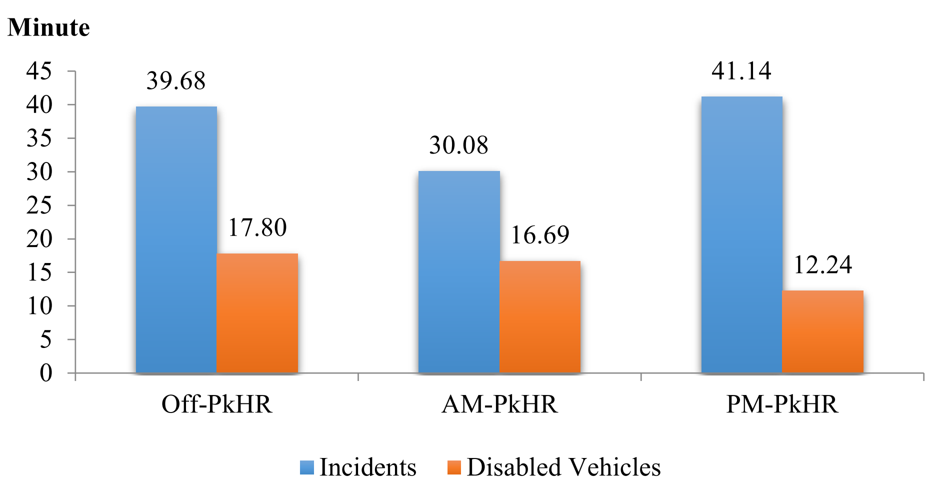


Figure A.16 Distribution of Incident Duration by Time of Day on I-83 in Year 2022

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 (*Δfuel*) and emission reduction (*Δemission*) 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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