Year 2024

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Performance Evaluation and Benefit Analysis For CHART

– Coordinated Highways Action Response Team –

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Mobility and Operations
State Highway Administration

Performance Evaluation of CHART

The Real-Time Incident Management System (Year 2024)

Table of Contents

EXECUTIVE SUMMARY

Objectives

This report presents the performance evaluation study of the Coordinated Highways Action Response Team (CHART) for the Year 2024, 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-seven years for the State Highway Administration (SHA).

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

The study consisted of two phases. Phase 1 focuses 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 2024 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 from 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 because 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 items to analyze incident management data.

This original study and evaluation analysis inevitably faced the difficulty of having insufficient information for analysis, since this was the first time CHART had 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 increased considerably since 1999. These results from CHART reflect the need to keep an extensive operational record 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 41,261 in 2024.

Table E.1 shows the total number of emergency response operations assiduously documented from 2020 to 2024.

Table E.1 Summary of the Total Number of Emergency Responses from 2020 to 2024

	2020	2021	2022	2023	2024	Δ (2024-2023)
Incidents only	34,590 (26,702)	38,275 (29,546)	38,957 (28,972)	40,073 (29,864)	41,261 (30,811)	2.96% (+3.17%)
Total [1]	70,115 (60,665)	76,722 (65,839)	75,841 (63,474)	82,987 (70,346)	78,179 (65,710)	-5.79% (-6.59%)

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 2024 increased by 2.96% compared to 2023.
- The number of incidents responded by CHART in 2024 increased by 3.17% compared to 2023.
- The numbers of both total emergency responses (including disabled vehicles) and those responded by CHART significantly decrease in 2024.

Evolution of the CHART 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 improved 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 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 2024 incident records indicate that there were a total of 2,784 incidents resulting in one-lane blockage, 9,895 incidents causing two-lane closures, and 6,011 incidents blocking three or more lanes. In addition, either disabled vehicles or minor incidents caused a total of 43,842 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

	2020	2021	2022	2023	2024	Δ (2023-2024)
Shoulder[2]	41,409	45,258	44,933	45,044	43,842	-2.67%
1 lane	3,221	3,290	3,320	3,100	2,784	-10.19%
2 lanes[3]	8,205	9,328	9,238	9,399	9,895	5.28%
3 lanes[3]	2,780	3,062	3,235	3,392	3,423	0.91%
≥ 4 lanes[3]	2,331	2,472	2,457	2,451	2,588	5.59%

**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 7,207 incidents/disabled vehicles in 2024; I-695, I-95, US-50, I/MD-295, and I-270 with 7,225, 23,625, 6,236, 2,288, and 3,324 incidents/disabled vehicles, respectively. CHART managed an average of 65 emergency requests per day on I-95 alone, and 20, 20, 17, 6, and 9 responses per day for I-495/95, I-695, US-50, I/MD-295, and I-270, respectively. The distribution of incidents/disabled vehicles on those major commuting corridors between 2020 and 2024 is shown in Table E.3:

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

	2020	2021	2022	2023	2024	Δ (2024 - 2023)
I-495/95	10,339	12,068	10,371	9,768	7,207	-26.22%
I-695	8,025	8,585	9,529	8,534	7,225	-15.34%
I-95	12,937	12,838	14,052	19,885	23,625	+18.81%
US-50	6,492	7,807	6,272	7,449	6,236	-16.28%
I/MD-295	2,694	3,120	2,738	2,756	2,288	-16.98%
I-270	4,058	4,484	4,200	3,994	3,324	-16.78%

** 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 2024 are shown in Table E.4. The highest frequency of incidents occurred on the I-95 northbound segment between Exits 67 and 74 in both AM and PM peaks, respectively. The southbound segment on I-95 between Exits 67 and 74 ranked the first with the respect to the number of disabled vehicle requests in 2024 in both AM and PM peak hours, respectively.

Table E.4 Top 10 Freeway Segments with the Most Incidents/Disabled Vehicles in 2024

	Incidents				Disabled vehicles			
	AM Peak		PM Peak		AM Peak		PM Peak	
1	I-95 N	Exit 67&74	I-95 N	Exit 67&74	I-95 S	Exit 67&74	I-95 S	Exit 67&74
2	I-95 S	Exit 56&57	I-95 N	Exit 55&56	I-95 N	Exit 67&74	I-95 N	Exit 67&74
3	I-95 S	Exit 67&74	I-95 S	Exit 67&74	I-95 N	Exit 61&64	I-95 N	Exit 61&64
4	I-895 S	Exit 8&12	I-895 N	Exit 12&14	I-95 N	Exit 64&67	I-95 N	Exit 77&80
5	I-95 S	Exit 58&59	I-95 N	Exit 50&52	I-95 S	Exit 62&64	I-95 N	Exit 64&67
6	I-495 OL	Exit 28&29	I-95 N	Exit 74&77	I-95 N	Exit 77&80	I-95 S	Exit 62&64
7	I-95 S	Exit 50&52	I-895 S	Exit 8&12	I-95 S	Exit 50&52	I-95 S	Exit 64&67
8	I-695 OL	Exit 16&18	I-695 IL	Exit 11&12	I-95 S	Exit 80&85	I-95 S	Exit 77&80
9	I-95 S	Exit 64&67	I-95 N	Exit 51&52	I-95 N	Exit 80&85	I-95 N	Exit 67&74
10	I-95 S	Exit 93&100	I-895 N	Exit 9&10	I-95 N	Exit 74&77	I-95 S	Exit 100&109

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

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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 2024. 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 2020 to 2024 are summarized in Table E.5:

Table E.5 Distribution* of Incidents/Disabled Vehicle Duration from 2020 to 2024

Duration (Hrs)	2020	2021	2022	2023	2024
D < 0.5	73%	72%	72%	74%	72%
0.5 ≤ D < 1	15%	15%	16%	15%	15%
1 ≤ D < 2	7%	8%	8%	7%	8%
2 ≤ D	5%	5%	5%	4%	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-895, 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 13.45, 15.20, 11.67, 14.99, and 10.05 minutes for TOC-3, TOC-4, TOC-7, SOC, and AOC, respectively, in 2024. Note that TOC-3 relocated back to their center on July 24th, 2024. All centers except TOC-3 experienced a slight increase in response time in 2024. 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 2020 to 2024

Response Time (mins)	2020	2021	2022	2023	2024		
					During OH[4]	After OH	Overall
TOC-3[6]	12.17	12.64	4.65	19.6	*13.47 (1,485)[5]*	*10.09 (6)*	*13.45 (1,491)*
TOC-4	12.98	14.03	14.51	14.88	*15.20 (4,248)*	*13.75 (22)*	*15.20 (4,270)*
TOC-7	11.42	11.83	11.78	11.42	*11.79 (2,810)*	*11.28 (850)*	*11.67 (3,660)*
SOC	14.32	14.67	14.79	14.40	*14.99 (9,119)*	*N/A*	*14.99 (9,119)*
AOC	9.03	9.45	10.04	9.95	*10.05 (10,566)*	*N/A*	*10.05 (10,566)*
OTHER	2.53	8.58	13.09	6.51	*N/A*	*8.46 (31)*	*8.46 (31)*
Weighted Average	**11.64**	**12.25**	**12.88**	**12.74**	***12.77 (28,228)***	***11.24 (909)***	***12.73 (29,137)***

** 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 data that have response times between 1 minute and 60 minutes.

3. Events included in this analysis were responded to 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 had been relocated to SOC due to staff related issues. TOC 3 relocated back to their center on July 24th, 2024.

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]	12.05 (1220)[5]	19.97 (265)	7.89 (5)	21.13 (1)	12.04 (1225)	19.97 (266)	13.45 (1491)
TOC-4	13.66 (3187)	19.85 (1059)	14.99 (19)	9.33 (4)	13.67 (3206)	19.81 (1063)	15.2 (4269)
TOC-7	11.32 (2299)	13.94 (511)	11.2 (682)	14 (172)	11.29 (2981)	13.96 (683)	11.79 (3664)
SOC	12.96 (6513)	20.08 (2604)	N/A	N/A	12.96 (6513)	20.08 (2604)	14.99 (9117)
AOC	9.3 (7169)	11.42 (3351)	N/A	N/A	9.3 (7169)	11.42 (3351)	9.98 (10520)
OTHER	N/A	N/A	8.17 (24)	10.24 (7)	8.17 (24)	10.24 (7)	8.64 (31)
Weighted Average	**11.54 (20388)**	**15.92 (7790)**	**11.18 (730)**	**13.8 (184)**	**11.53 (21118)**	**15.87 (7974)**	**12.72 (29092)**

** 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. TOC 3 relocated back to their center on July 24th, 2024.

Also, the 2024 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 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 8.99 minutes.

The duration of incidents managed by CHART response units averaged 26.01 minutes, shorter than the average duration of 34.34 minutes for those incidents by other agencies. On average, CHART operations in Year 2024 reduced the average incident duration by about 24.3 percent.

Performance improvement of CHART operations from years 2020 to 2024 is summarized in Table E.8:

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

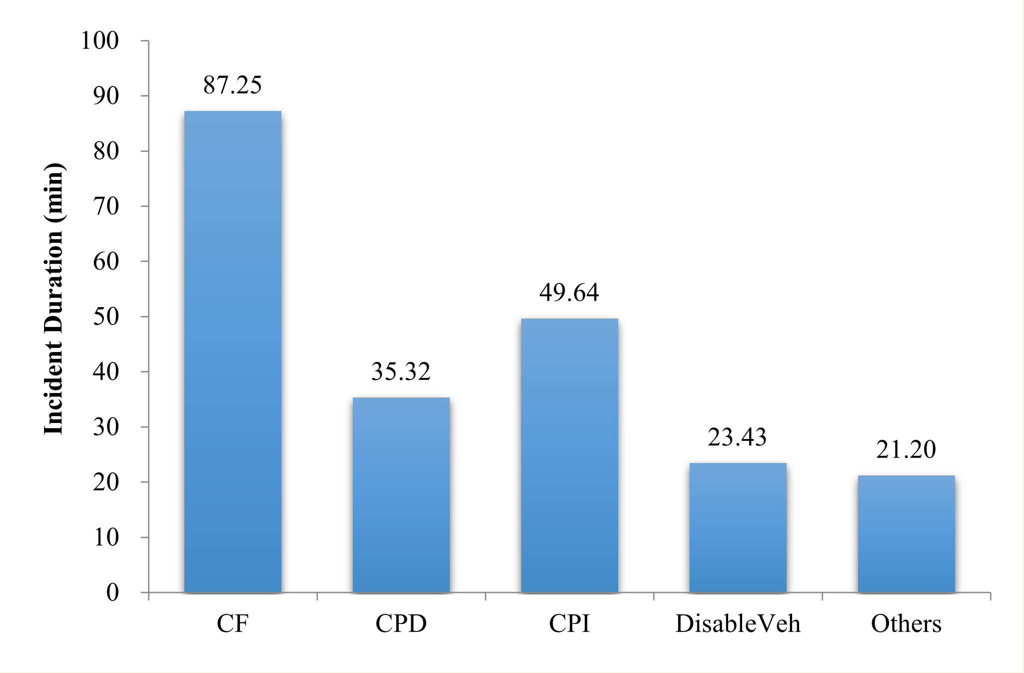
Year	With CHART (mins)	Without CHART (mins)
2020	27.04	37.02
2021	26.31	37.82
2022	26.02	37.54
2023	25.44	36.09
2024	26.01	34.34

** This analysis is based on incidents which have included 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 87 minutes, while those causing property damage (CPD) and personal injuries (CPI) lasted, on average, 35 and 50 minutes, respectively (see Figure E.1). The average duration for incidents by only disabled vehicles was 23 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 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 2024

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 2024, CHART responded to a total of 41,261 incidents and assisted 36,918 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 961 potential lane-changing-related collisions in 2024, 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 the driving population's income) have increased in 2024. The ratio in difference between incident durations with and without CHART exhibits a decrease in 2024. Overall, the delay reduction due to CHART's services in 2024 (39.092 million vehicle-hours) decreased by 7.95 percent, compared to the performance in 2023 (42.467 million vehicle-hours). The combined impact of all key contributing factors has resulted in a net benefit decrease from \$2,230.57M in 2023 to \$2,148.69M, or, to \$2,119.10M in 2024 if with the new emission parameters. A comparison of the direct benefits from reduced delay times, fuel consumption, and emissions, from 2020 to 2024, is summarized in Table E.9:

Table E.9 Comparison of Direct Benefits from 2020 to 2024

	Total Direct Benefits (million)[1,2,3,4,5]	# of Incidents Eligible for the Benefit Estimate[6]
2020	$1,080.83	28,513
2021	$1,875.25	31,253
2022	$2,030.56	32,130
2023	$2,230.57	33,297
2024a[5]	$2,148.69	34,145
2024b[5]	$2,119.10	34,145

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. Starting from the 2024 report, a new set of parameters for computing emission benefit is introduced to reflect recent vehicle emission standards. The results of 2024a shows the benefits computed with the original emission parameters, while the statistics of 2024b shows the same measurements but with the new parameters. See Chapter 7 for further information on the new emission parameters.

6. 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 reductions due to CHART's services on I-95, I-495, I-270, I-695, I-70, and I-83 are 11.74, 3.65, 1.28, 4.33, 1.80, and 0.86 million vehicle-hours, respectively, in 2024. Such direct benefits for users over each major road in 2024 are summarized in Table E.10:

Table E.10 Direct Benefits for Major Roads in 2024 due to CHART operations

Roads	Total Direct Benefits (2024a)[5] (million)[1,2,3,4]	Total Direct Benefits (2024b)[5] (million)[1,2,3,4]	# of Incidents Eligible for the Benefit Estimate
I-95	$664.42	$656.06	7,309
I-95/495	$201.90	$199.18	3,274
I-270	$69.12	$68.09	1,075
I-695	$238.57	$235.22	3,471
I-70	$101.33	$100.04	1,444
I-83	$48.78	$48.18	1,042
Others	$824.57	$812.33	16,530
Total	$2,148.69	$2,119.10	34,145

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

2. The direct benefits represent reductions in car/truck delay times, fuel consumption, and emissions due to the CHART effective operations.

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

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

5. Starting from the 2024 report, a new set of parameters for computing emission benefit is introduced to reflect the recent adoption in vehicle emission standards. The results in 2024a show the benefits computed with the original emission parameters, while the statistics in 2024b show the same measurements but with the new parameters. See Chapter 7 for further information on the new emission parameters.

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 2.55 percent from the year 2023 to year 2024, as shown in Table E.11.
- The ratio, reflecting the difference between incident durations with CHART and those without CHART, increased from 27.09 percent in 2023 to 22.59 percent in 2024, as shown in Table E.12.
- Table E.13 shows that the adjusted AADT in 2024 decreased by 1.22 percent on the major roads in Maryland compared to 2023.
- Table E.14 shows that average truck percentage decreased in the year 2024 over all major roads in Maryland, by 0.1 percent on average.

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

	2023	2024	Δ('23 ~ '24) [2]
No. of Incidents [1]	33,297	34,145	***2.55***

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

2. The percentage change in No. of Incidents (X) from Year 2023 to Year 2024 is calculated as follows: $\Delta\mathbf{X}(\%) = \frac{X_{2024} - X_{2023}}{X_{2023}} \times 100$

Table E.12 Incident duration reduction in year 2023 and 2024

	With CHART(mins) (A)	Without CHART(mins) (B)	Difference(mins) (B-A)	Ratio in Difference ((B-A)/B)
2023	27.42	37.61	10.19	27.09 %
2024 All year	27.90	36.04	8.14	22.59 %
2024 January to June	27.38	36.25	8.87	24.47 %
Δ('23 ~ '24 all year) [2]	1.75%	-4.17%	-20.12%	-16.61 %
Δ('23 ~ '24 Jan to June) [3]	-0.15%	-3.62%	-12.95%	-9.67 %

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

2. The percentage change in incident duration (X) from Year 2023 to Year 2024 is calculated as follows:

$\Delta\mathbf{X}(\%) = \frac{X_{2024} - X_{2023}}{X_{2023}} \times 100$

3. The percentage change in incident duration (X) from Year 2023 to the period of January-June in Year 2024 is calculated as follows: $\Delta\mathbf{X}(\%) = \frac{X_{2024\ \text{data from Jan.to June}} - X_{2023}}{X_{2023}} \times 100$. *As of July 2024, ERTs are no longer actively patrolling and are staged in high call volume areas, waiting until called upon for assistance.*

Table E.13 The adjusted AADT (with peak hour factor) for Major Roads from 2023 and 2024

	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	**2023**	12,079	7,905	7,612	10,453	4,086	2,404	4,333	2,487	3,400	**54,756**
	2024	11,908	7,954	7,223	10,471	4,013	2,378	4,320	2,481	3,340	**54,088**
Δ('23 ~ '24) (%)*		-1.42	0.62	-5.11	0.17	-1.79	-1.08	-0.30	-0.24	-1.76	-1.22

Note: The percentage change in the adjusted AADT(X) from Year 2023 to Year 2024 is calculated as follows:

$$\Delta\mathbf{X}(\%) = \frac{X_{2024} - X_{2023}}{X_{2023}} \times 100$$

Table E.14 Truck percentage for Major Roads from year 2023 and 2024

	Year	I-495	I-95	I-270	I-695	MD 295	US 50	US 1	I-83	I-70	Average
Truck %	**2023**	7.96	9.77	3.48	6.50	1.77	5.26	3.85	10.43	9.65	**6.52**
	2024	7.08	11.23	3.67	6.37	1.86	4.66	3.88	10.49	9.37	**6.51**
Δ('23 ~ '24)(%)*		-11.06	14.94	5.46	-2.00	5.08	-11.41	0.78	0.58	-2.90	-0.10

Note: The percentage change in the truck percentage (X) from Year 2023 to Year 2024 is calculated as follows:

$$\Delta\mathbf{X}(\%) = \frac{X_{2024} - X_{2023}}{X_{2023}} \times 100$$

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 2024 value, but setting all other factors identical to those in 2023; and
- Following the same procedures to analyze the sensitivity of the total 2024 benefits with respect to each key factor.

The results of sensitivity analysis for each factor are shown in Table E.15. The decrease in the average adjusted AADT by 1.22 percent in 2024 contributed to a decrease of 3.48 percent in total benefit. The number of lane-blockage incidents increased by 2.55 percent in 2024, resulting in the benefit increase of 2.01 percent. Note that the ratio with respect to the performance difference between incident durations with- and without-CHART involvement decreased by 20.12 percent, and thus directly resulted in a 16.62 percent decrease in total benefit. This is likely due to the policy change in July 2024, from then ERTs stopped patrolling and temporarily stationed in the areas of high call volume , i.e., waiting until called upon for assistance. If the policy had remained unchanged, the performance difference between incident durations with- and without-CHART would have only decreased by 12.95 percent.

An increase of 3.42 percent in the total benefit is due solely to the average income raise of 4.44 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 (2023)				2,230.57
Key Factor			Δ ('23 - '24)	Estimated Benefit
Sensitivity Analysis	Adjusted AADT		▼1.22%	1,873.10 (▼3.48%)[1]
	Number of incidents		▲2.55%	1,915.10 (▲2.01%)
	Incident duration difference between w/ and w/o CHART	'24 All year	▼20.12%	1,859.79 (▼16.62%)
		'24 Jan. to June	▼12.95%	2,014.84 (▼9.67%)
	Truck percentage		▼0.1%	2,231.14 (▲0.03%)
	Monetary unit of gas price		▼5.83%	2,228.42 (▼0.1%)
	Monetary unit of time value		▲4.44%	2,306.83 (▲3.42%)
Benefit of the Current Year (2024a)				**2,148.69 (▼3.67%)**[2]
Benefit of the Current Year (2024b)				**2,119.10 (▼5.00%)**[2]

Note: 1. The number in each parenthesis shows the percentage of benefit change from year 2023.
2. Starting from the 2024 report, a new set of parameters for computing emission benefit is introduced to reflect recent advancements in vehicle emission standards. The results in 2024a show the benefits computed with the original emission parameters, while the statistics in 2024b show the same measurements but with the new set of parameters. See Chapter 7 for further information on the new emission parameters.

Conclusions and Recommendations

Grounded in the lessons from the earlier studies, this study has conducted a rigorous evaluation of CHART's performance in 2024 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 2024 was 12.73 minutes (See Table E.6). 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 2024, are listed below:

- Increase the resources for CHART to sustain the high-quality incident response operation, including more staff and hardware supports.
- Provide constant training to staff in the control center responsible for recording incident related information to ensure 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 to employ 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 2024 CHART Performance Evaluation

- Both the total number of statewide emergency responses and CHART responses slightly decreased from Year 2023 to Year 2024 (by 5.79% and 6.59%, respectively).
- Since TOC 3 relocated back to their center on July 24th, 2024, the number of responses by TOC3 increased significantly in 2024 (from 2 in 2023 to 2,909 in 2024).
- In 2024, the average incident duration with CHART was 26.01 minutes, much shorter than the average of 34.34 minutes for those incidents responded by other agencies. The reduction in the average incident duration is about 24 percent.
- Both AADT and truck percentage on most major roads did not experience major changes in 2024. The incident duration difference between with and without CHART for the entire year of 2024 is lower than that of 2023. This might be related to the pause of the CHART vehicle patrolling on the roadways.
- Among major corridors, I-95 experienced the most significant increase in emergency response frequency in 2024 compared to 2023 (by about 18%), while I-495/I-95 saw the most significant decrease (by about 26%). The total emergency response frequency on US 50 and I-695 decreased by 16% and 15%, respectively, compared to 2023.
- The total benefit of CHART operation increased by 0.11 percent, nearly the same as in 2023.
- Starting from July 2024, ERTs are no longer actively patrolling and station mainly in areas of high call volume, i.e., waiting until called upon for assistance, which partially contributes to the reduction of incident duration difference between w/ and w/o CHART.

The above changes, along with other factors, collectively contributed to the resulting direct benefits by CHART's performance in 2024.

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 41,261 reports in 2024. A summary of total emergency response operations documented from 2020 to 2024 is presented in Table 1.1.

Table 1.1 Total Number of Emergency Response Operations

Records	2020	2021	2022	2023	2024
Incidents*	34,590 (26,702)	38,275 (29,546)	38,957 (28,972)	40,073 (29,993)	41,261 (30,811)
Disabled Vehicles	35,525 (33,963)	38,447 (36,293)	36,884 (34,502)	42,914 (40,540)	36,918 (34,899)
Total	70,115 (60,665)	76,722 (65,839)	75,841 (63,474)	82,987 (70,533)	78,179 (65,710)

**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 2023 and 2024, 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 2024 CHART performance evaluation. This includes the total available incident reports, the percentage of missing data for each critical performance parameter, and a comparison of 2024 data quality with that of 2023.

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 2024 performance evaluation and compares it with the data from CHART 2023.

2.1 Analysis of Data Availability

2.2 Analysis of Data Quality

2

2.1 Analysis of Data Availability

In 2024, CHART recorded a total of 78,179 emergency response cases. These are categorized into two groups: incidents and disabled vehicles. A summary of the total available incident reports for the years 2022, 2023, and 2024 is shown in Table 2.1.

Table 2.1 Comparison of Available Data for 2022, 2023, and 2024

Available Records		2022		2023		2024	
		Records	Ratios (%)	Records	Ratios (%)	Records	Ratios (%)
CHART II Database	Disabled Vehicles	36,884	48.6	42,914	51.7	36,918	47.2
	Incidents	38,957	51.4	40,073	48.3	41,261	52.8
Total		75,841	100	82,987	100	78,179	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 2023 and 2024.

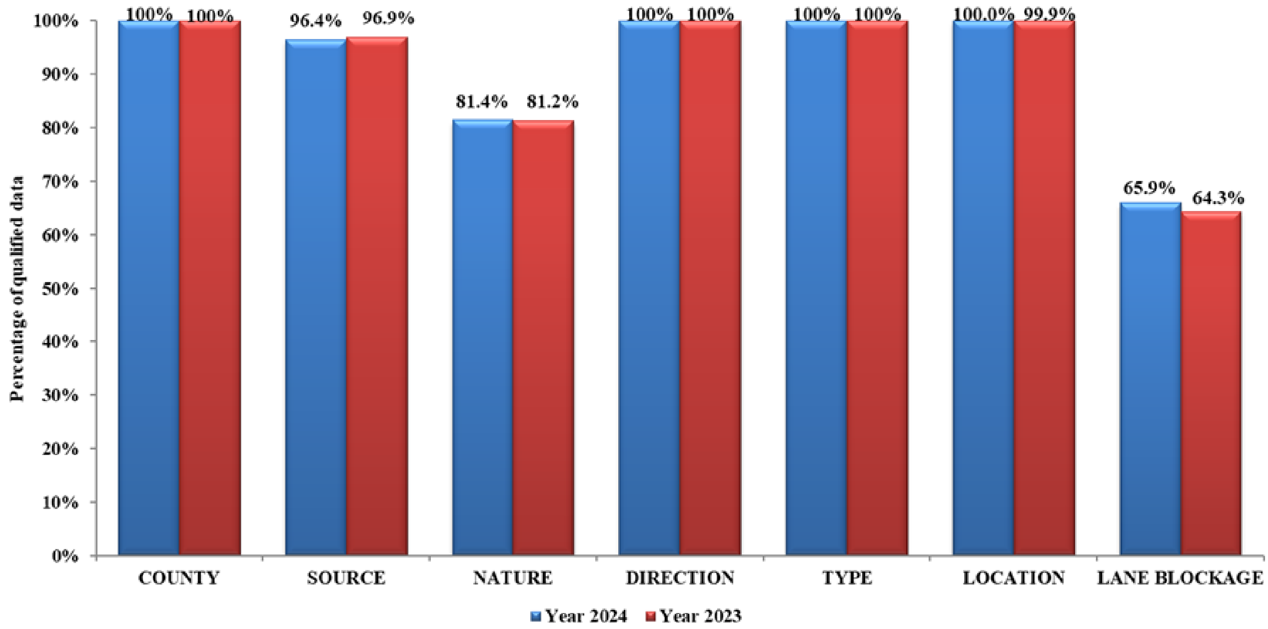


Figure 2.1 Summary of Data Quality for Critical Indicators

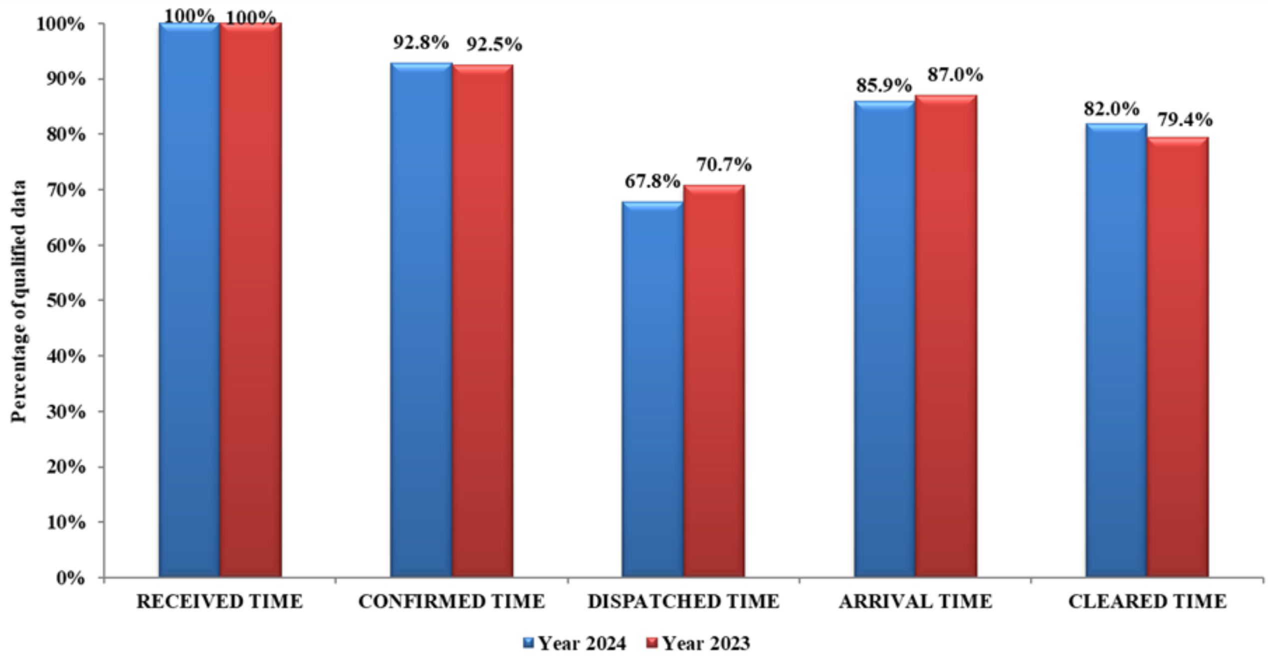


Figure 2.2 Summary of Data Quality for Time Indicators

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 81.4 percent of emergency responses reported in 2024 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 96.4 percent of all emergency responses recorded in 2024 contained the source of detection, which is almost the same as the previous year's data. In 2024, about 93.75 percent of incidents reported and 99.40 percent of the disabled vehicles reported had a definite detection source.

Operational Time-Related Information

To evaluate the efficiency and effectiveness of emergency response operations, CHART in 2024 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 2024 is summarized in Table 2.2. Overall, CHART responded to a total of 41,226 incidents in 2024. Over the same period, the response team also attended to 36,897 disabled vehicle requests.

Table 2.2 Emergency Assistance Reported in 2024

Operation Center	TOC3	TOC4	SOC	TOC7	AOC	OTHER	TOTAL
Disabled Vehicles	725 (0)	3,333 (4,918)	8,603 (15,571)	4,100 (5,406)	20,136 (17,010)	0 (9)	36,897 (42,914)
Incidents	2,184 (2)	5,731 (5,810)	15,342 (18,543)	4,611 (4,237)	13,358 (11,460)	0 (21)	41,226 (40,073)
Total	2,909 (2)	9,064 (10,728)	23,945 (34,114)	8,711 (9,643)	33,494 (28,470)	0 (30)	78,123 (82,987)

**Note: 1. Numbers in each parenthesis the corresponding data from 2023.*
2. TOC 3 relocated back to their center on July 24th, 2024.

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 2024. Note that about 99.97 percent of data have some information related to the locations (road names and exit numbers) and about 63 percent of them can be used to clearly identify the event sites. For the remaining 37 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	99.28%	99.29%	99.28%
Location	99.97%	99.98%	99.97%
Valid Data for Road & Location	58.03%	68.42%	62.94%

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 2024 shows that up to 65.9 percent of emergency response reports involved lane/shoulder blockage (see Figure 2.1). This value is higher than 64.3 percent in 2023.

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

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 78 percent) of incidents/disabled vehicles in 2024 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 TOC7 and AOC increased while TOC4 and SOC 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	2024	2023	2024	2023	2024	2023
Weekdays	85%	0%	80%	79%	75%	90%
Weekends	15%	100%	20%	21%	25%	10%

Center	SOC		AOC		Others		Total	
Year	2024	2023	2024	2023	2024	2023	2024	2023
Weekdays	77%	73%	78%	83%	2%	20%	78%	79%
Weekends	23%	27%	22%	17%	98%	80%	22%	21%

Notes: 1. "Others" includes RAVENS TOC.
2. TOC 3 relocated back to their center on July 24th, 2024.

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 2024 occurred during peak hours, which is slightly lower than that in 2023.

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

Center	TOC3		TOC4		TOC7	
Year	2024	2023	2024	2023	2024	2023
Peak	30%	0%	30%	33%	28%	33%
Off-Peak	70%	100%	70%	67%	72%	67%

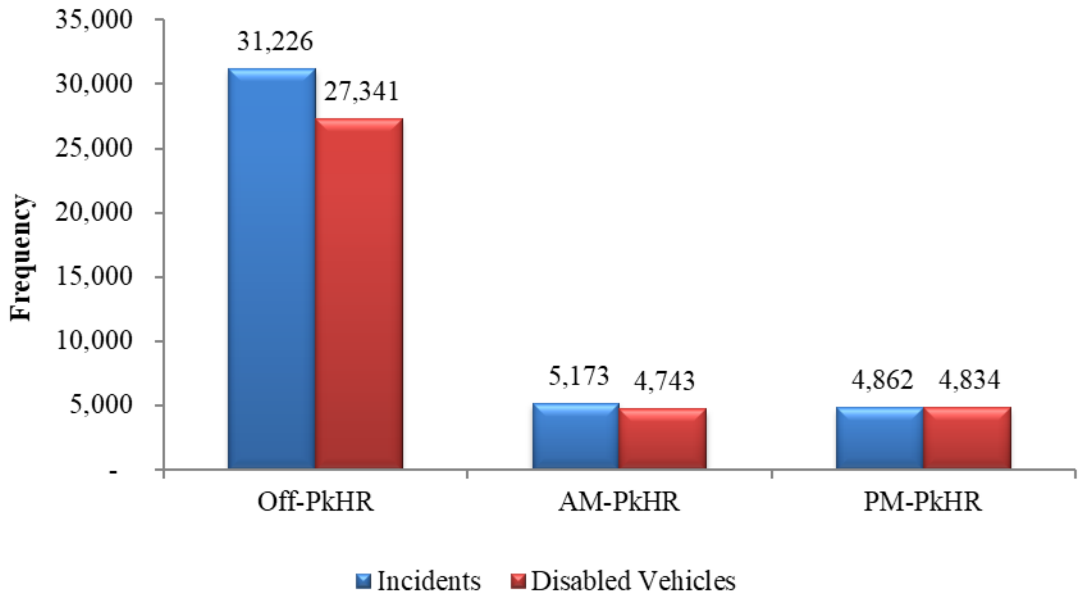
Center	SOC		AOC		Others		Total	
Year	2024	2023	2024	2023	2024	2023	2024	2023
Peak	21%	21%	26%	29%	0%	0%	25%	27%
Off-Peak	79%	79%	74%	71%	100%	100%	75%	73%

Notes: 1. "Others" includes RAVENS TOC.
2. TOC 3 relocated back to their center on July 24th, 2024.
3. 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.

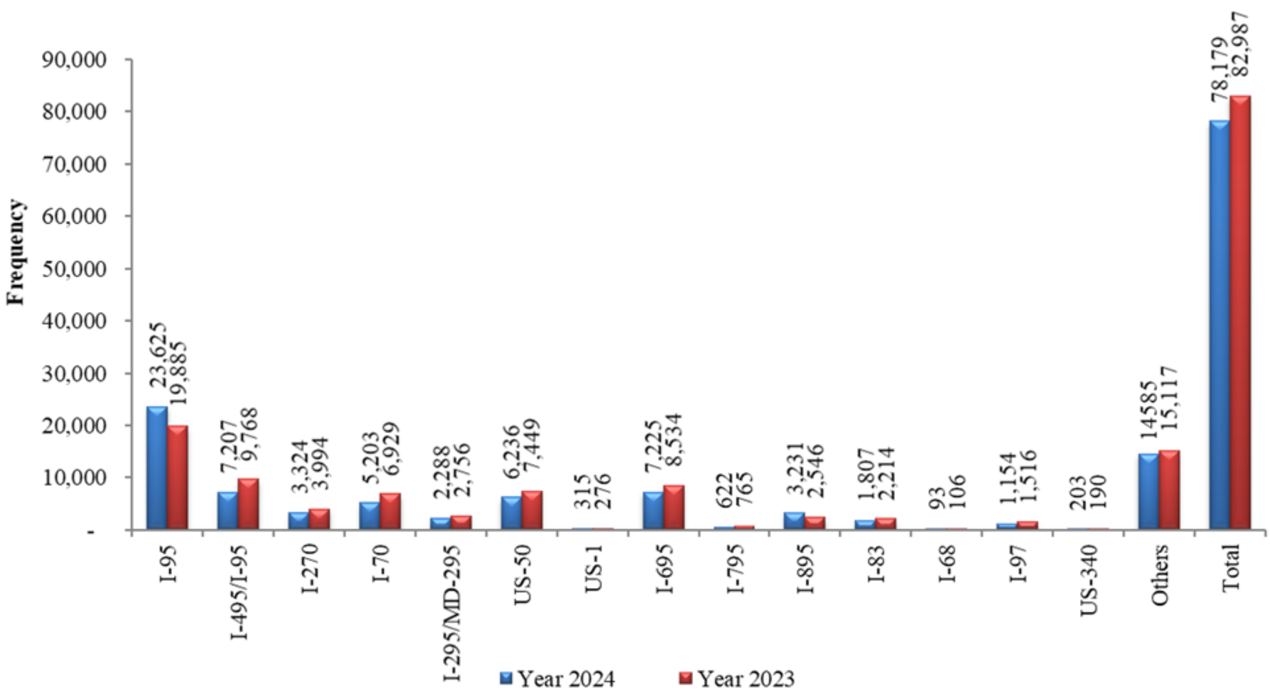


** Off-PkHR, AM-PkHR, and PM-PkHR stand for Off-Peak hours, AM-Peak hours, and PM-Peak hours, respectively.*

Figure 3.1 Distributions of Incidents/Disabled Vehicles by Time of Day in 2024

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

Figure 3.2 compares the frequency distribution among roads between 2024 and 2023, and Figure 3.3 depicts the frequency distribution of incidents and disabled vehicles for 2024.



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

Figure 3.2 Distributions of Incidents/Disabled Vehicles by Road in 2024 and 2023

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 2024 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 23,625 incidents/disabled vehicles in 2024, while I-695 had 7,225 incidents/disabled vehicles within the same period. I-495/95, US-50, I-70 and I-270 had 7,207, 6,236 5,203, and 3,324 incidents/disabled vehicles, respectively. Also, notice that the CHART-II database includes 1,061 incidents/disabled vehicles detected by CHART with incomplete information for road names in 2024.

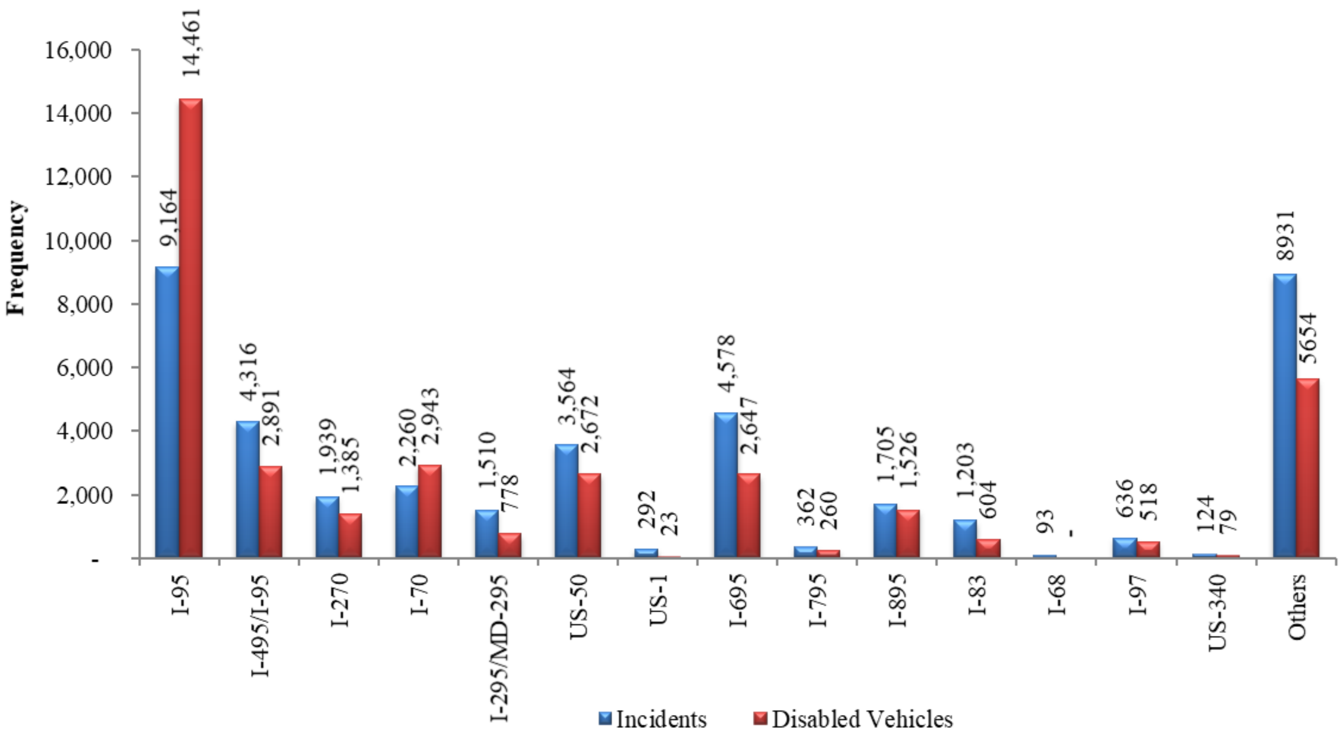


Figure 3.3 Distributions of Incidents/Disabled Vehicles by Road in 2024

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

Figures 3.4 and 3.5 present comparisons of frequency distributions by time of day on major roads in Maryland for incidents and disabled vehicles. As shown in these figures, more incidents occurred during p.m. peak hours than a.m. peak hours on I-95, I/MD-295, and I-83.

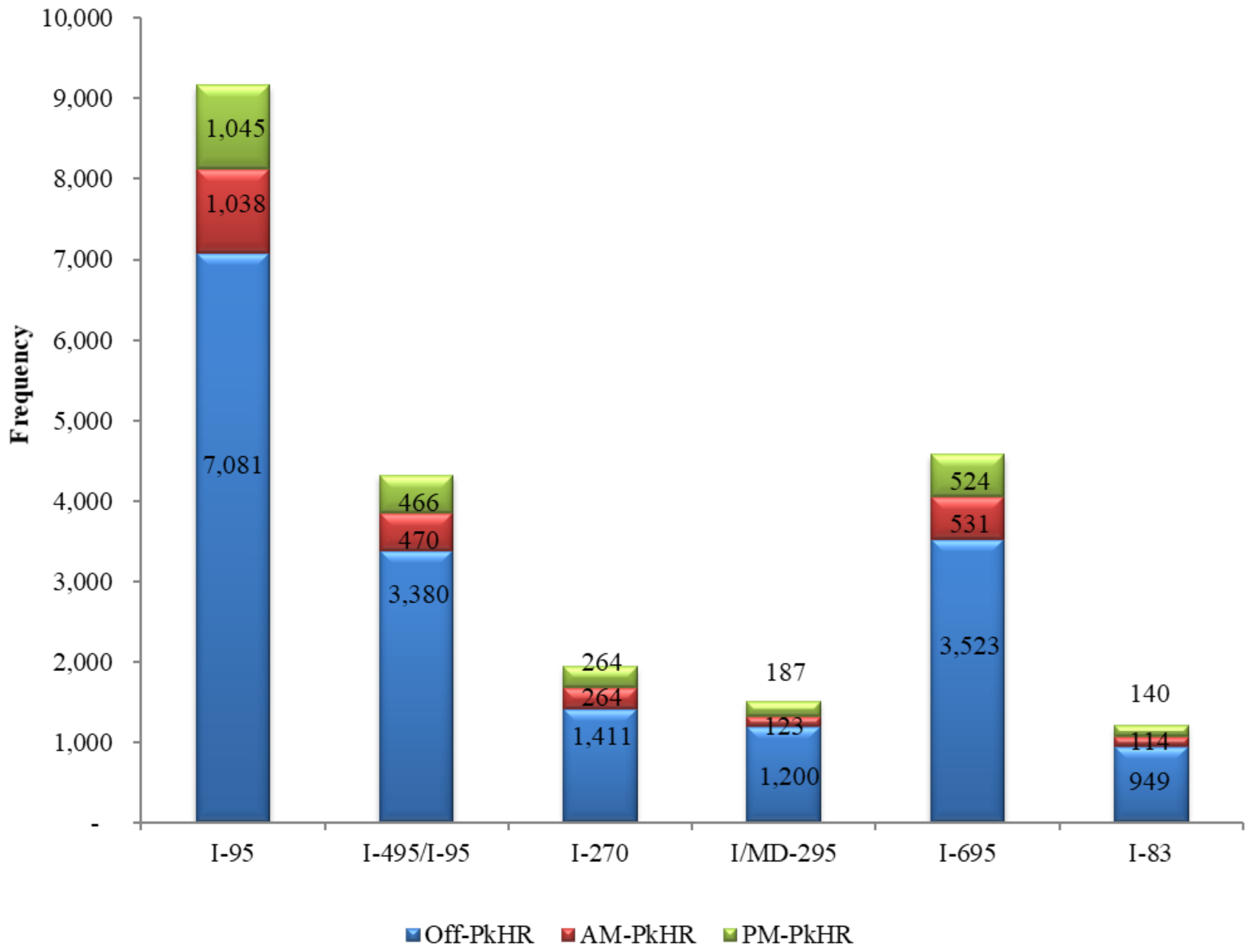


Figure 3.4 Distributions of Incidents by Time of Day on Major Roads in 2024

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 .

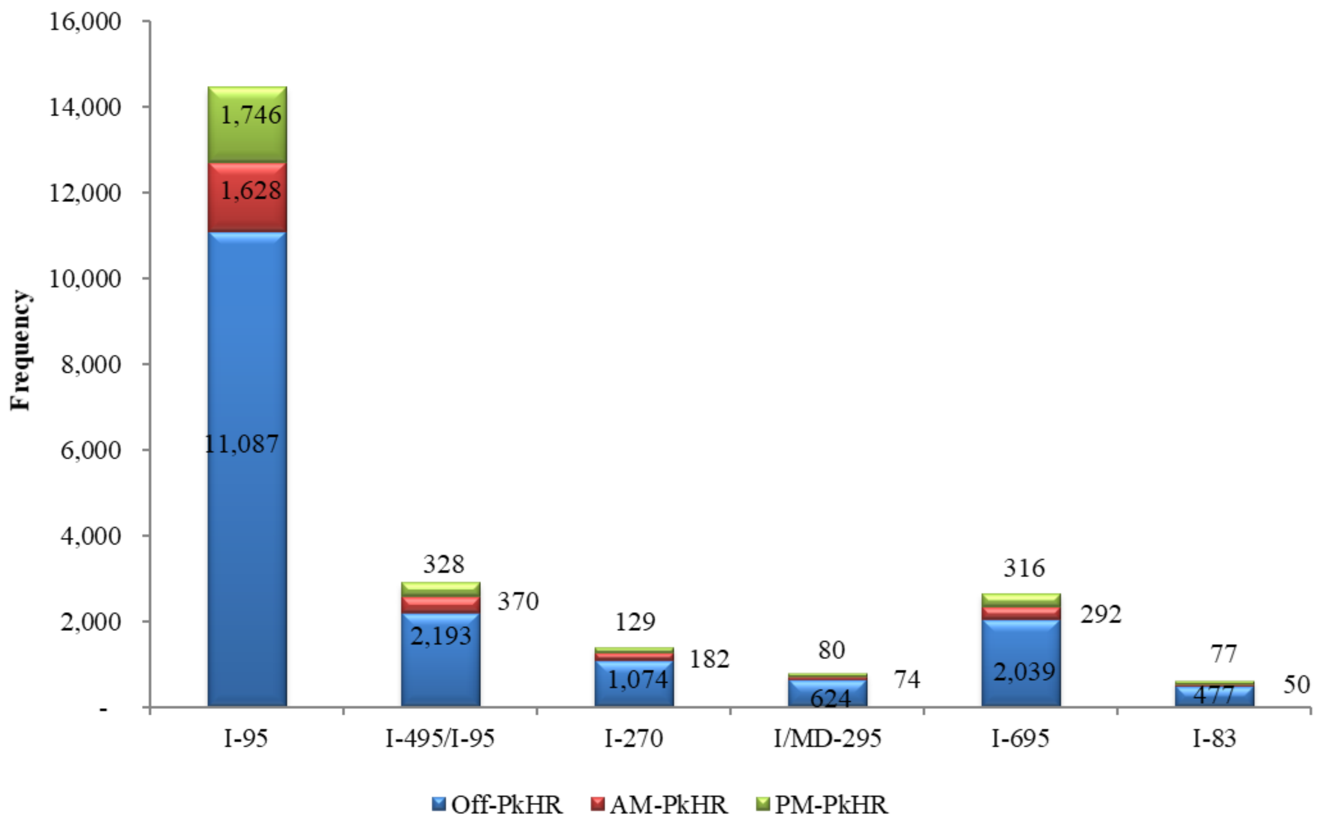


Figure 3.5 Distributions of Disabled Vehicles by Time of Day on Major Roads in 2024

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

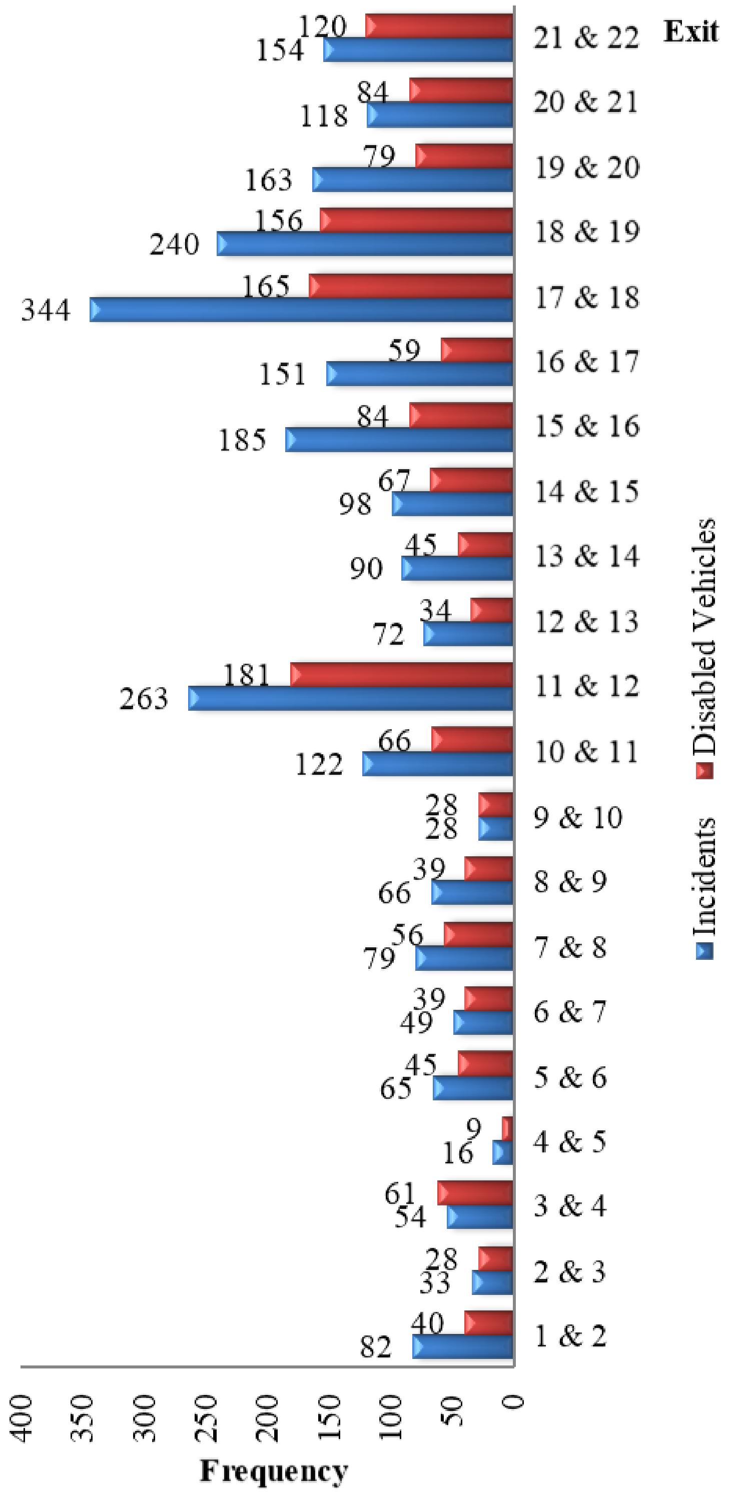


Figure 3.6 Distributions of Incidents/Disabled Vehicles by Location on I-695

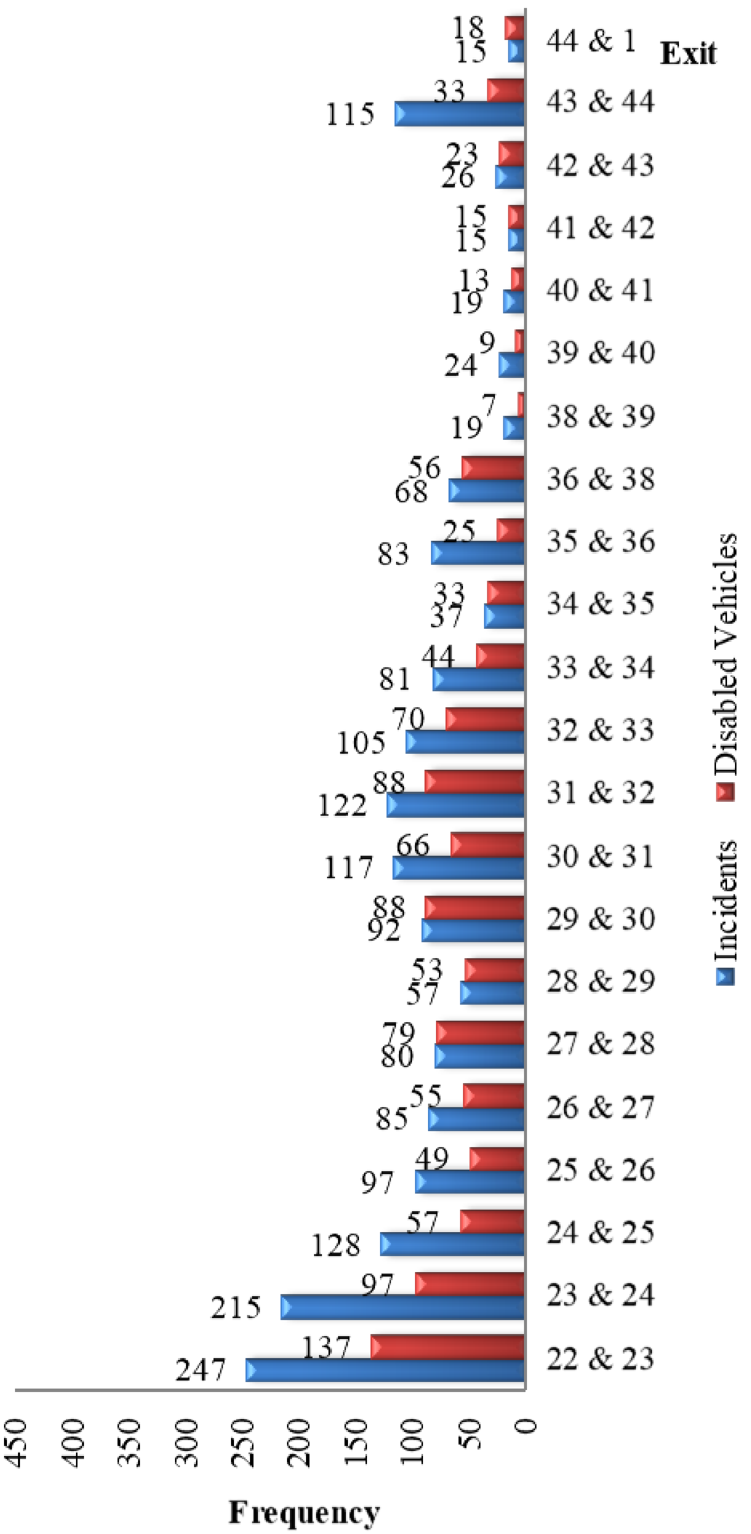


Figure 3.6 Distributions of Incidents/Disabled Vehicles by Location on I-695 (cont.)

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

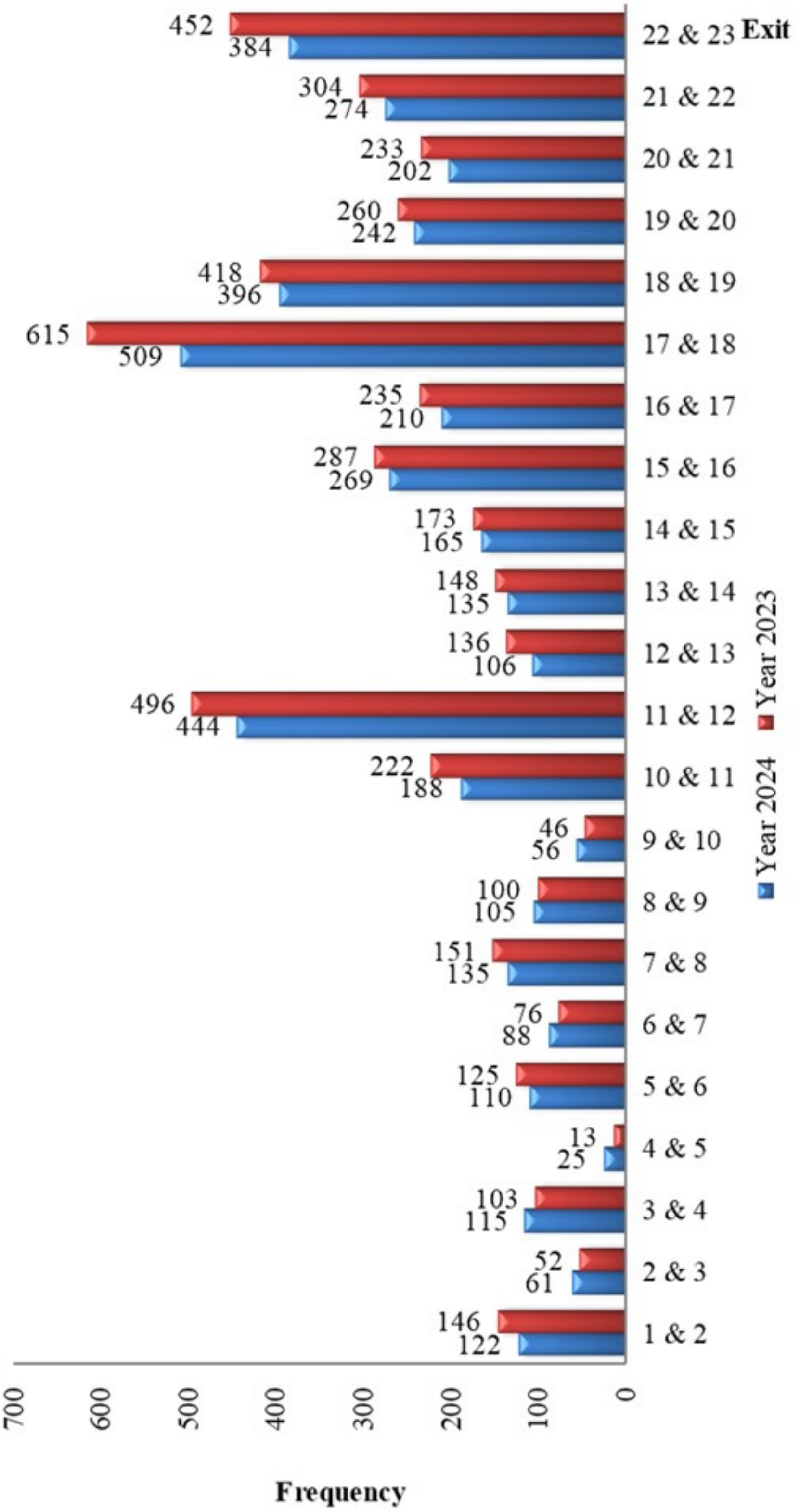


Figure 3.7 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-695

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

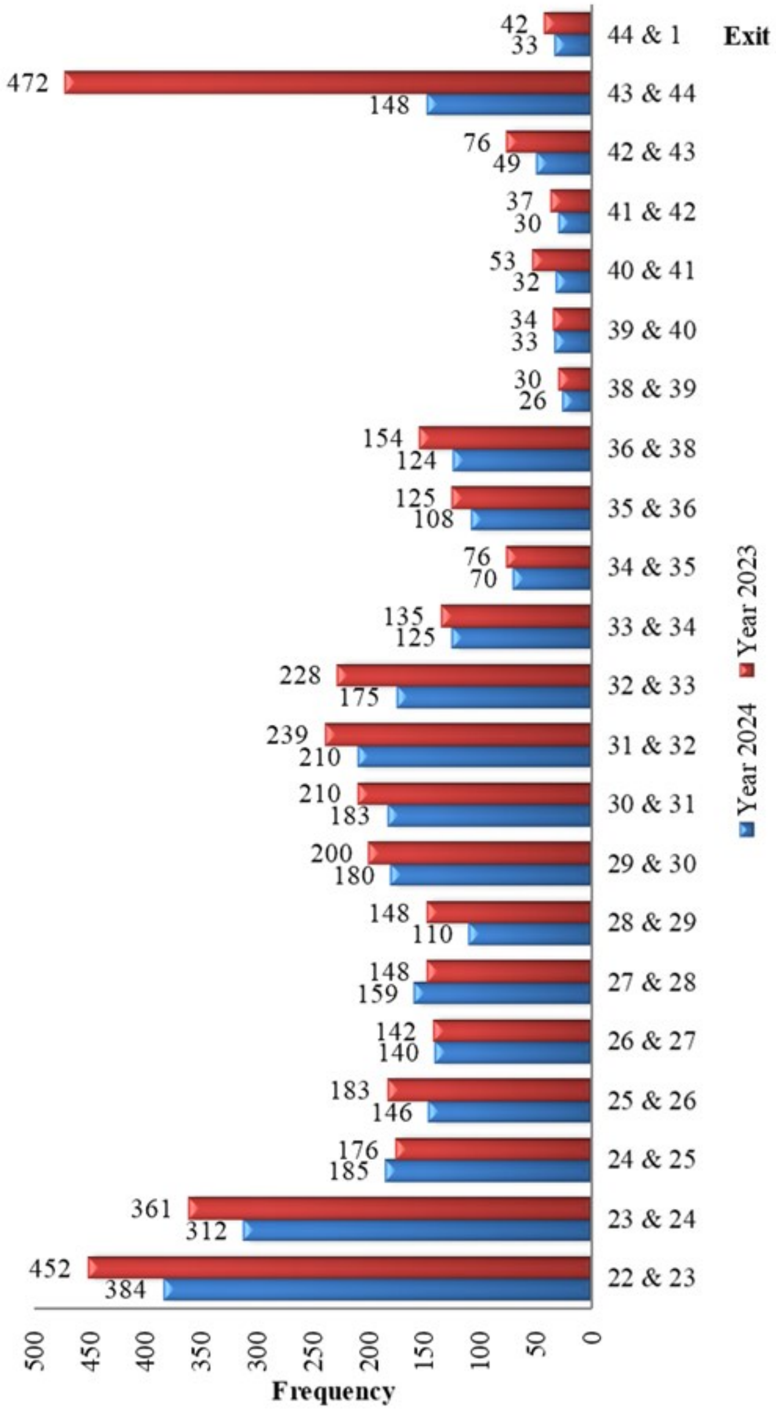


Figure 3.7 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-695 (Cont.)

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 2024, while Figure 3.7 compares these values with the results in 2023. The high-incident segments are from Exit 17 to 18, Exit 11 to 12, and Exit 22 to 23 (344, 263 and 247, respectively). The three high frequencies of disabled vehicles (181, 165 and 156 cases) were recorded on the segments between Exits 11 and 12, Exits 17 and 18, and Exits 18 and 19, which are close to the I-95, I-70 and MD-26 interchanges, respectively.

The subsequent figures present the comparison between 2024 and 2023 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 (246 cases) occurred between Exits 28 and 29 of I-495. The location with the highest frequency of disabled vehicles (182 cases) occurred between Exits 17 and 19. A comparison with the

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

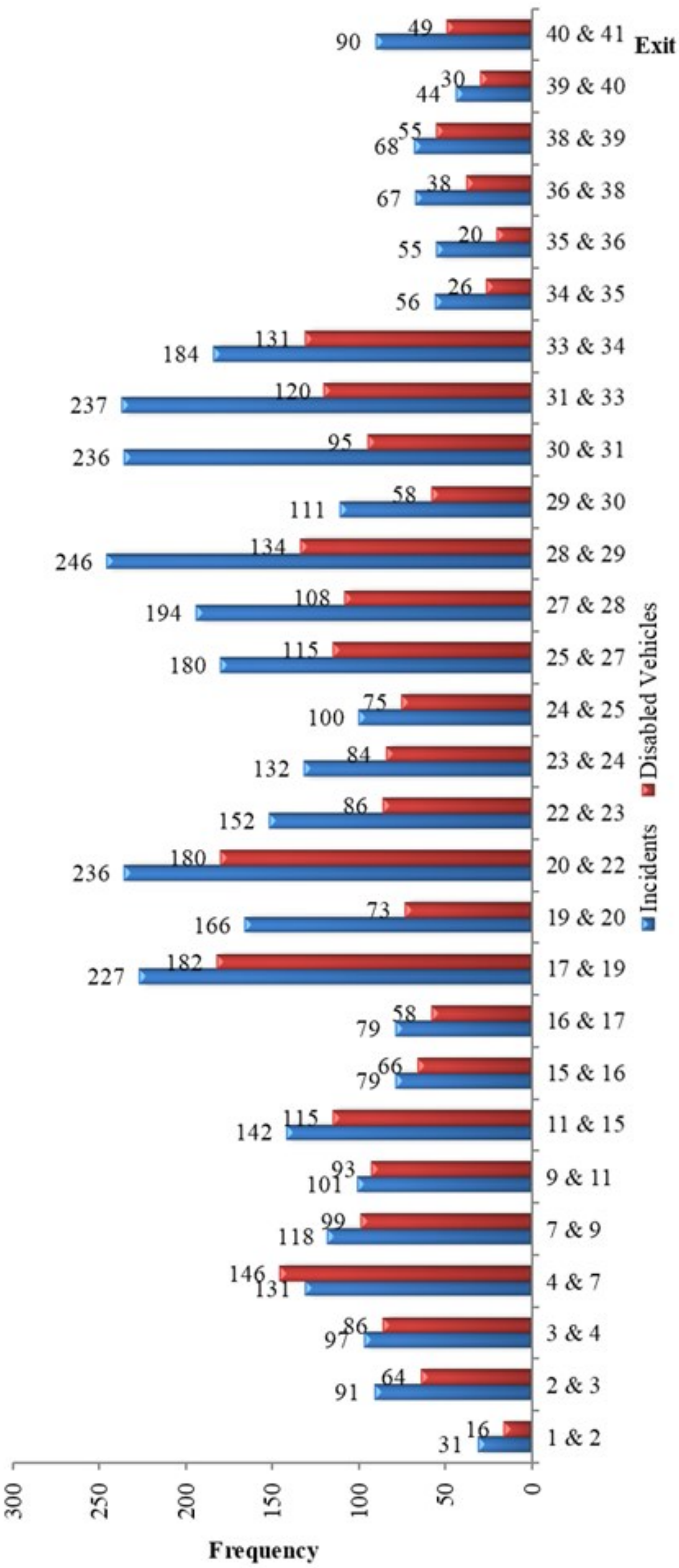


Figure 3.8 Distributions of Incidents/Disabled Vehicles by Location on I-495/I-95

3.2 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

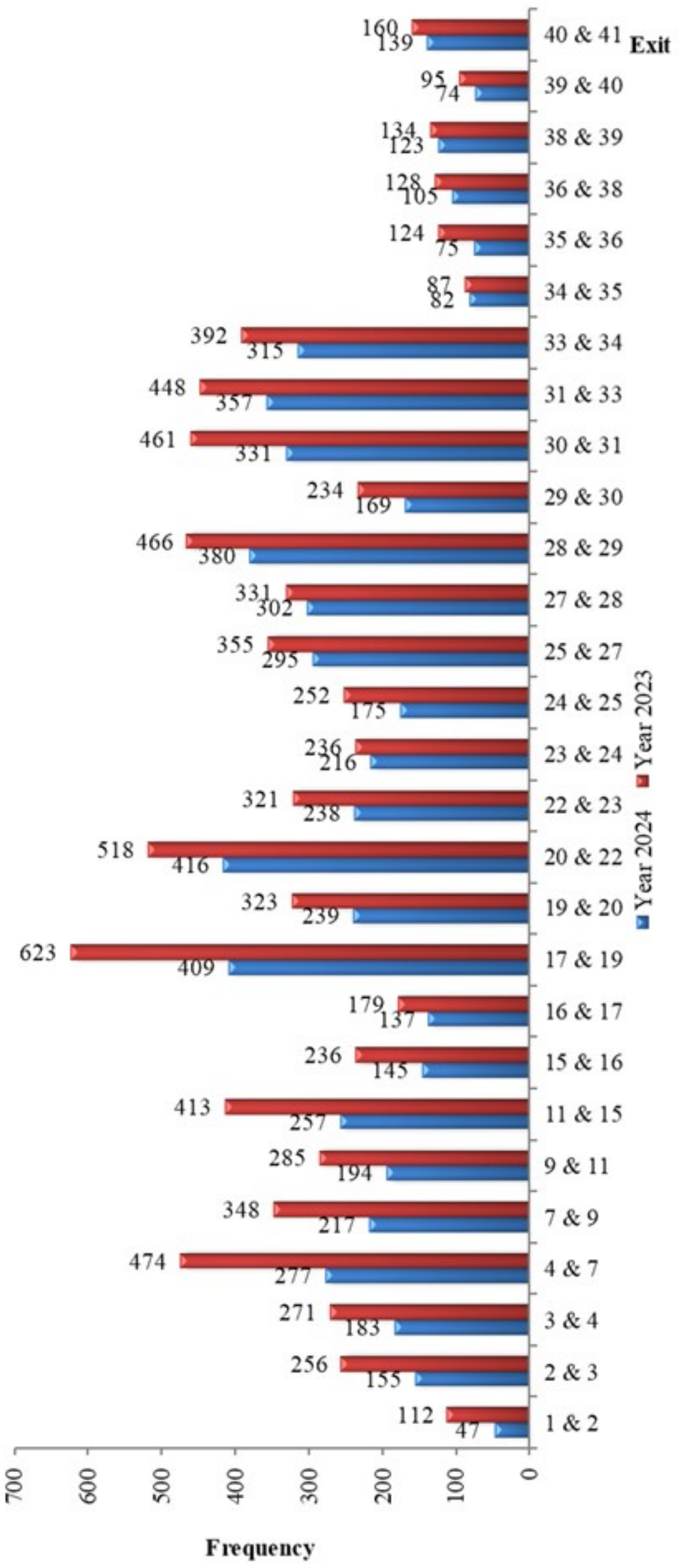


Figure 3.9 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-495/I-95

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 2024 and 2023. As shown in Figure 3.10, the highest number of incidents occurred at the segment between Exits 67 and 74 (1,757 cases). The same segments experienced a high number of disabled vehicles (2,682 cases).

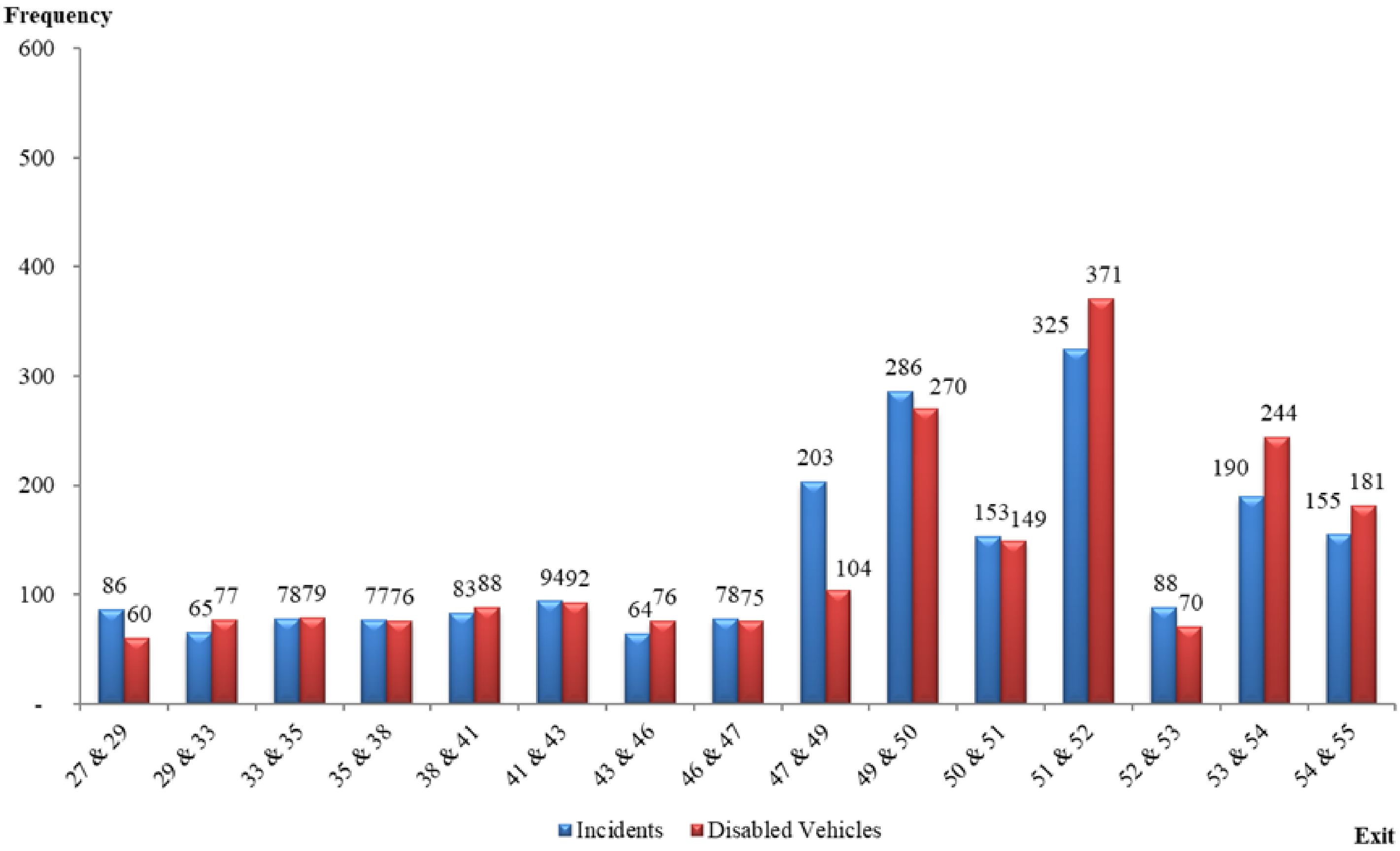


Figure 3.10 Distributions of Incidents/Disabled Vehicles by Location on I-95

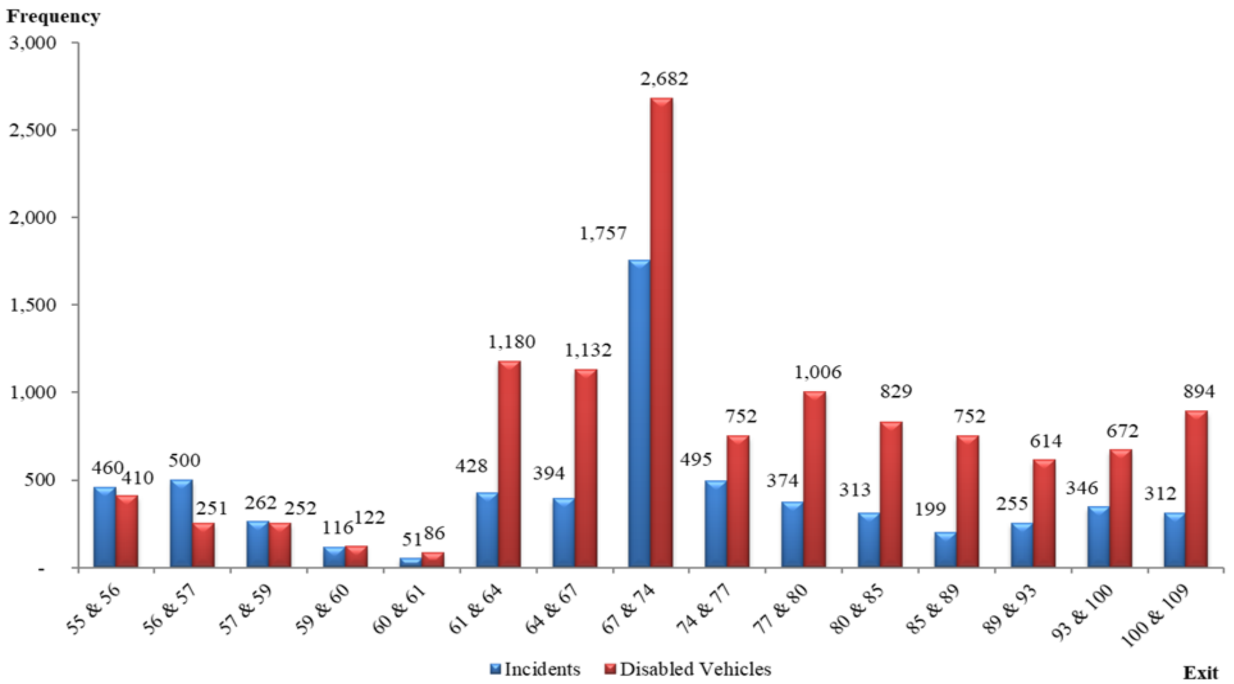


Figure 3.10 Distributions of Incidents/Disabled Vehicles by Location on I-95 (cont.)

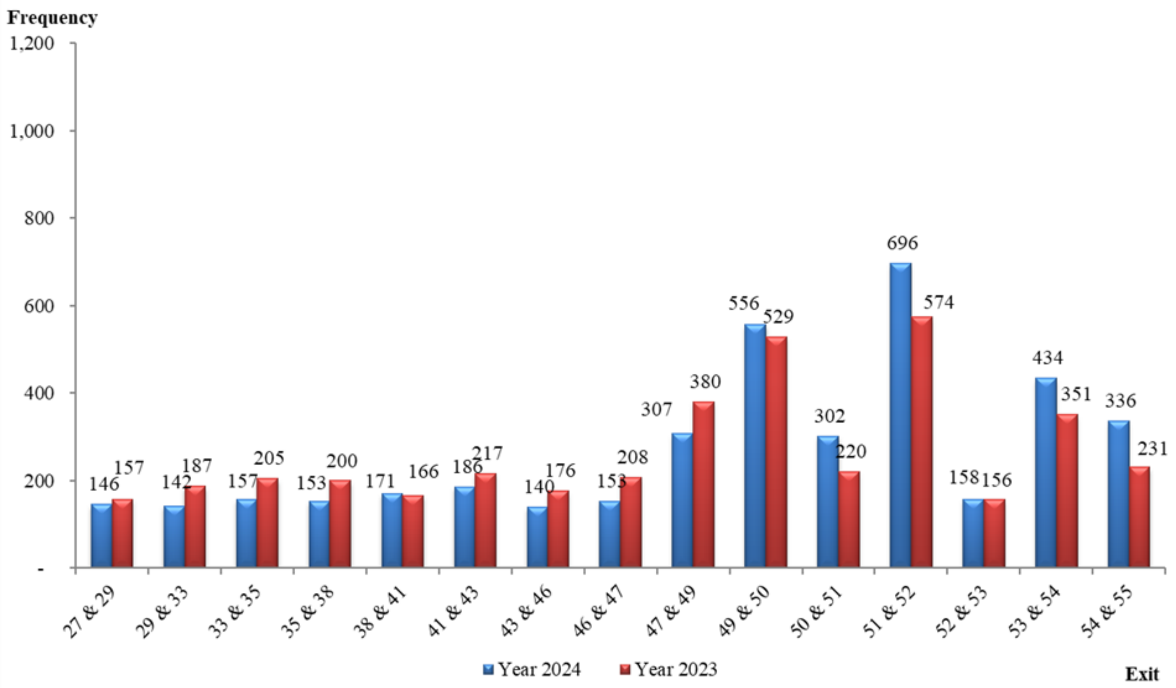


Figure 3.11 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-95

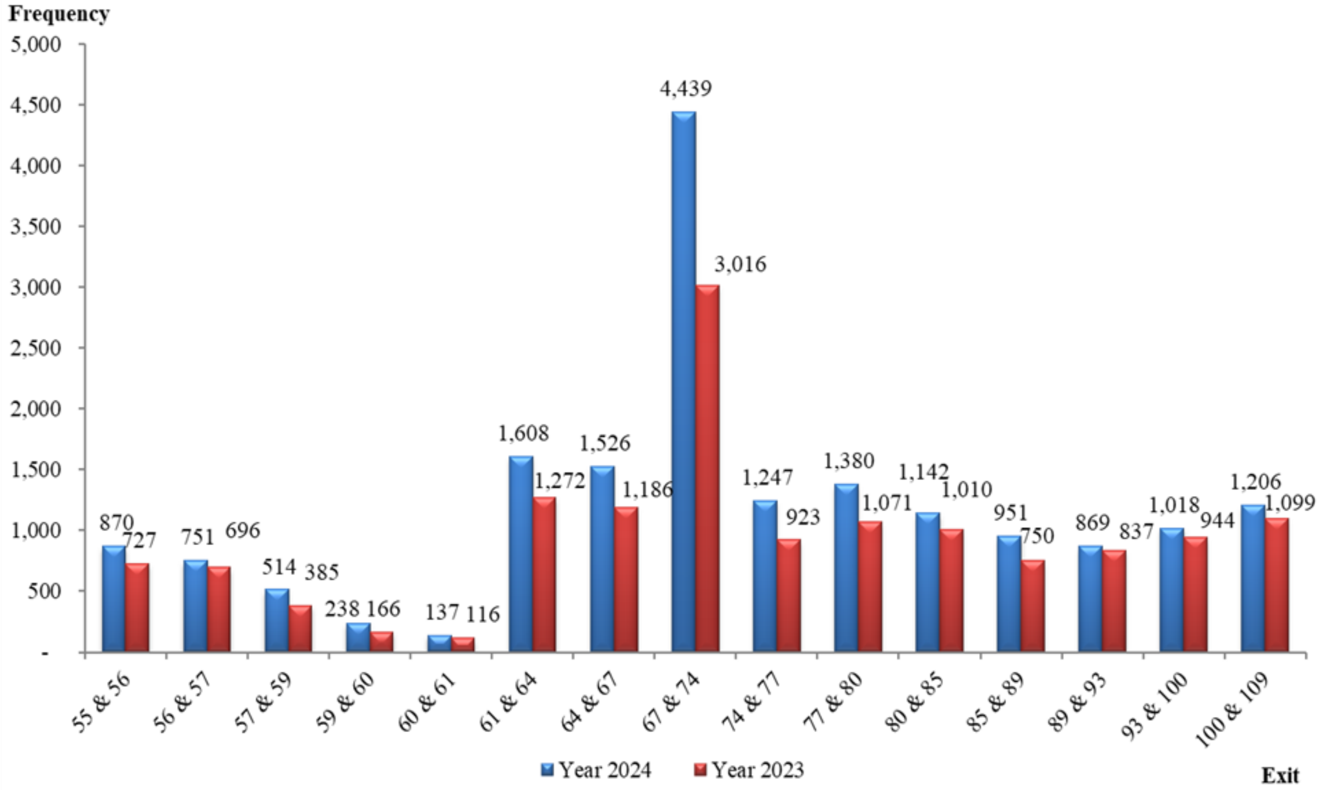


Figure 3.11 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-95 (cont.)

In 2024, 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 4,439 revealing the same patterns as in 2023 (3,016 cases, ranked the 1st). The segment on I-95 between Exits 61 and 64 was the second largest number of incidents/disabled vehicles requests (1,608 cases) in 2024. All I-95 segments were reported to experience more requests of responding to incident/disabled vehicles than in 2023.

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 2024. The segment between Exits 6 and 8 on I-270 experienced the highest numbers of incidents (148 cases), and the segment between Exit 26 and 31 experienced the highest number of disabled vehicles (127 cases).

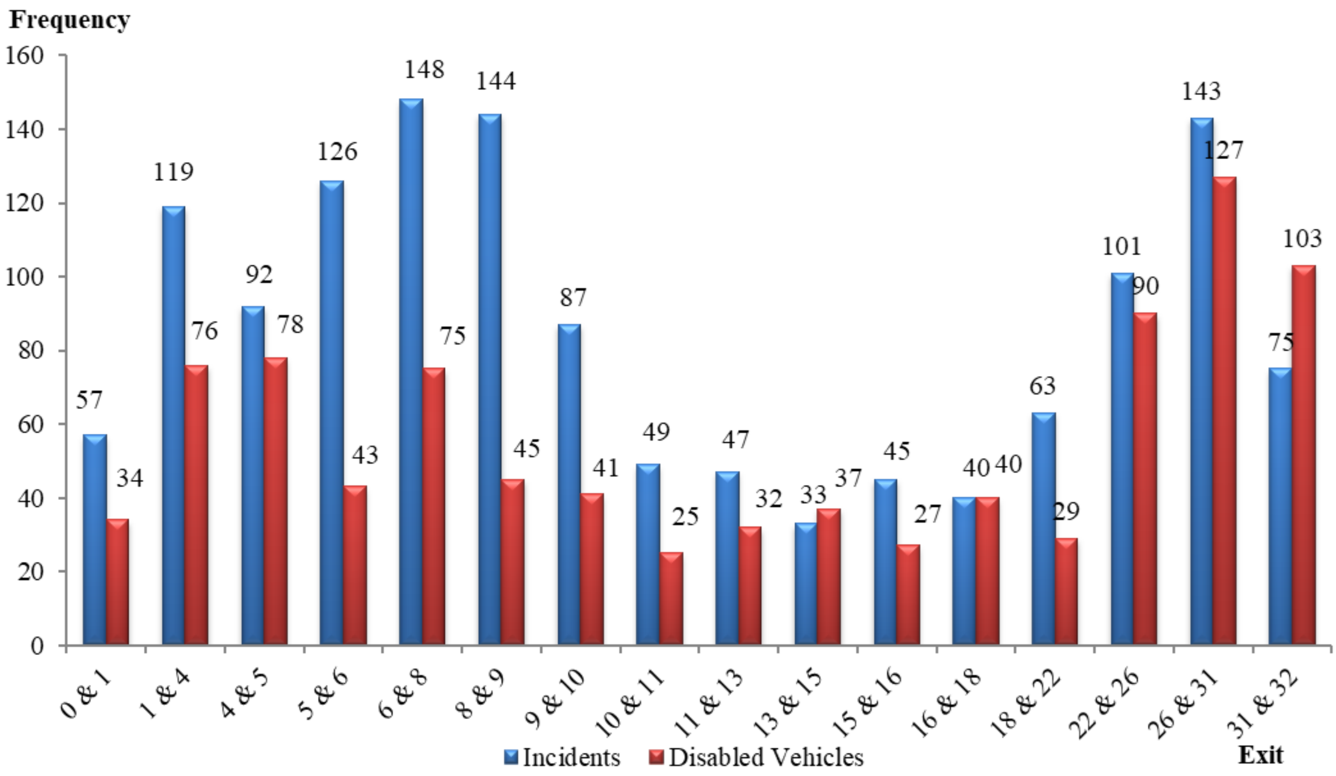


Figure 3.12 Distributions of Incidents/Disabled Vehicles by Location on I-270

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY ROAD AND LOCATION

3.2

Figure 3.13 shows a comparison between 2024 and 2023 data; all I-270 segments show fewer incident/disabled vehicles requests than those observed in 2023, except for the segment from Exit 13 to Exit 15.

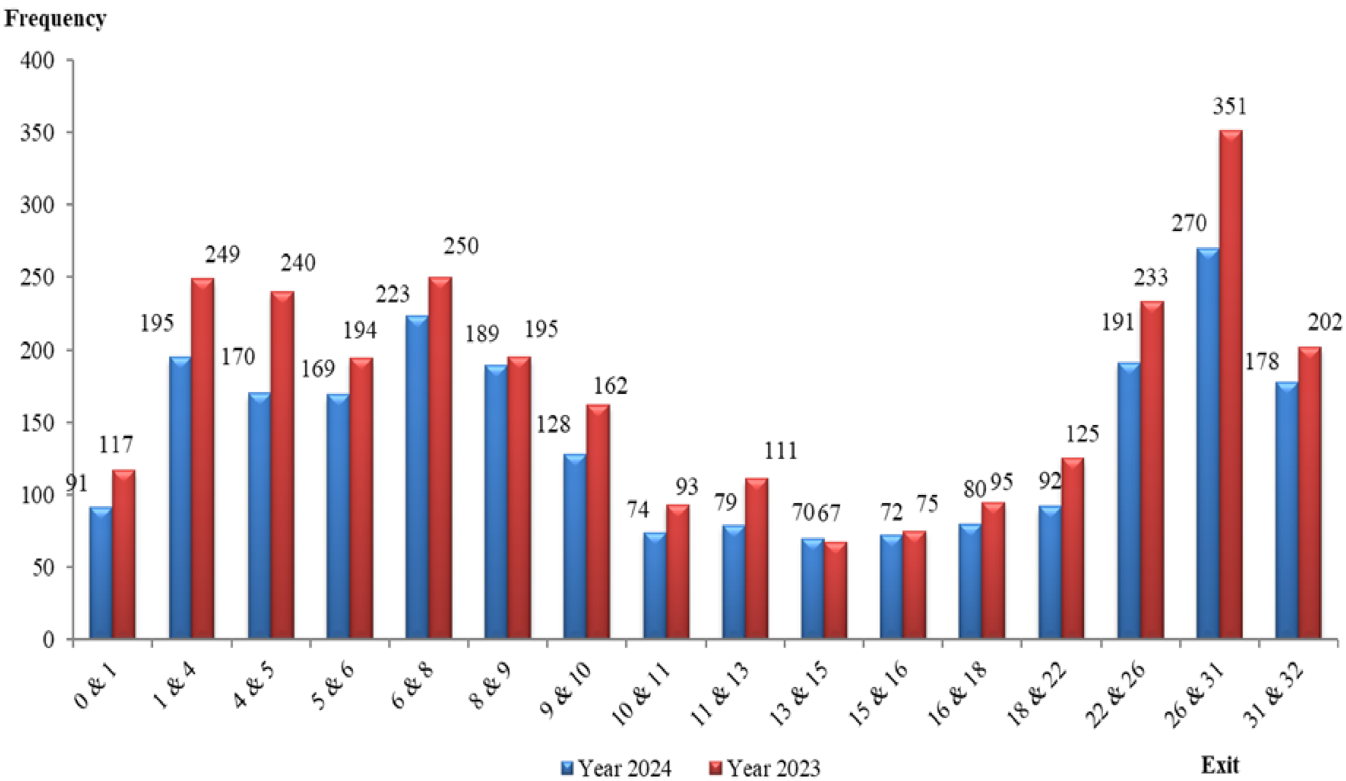
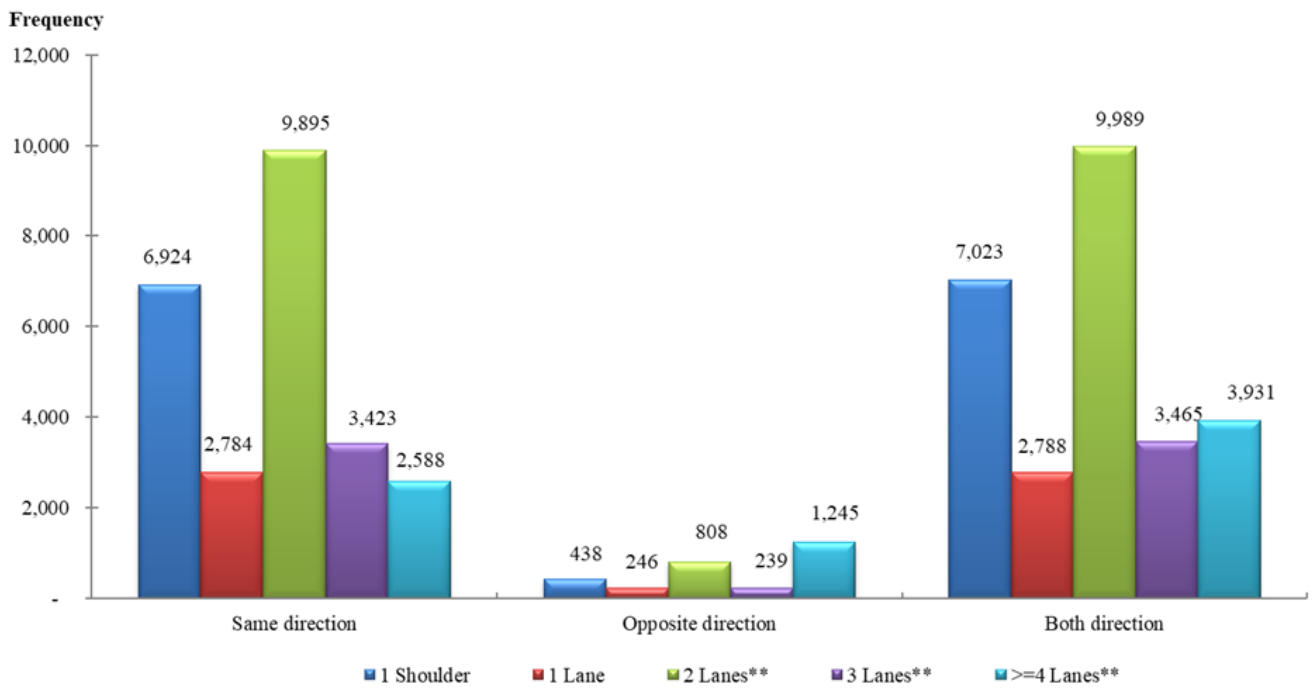


Figure 3.13 Comparisons of Incidents/Disabled Vehicles by Location on I-270

3.3 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY LANE BLOCKAGE TYPE

Figure 3.14 illustrates the distribution of incidents by lane blockage in 2024. A large portion of those incidents involved one-lane or two-lane blockages. The comparison of 2024 incidents/disabled vehicles distribution by lane blockage with 2023 data is illustrated in Figure 3.15. Note that all reported disabled vehicles are classified as shoulder lane blockages in Figure 3.15.

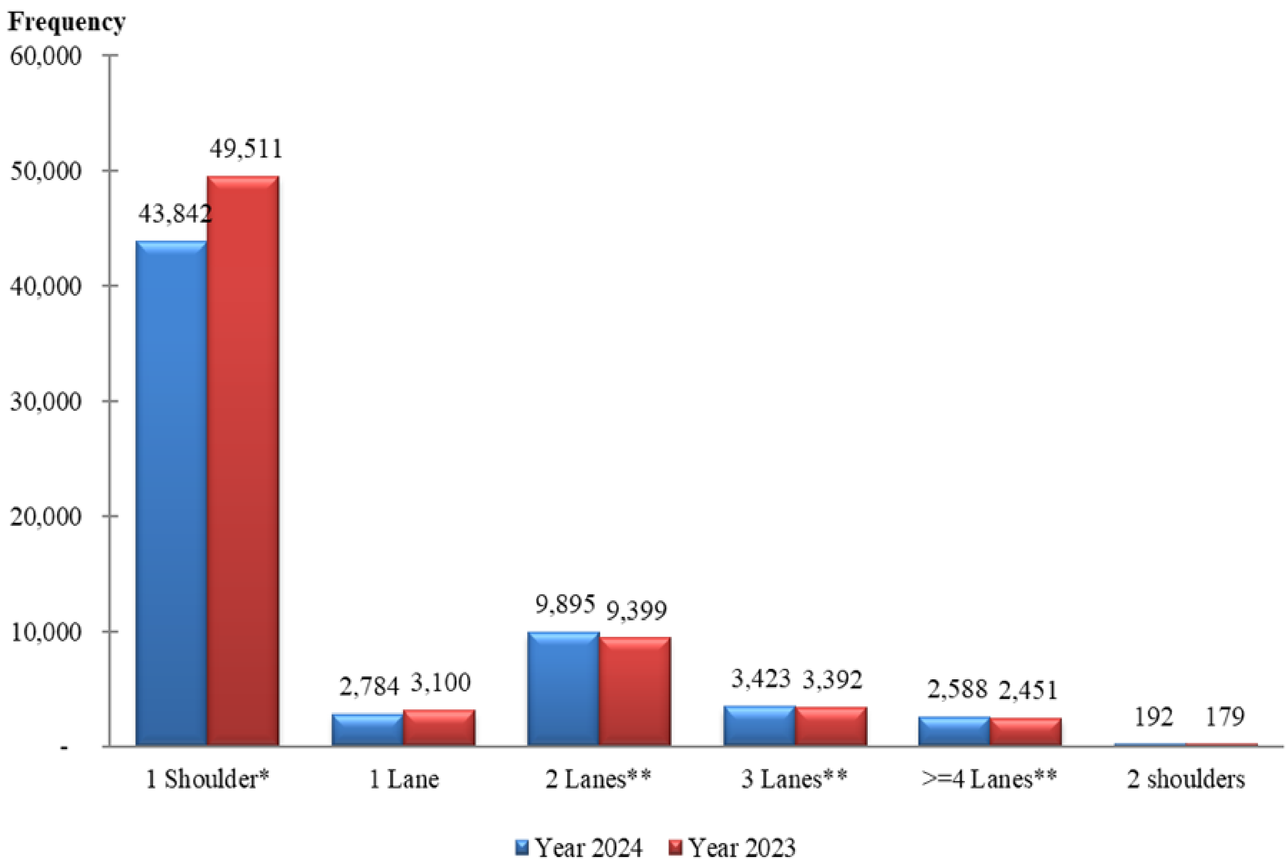


*Note: *This analysis uses only incidents (not including "Disabled Vehicles")*
***Also includes Shoulder Lane Blockages*

Figure 3.14 Distributions of Incidents* by Lane Blockage

DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY LANE BLOCKAGE TYPE

3.3

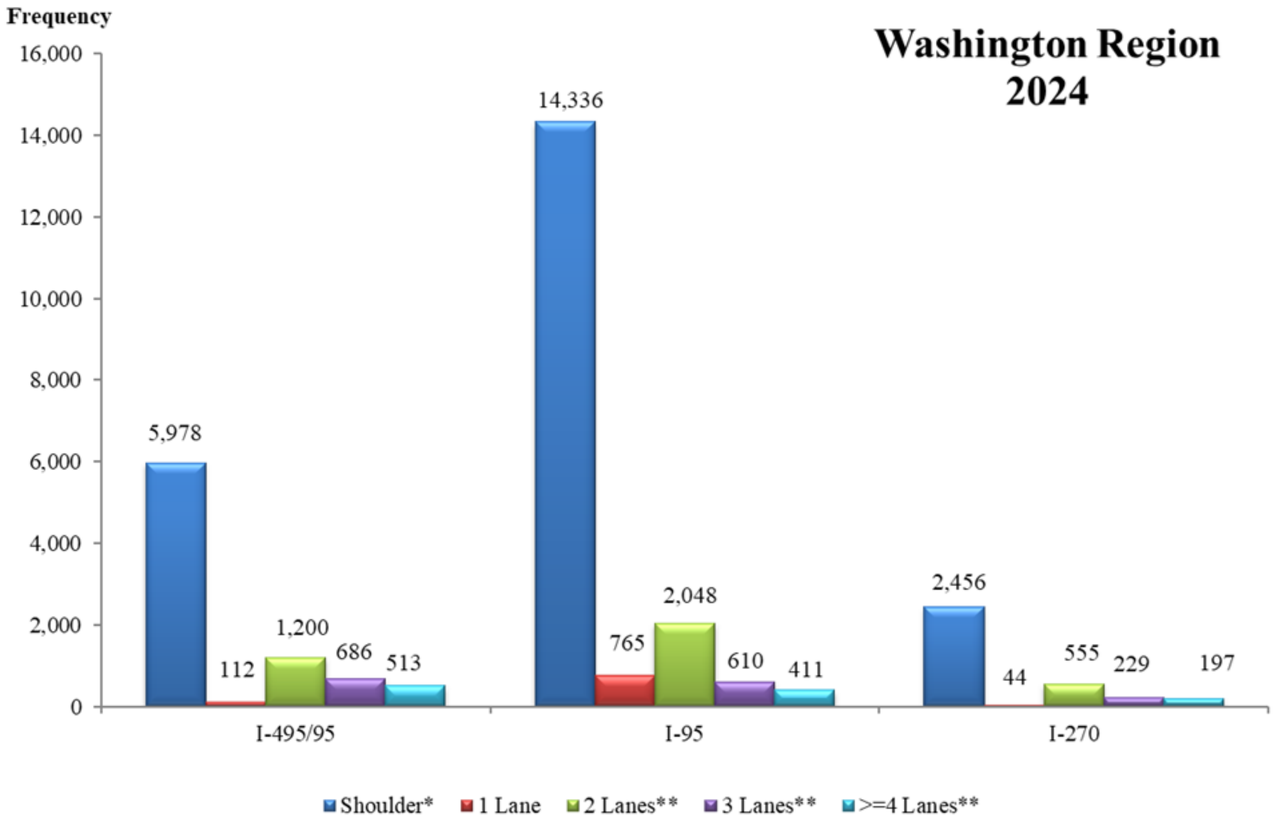


*Note: * Disabled Vehicles are all classified as Shoulder Lane Blockages.*
*** Also includes Shoulder Lane Blockages.*

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

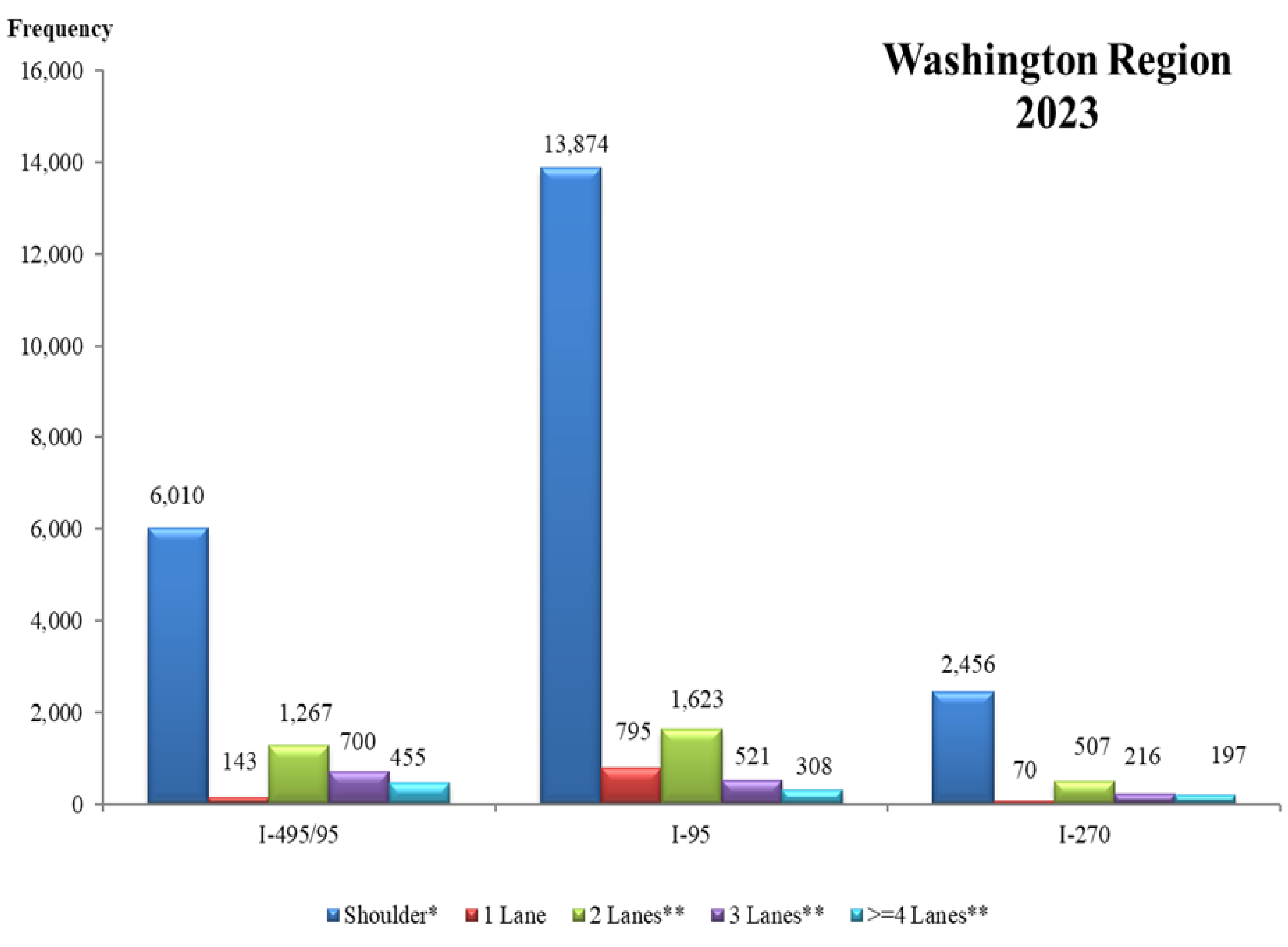
3.3 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY LANE BLOCKAGE TYPE

Figures 3.16 and 3.17 depict a comparison of lane blockage incidents between 2024 and 2023 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*

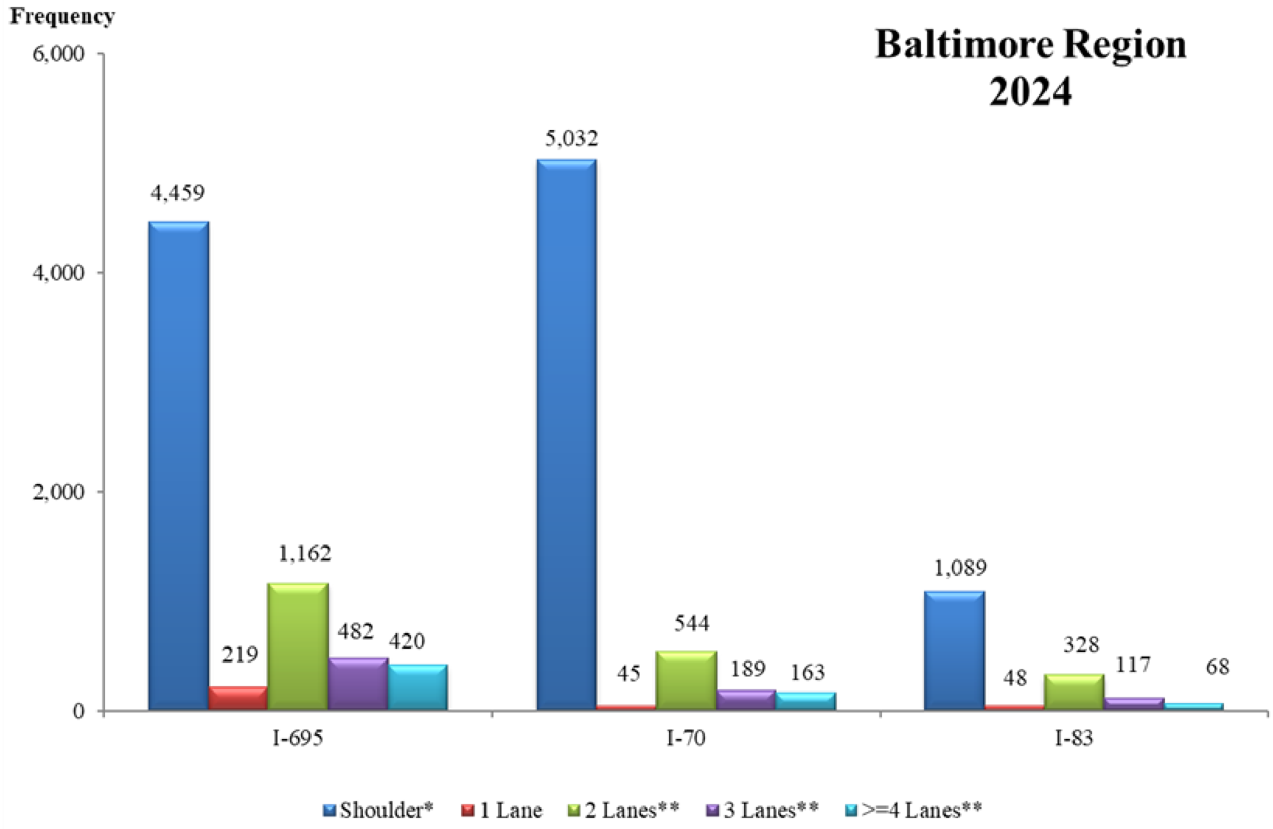
Figure 3.16 Distributions of Lane Blockages Occurring on Major Freeways in the Washington Area



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

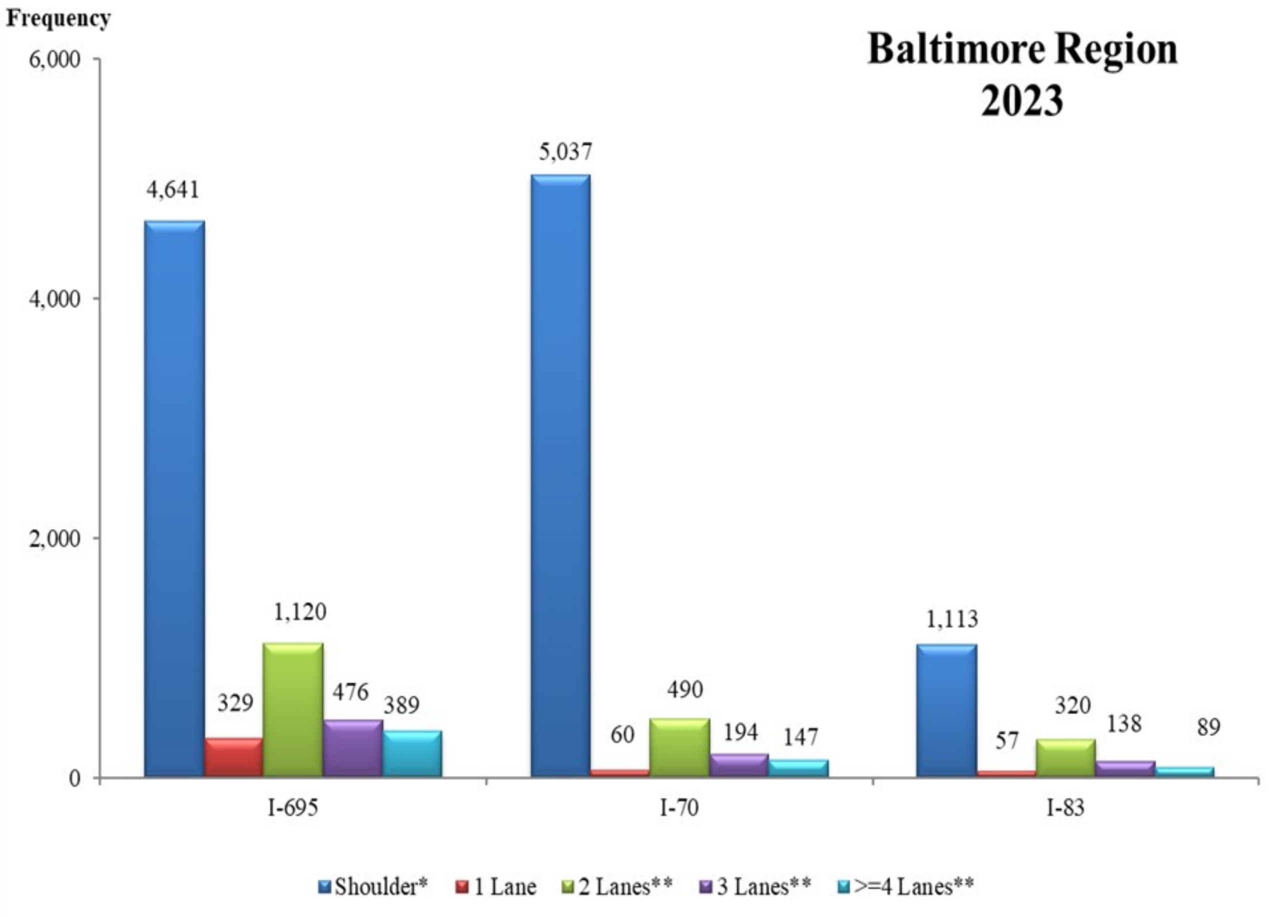
Figure 3.16 Distributions of Lane Blockages Occurring on Major Freeways in the Washington Area (Cont.)

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



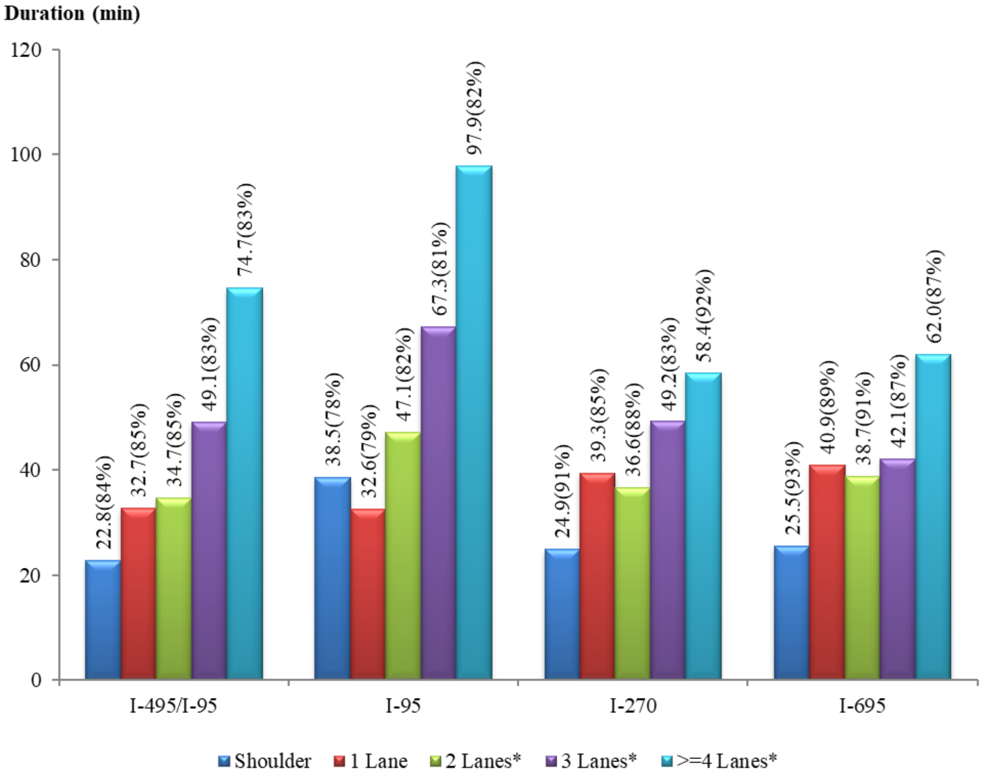
*Note: *Disabled Vehicles are all classified as Shoulder Lane Blockages*
***Also includes Shoulder Lane Blockages*

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 twenty 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 66 percent of incidents and disabled vehicles had durations of less than 30 minutes.

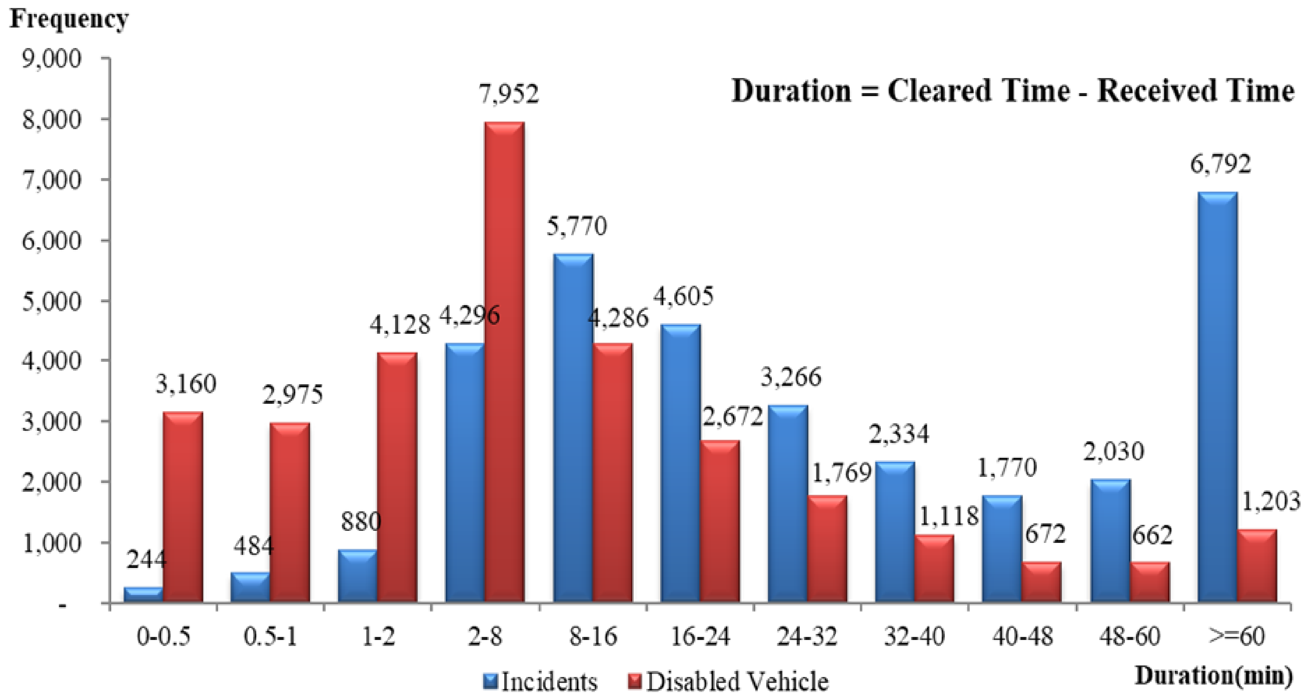
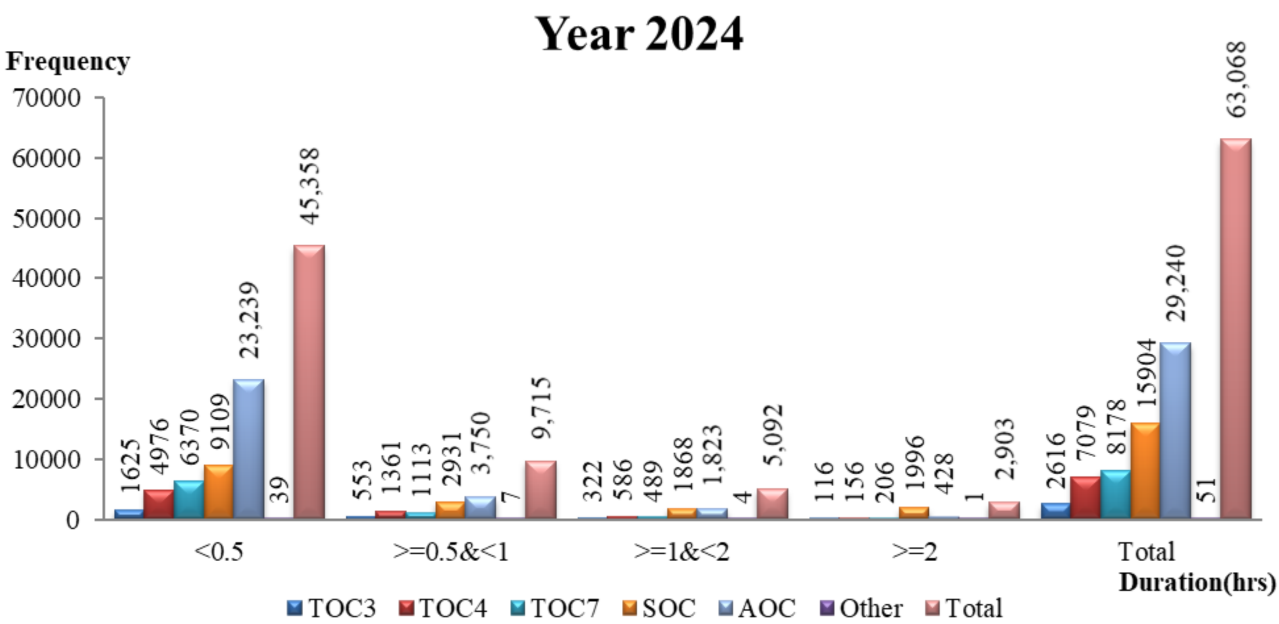


Figure 3.19 Distributions of Incidents/Disabled Vehicles by Duration in 2024

Although most incidents in 2024 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.

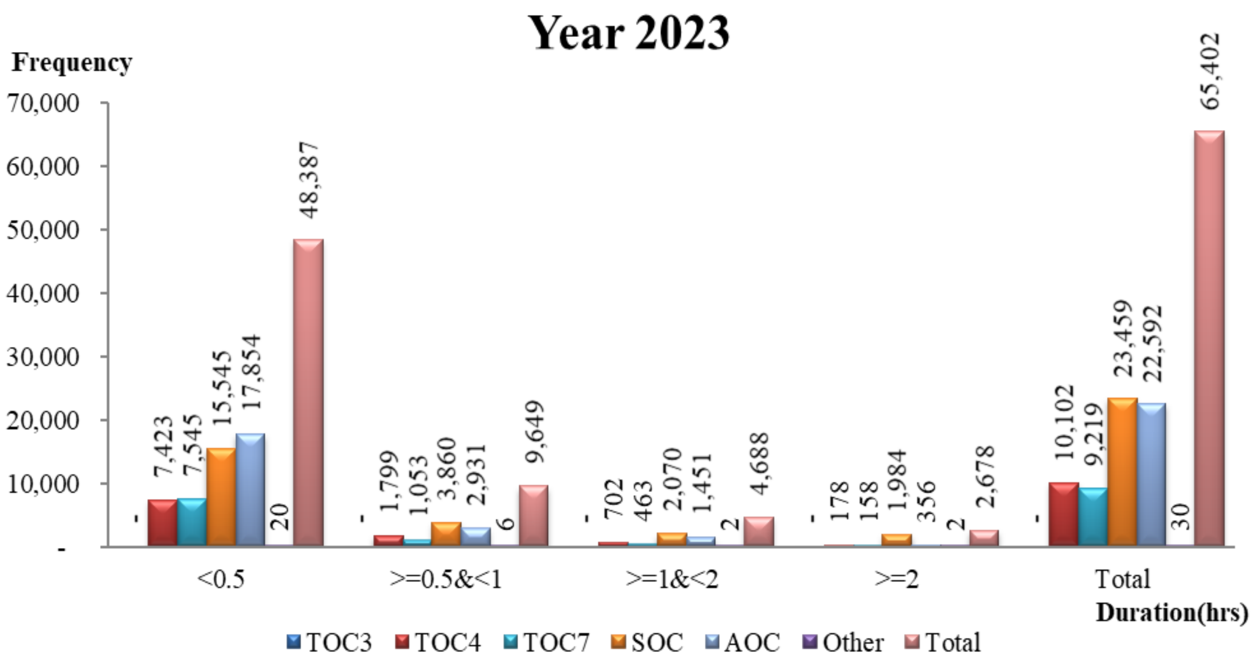
3.4 DISTRIBUTION OF INCIDENTS AND DISABLED VEHICLES BY BLOCKAGE DURATION

Figure 3.20 presents the distribution of records in 2024 and its comparison with 2023 data. About 30 percent and 22 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 43 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 2024.



Note: TOC 3 relocated back to their center on July 24th, 2024.

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



Note: TOC 3 relocated back to their center on July 24th, 2024.

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

CHAPTER 4

EVALUATION OF EFFICIENCY AND EFFECTIVENESS

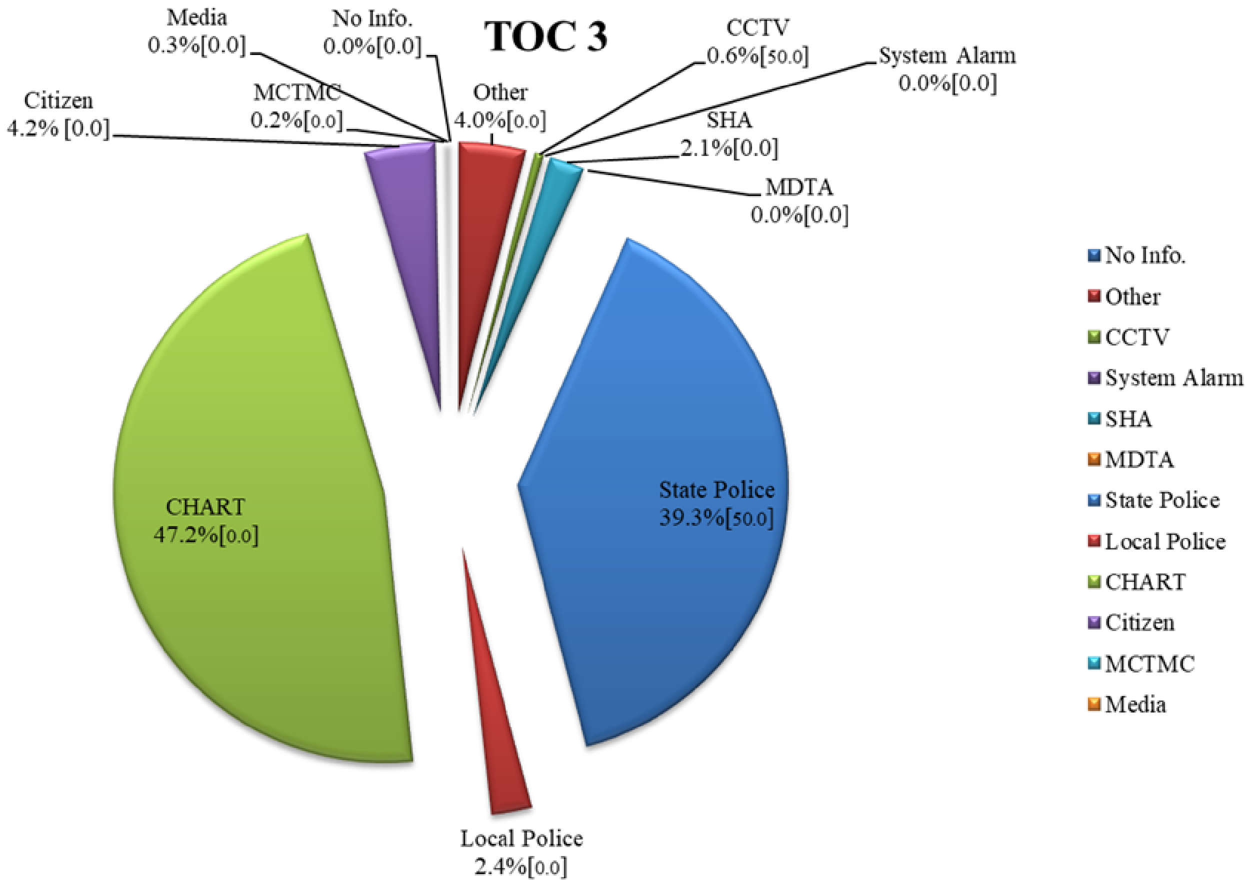
4

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 2024 incident/disabled vehicle management records, the overall response rate was 88.6 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.

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

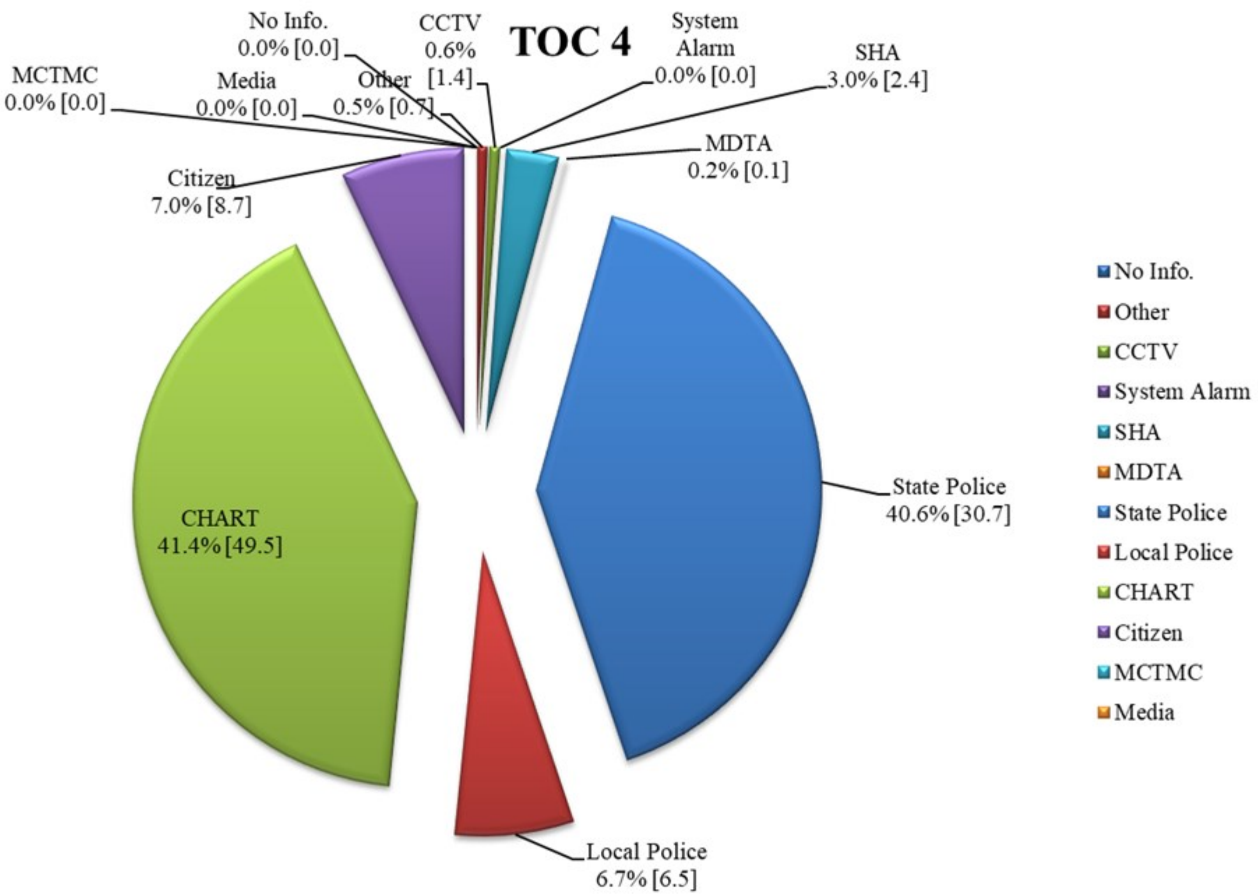


Note: 1. Numbers in [ ] show the percentages from Year 2023.

2. Actual frequencies for incidents/disabled vehicles detected by No info., System Alarm, MDTA, MCTMC, and Media in 2024 are 0, 1, 0, 1 and 8 in the CHART-II database.

3. TOC 3 relocated back to their center on July 24th, 2024.

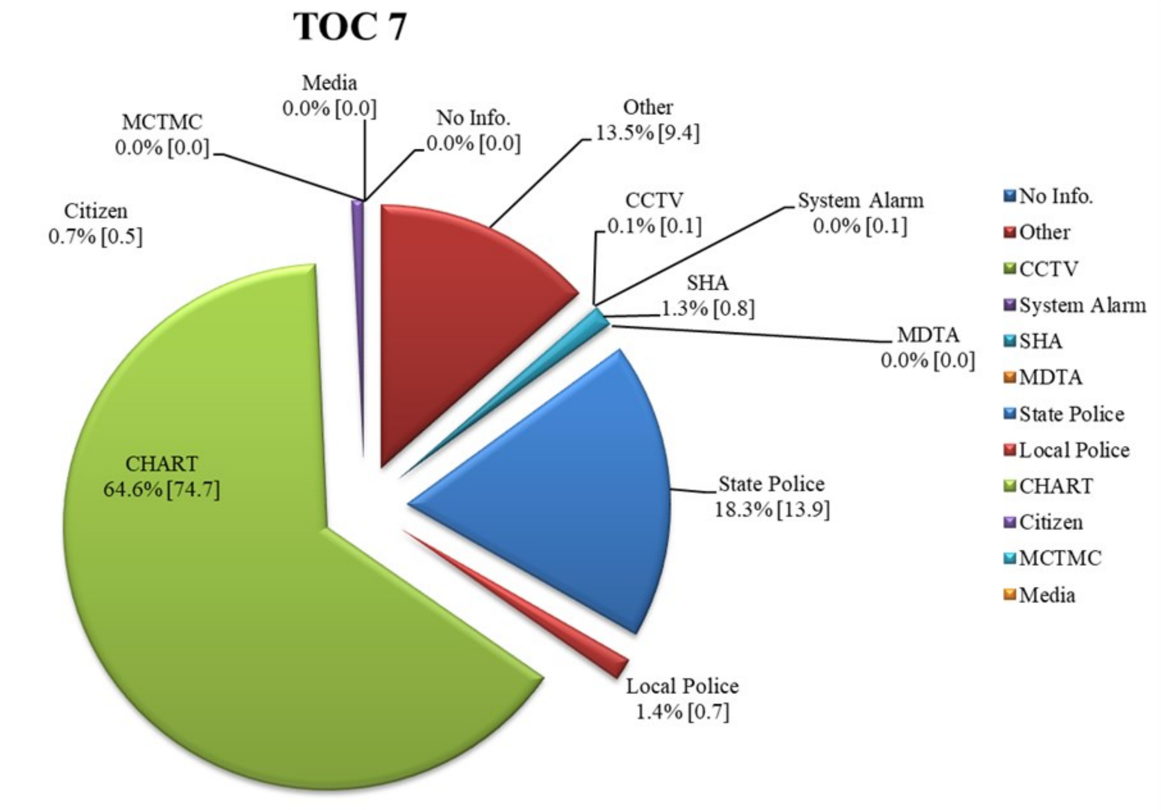
Figure 4.1 Distributions of Incidents/Disabled Vehicles by Detection Source for TOC 3



Note: 1. Numbers in [ ] show the percentages from Year 2023.

2. Actual frequencies for incidents/disabled vehicles detected by No info., System Alarm, MDTA, MCTMC, and Media in 2024 are 0, 0, 18, 0 and 1 in the CHART-II database.

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



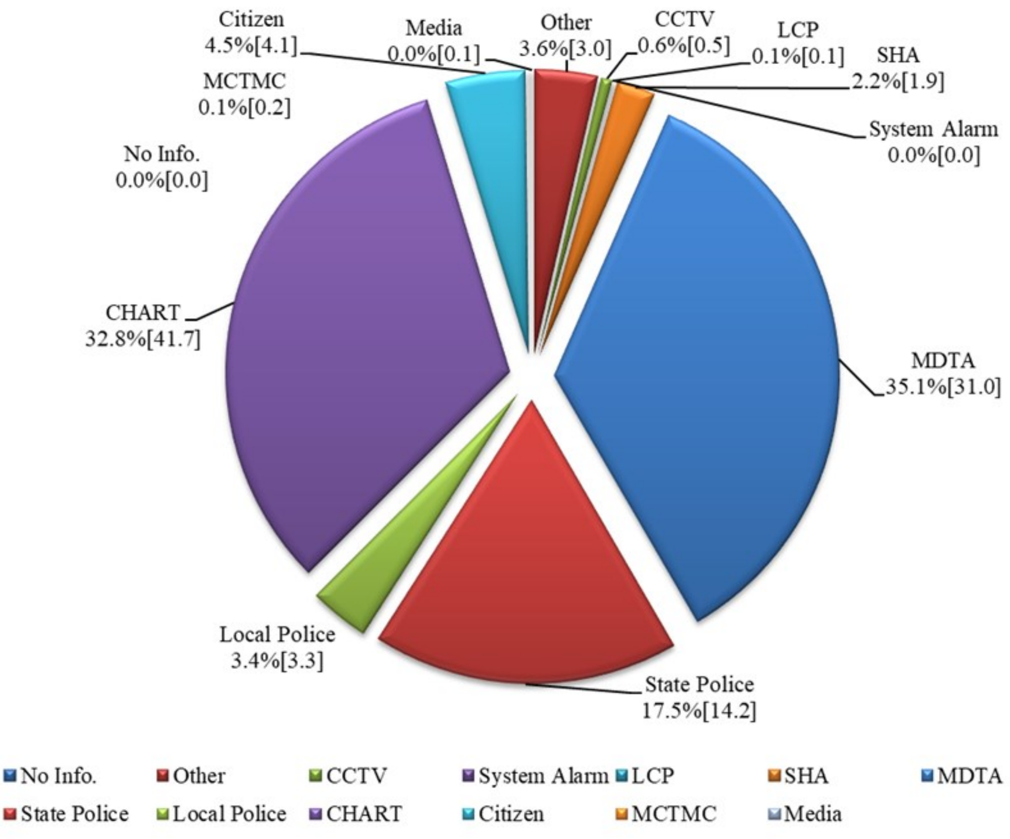
Note: 1. Numbers in [ ] show the percentages from Year 2023.

2. Actual frequencies for incidents/disabled vehicles detected by No Info., System Alarm, MDTA, MCTMC, and Media in 2024 are 0, 3, 0, 0, and 0 in the CHART-II database.

Figure 4.3 Distributions of Incidents/Disabled Vehicles by Detection Source for TOC 7

4.1 EVALUATION OF DETECTION EFFICIENCY AND EFFECTIVENESS

With respect to the distribution of all detection sources, the statistics in Figure 4.4 clearly show that about 49 percent of incidents in 2024 were detected by MDOT SHA/ CHART patrols, i.e., a higher percentage than in 2023. About 16.8 percent were reported by the MSP, similar to the 17.1 percent figure in 2023. Note that the numbers in parentheses indicate the 2023 statistics.



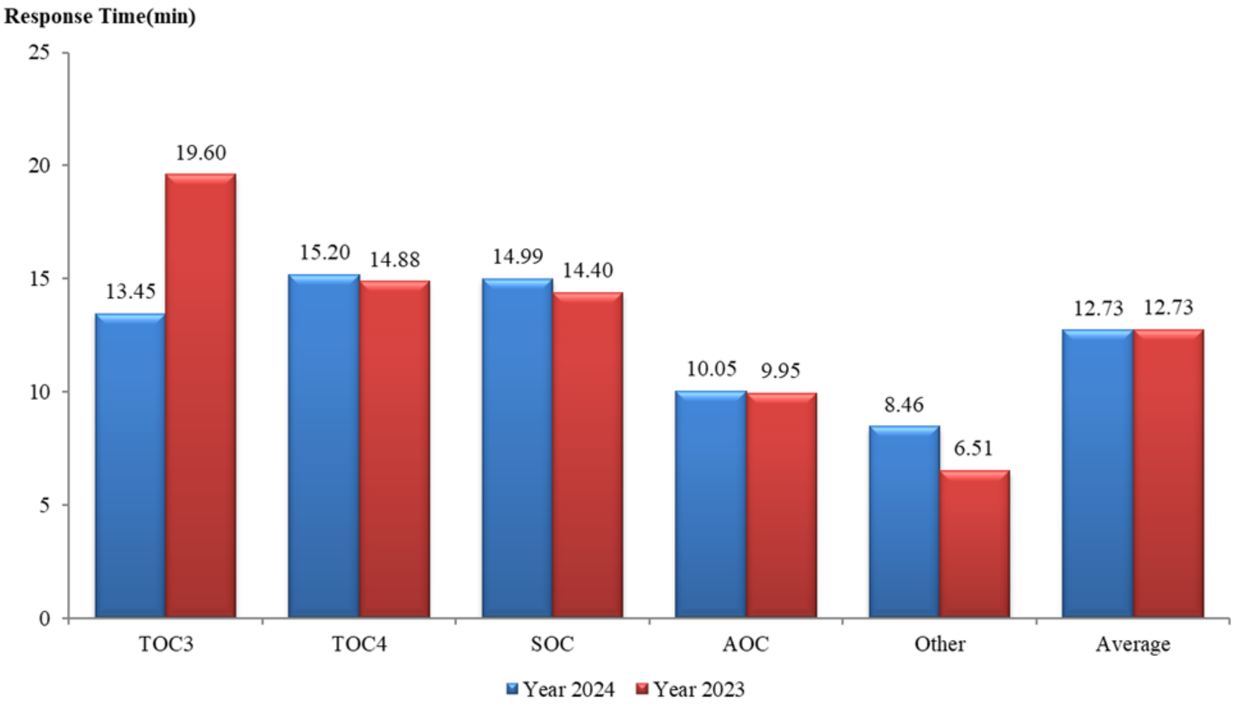
Note: 1. Numbers in [ ] show the percentages from Year 2023.
2. The actual frequency for incidents/disabled vehicles detected by No info. and System Alarm in 2024 is 0 and 20 in the CHART-II database.

Figure 4.4 Distributions of Incidents/Disabled Vehicles by Detection Source

ANALYSIS OF RESPONSE EFFICIENCY 4.2

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

The average response time for incidents in 2024 is given in Figure 4.5. The average response time in 2024 was 12.73 minutes, the same as in 2023 (12.73 minutes).

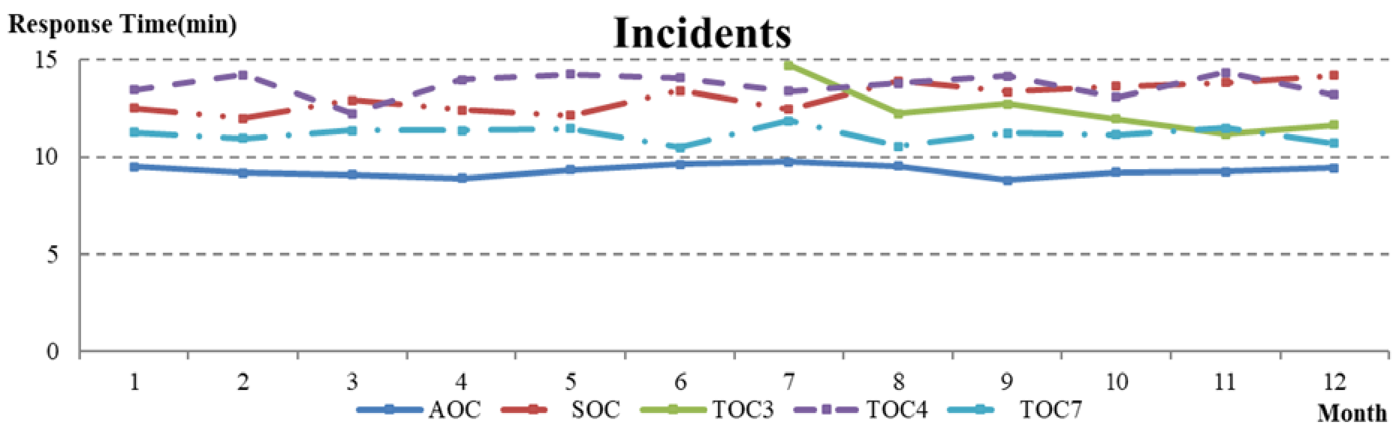


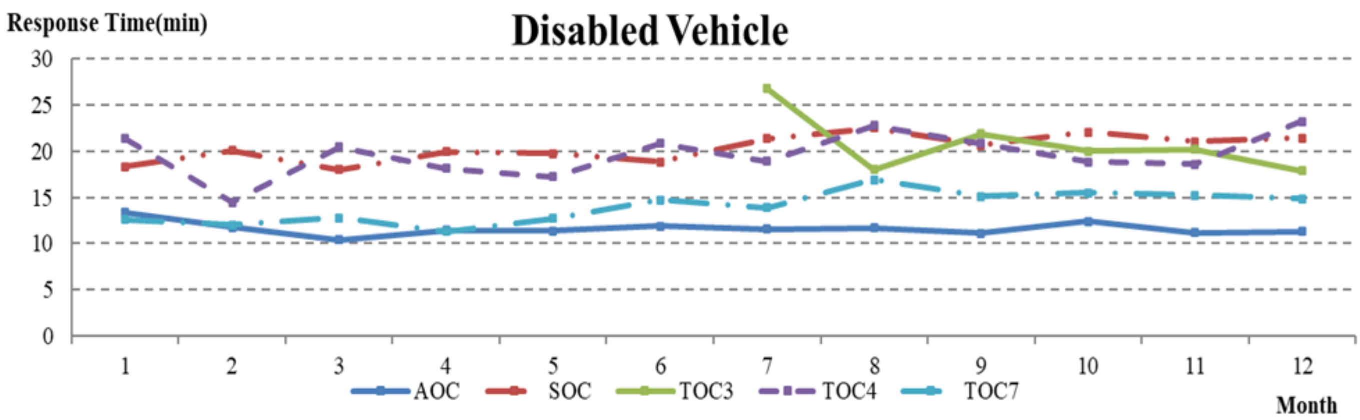
*Note:
1. *TOC 3 relocated back to their center on July 24th, 2024.*
2. *In 2023, only one valid incident was recorded in TOC3.*

Figure 4.5 Distributions of Average Response Times

4.2 ANALYSIS OF RESPONSE EFFICIENCY

In Figure 4.6 the average response times of incidents by TOC 4, TOC 7, and SOC are fairly consistent throughout the year and are mostly between eleven and fifteen minutes. AOC also shows fairly consistent response times up to ten minutes through year 2024. On the other hand, the response times for disabled vehicles show significant fluctuations for TOC4 and TOC7. TOC4 shows a big drop in the average response time for disabled vehicles in February, whereas it exhibits an increase in the average response time for disabled vehicles in August. Overall, the average response times for ACO are relatively shorter than for TOCs in most months.

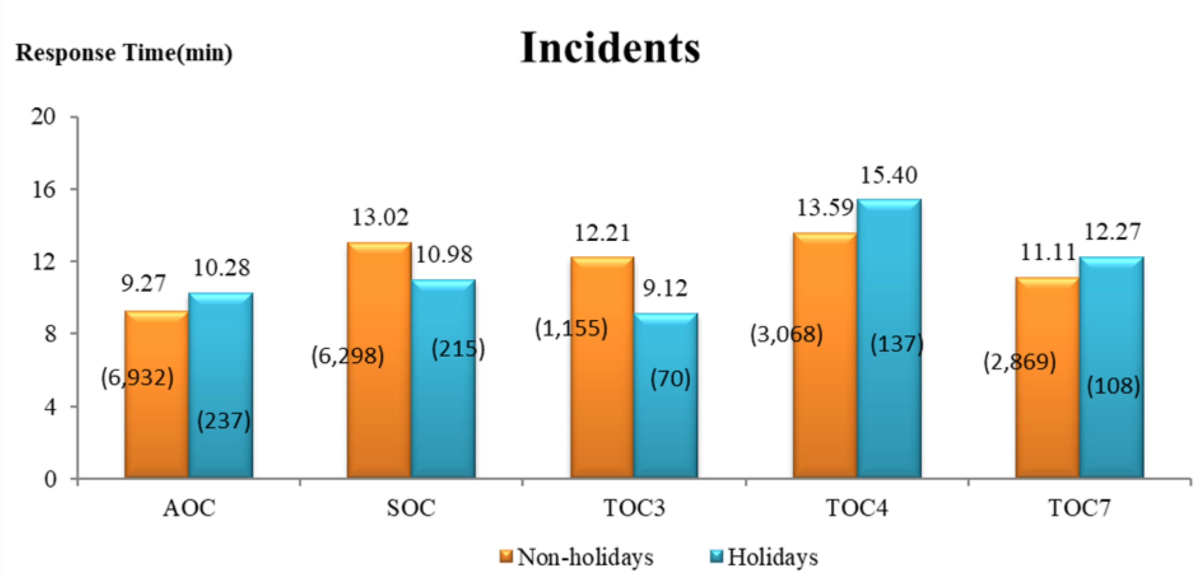


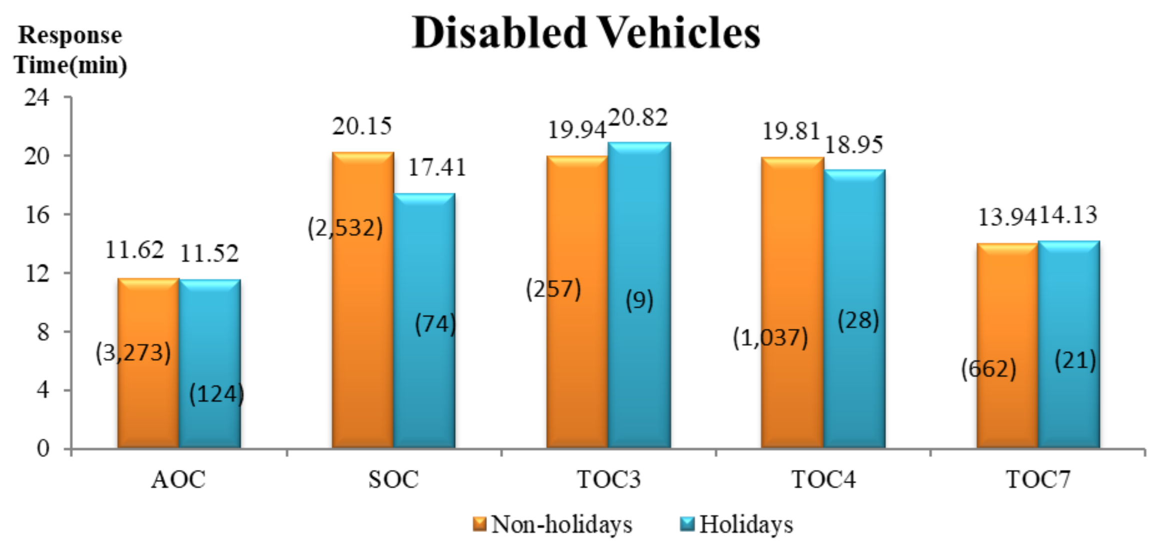


Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. TOC 3 relocated back to their center on July 24th, 2024.

Figure 4.6 Average Response Times for Operation Centers by Month in 2024

Figure 4.7 illustrates the fact that TOC7 shows slightly faster response times for incidents and disabled vehicles during non-holidays in 2024.





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

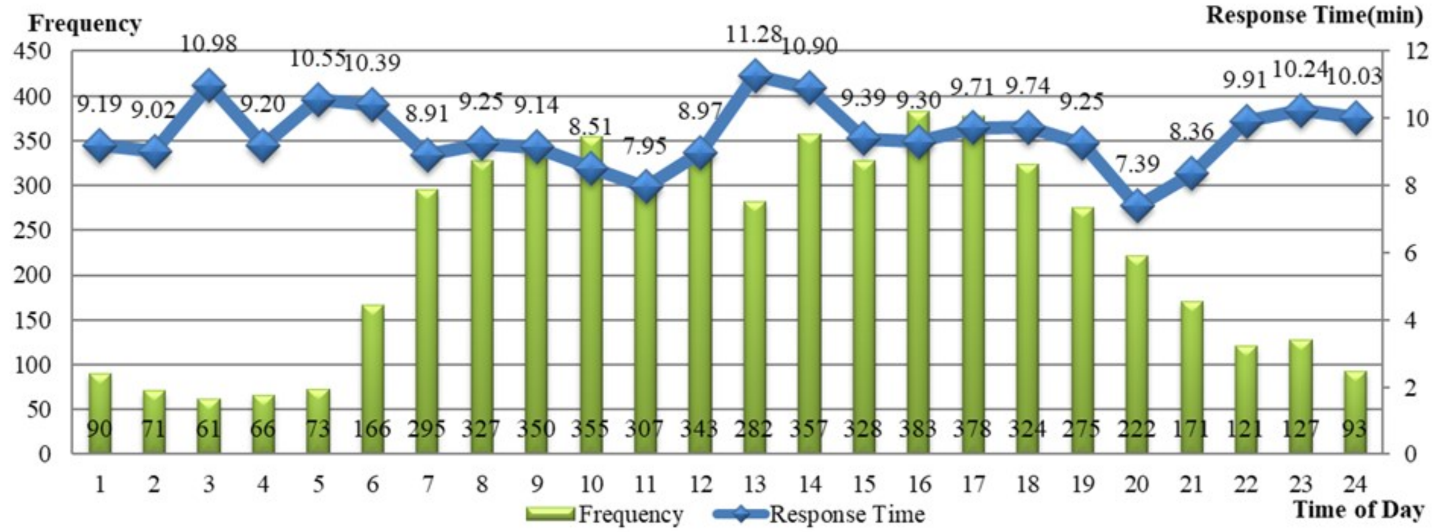
2. Numbers in each parenthesis show the data availability.

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

Figure 4.7 Average Response Times for Operation Centers on Holidays and Non-Holidays in 2024

4.2 ANALYSIS OF RESPONSE EFFICIENCY

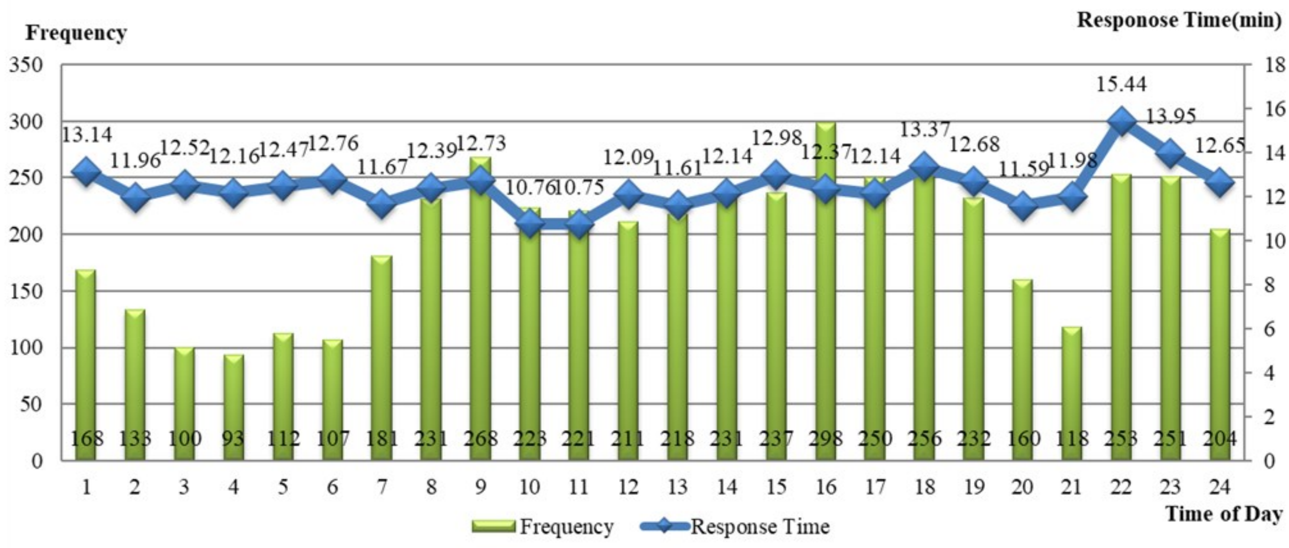
Figures 4.8 to 4.12 present the average response times by time of day during weekdays for each operation center. The bar graph represents the average incident frequencies to which the operation center responded while the line graph illustrates its average response times by the time of day. Overall, SOC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



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

Figure 4.8 Average Response Times for AOC by Time of Day on Weekdays in 2024

ANALYSIS OF RESPONSE EFFICIENCY 4.2



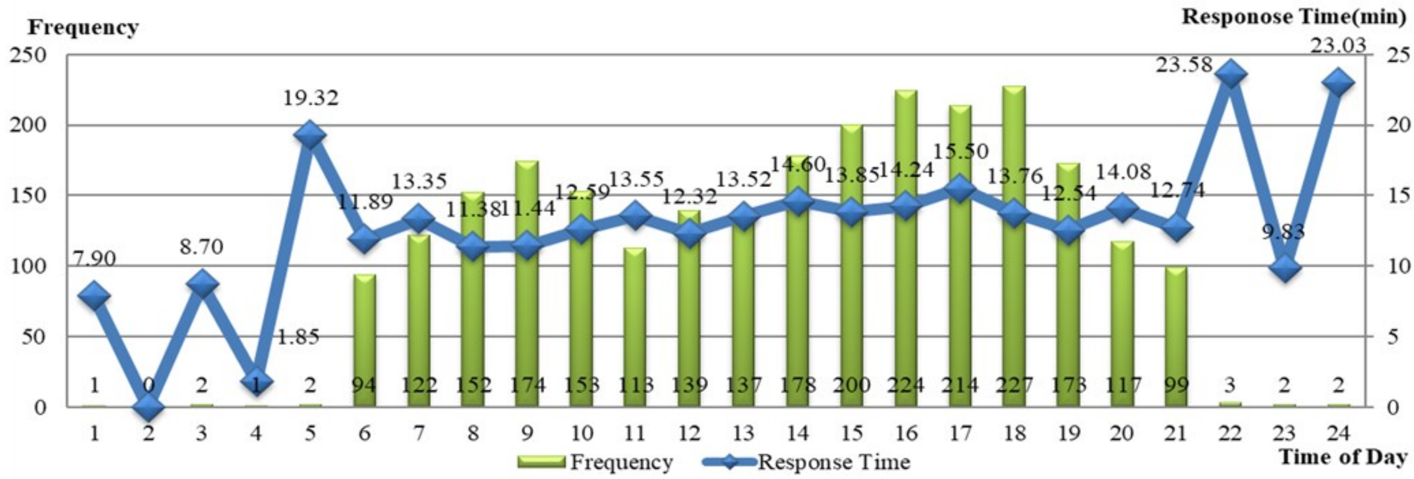
Note: Incident data only for response times between 1 minute and 60 minutes are used for this analysis.

Figure 4.9 Average Response Times for SOC by Time of Day on Weekdays in 2024

The response times by TOC 4 are quite consistent during their operational periods (5 a.m. – 9 p.m.), and the responded incident frequencies also exhibit distinct patterns during peak periods. On the other hand, the response times by TOC3 fluctuate during its operational hours.

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

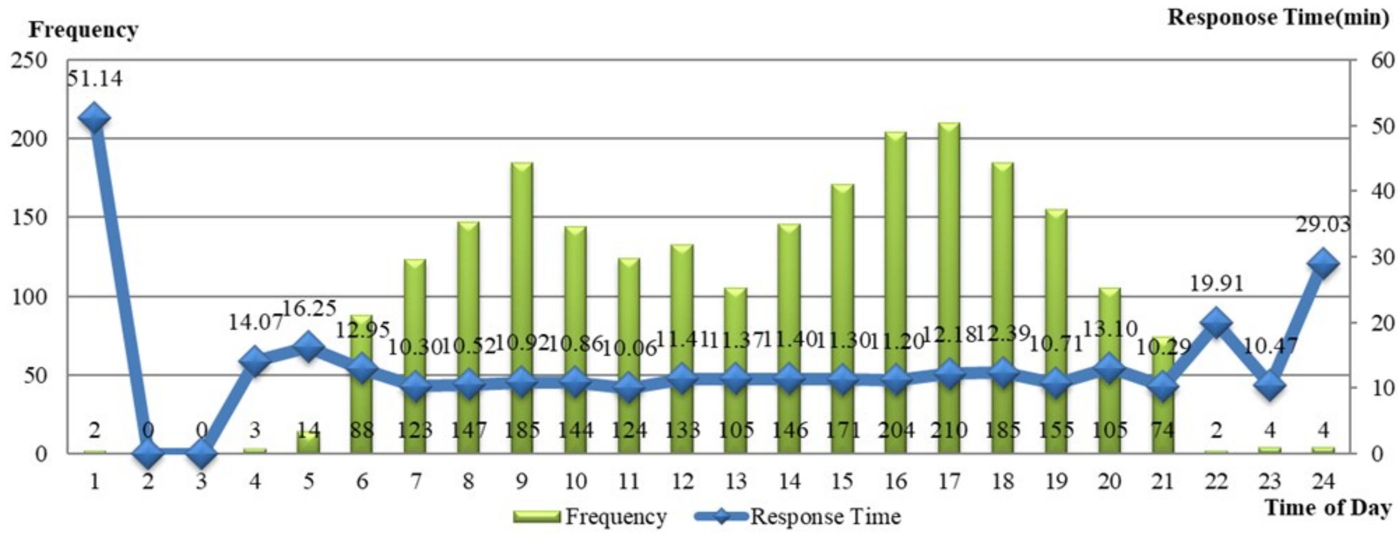
Figure 4.10 Average Response Times for TOC3 by Time of Day on Weekdays in 2024



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

Figure 4.11 Average Response Times for TOC4 by Time of Day on Weekdays in 2024

As shown in Figure 4.12, the highest incident frequency for TOC7 has been exhibited around the PM peak period (4:00 p.m. - 6:30 p.m.), while the response times remain quite consistent across all operational periods.

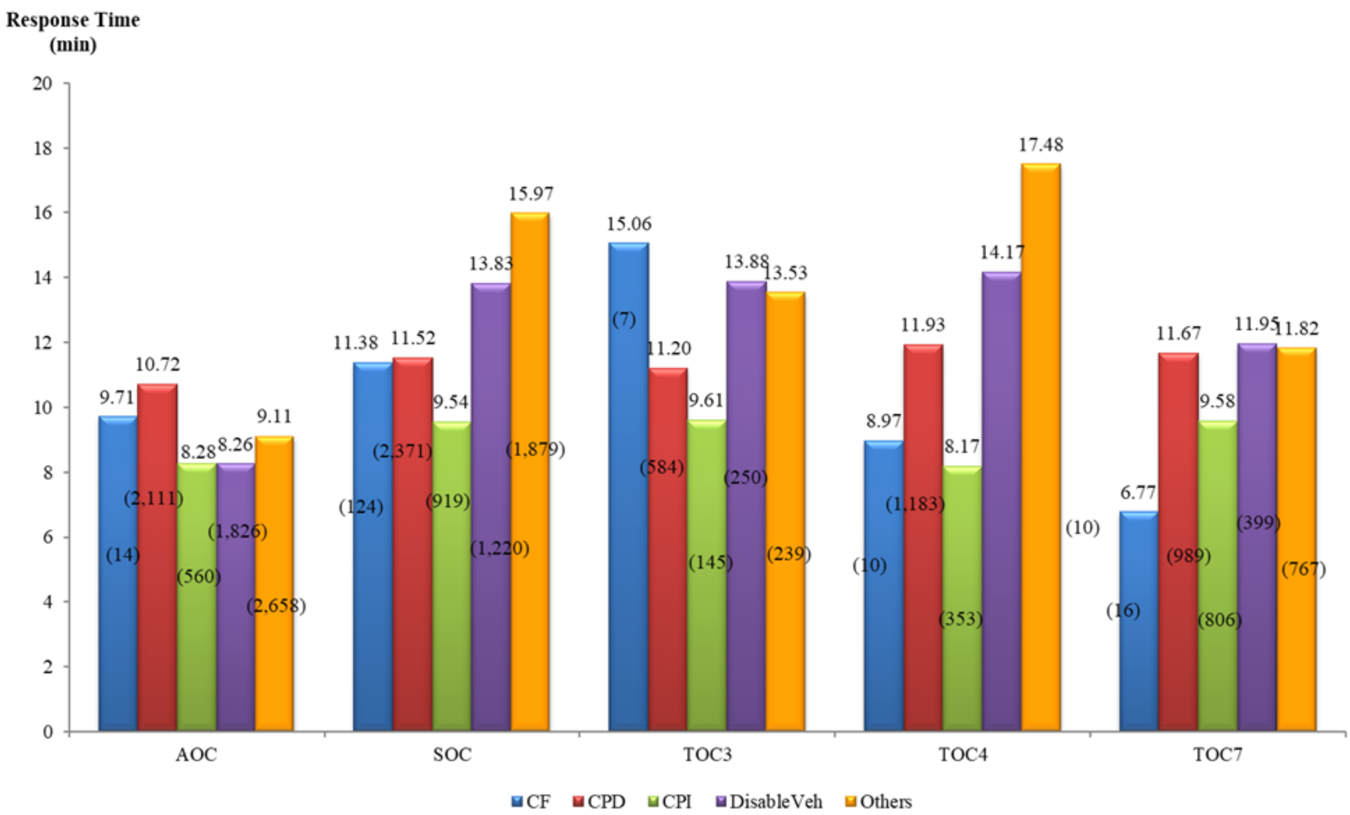


Note: Incident data only for response times between 1 minute and 60 minutes are used for this analysis.

Figure 4.12 Average Response Time for TOC7 by Time of Day on Weekdays in 2024

ANALYSIS OF RESPONSE EFFICIENCY

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



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

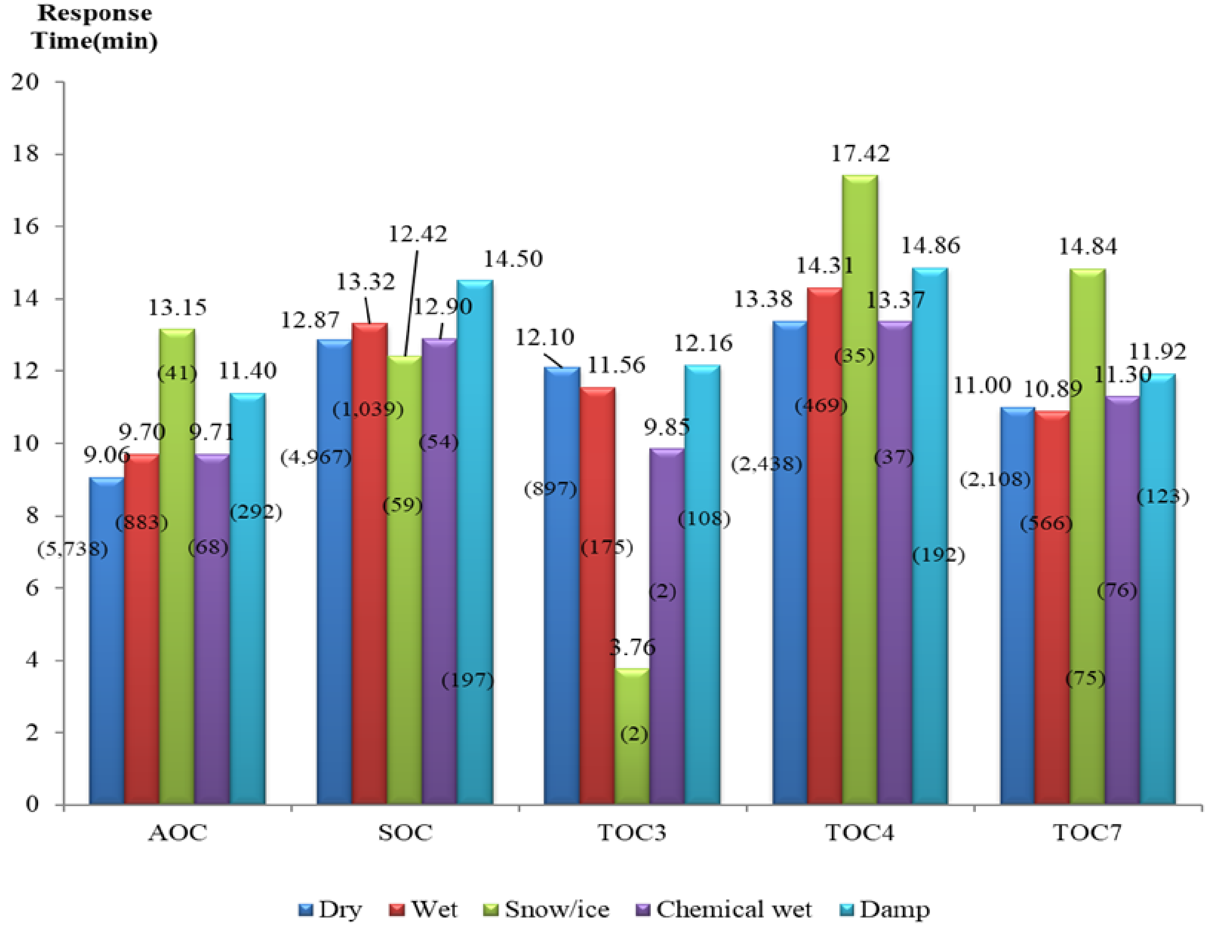
2. Numbers in parentheses show frequencies.

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

Figure 4.13 Average Response Times for Operation Centers by Incident Nature in 2024

4.2 ANALYSIS OF RESPONSE EFFICIENCY

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



Note: 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. Numbers in the parenthesis show the data availability for this analysis.
3. Starting in July 2024, the pavement condition "Damp" was added to the system.

Figure 4.14 Average Response Times for Operation Centers by Pavement Conditions in 2024

Figures 4.15 through 4.19 present the response times for operation centers by detection source. The bar graph represents the available data to compute the average response times, while the line graph represents the computed average response times. The major detection source for AOC is MDTA, while the state police detects the most incidents to which SOC responded. For SOC, on average, the incidents detected by CHART units have relatively fast responses.

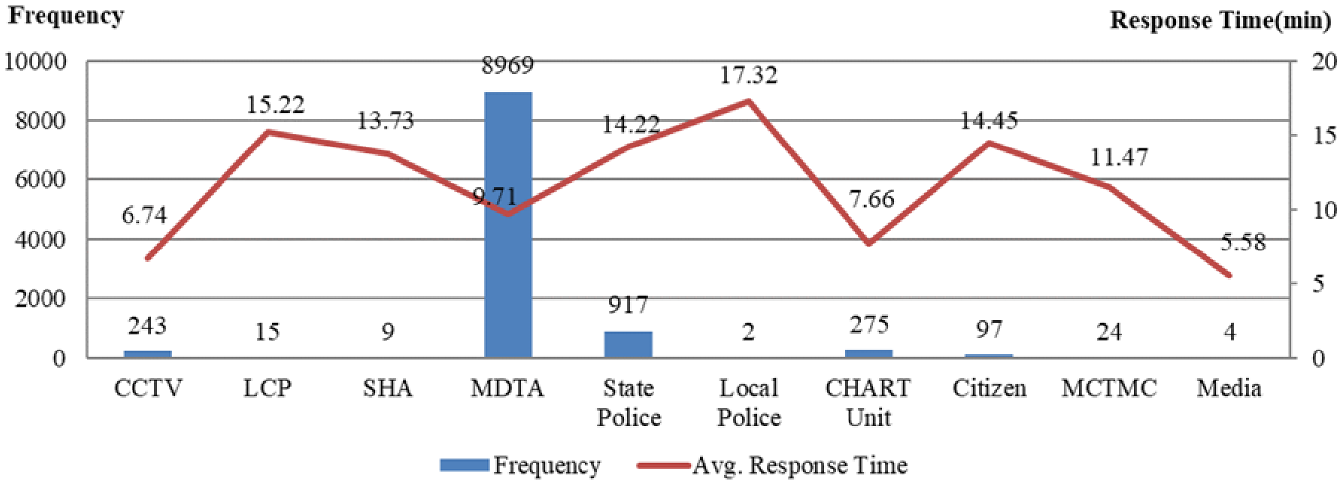


Figure 4.15 Average Response Times for AOC by Detection Source in 2024

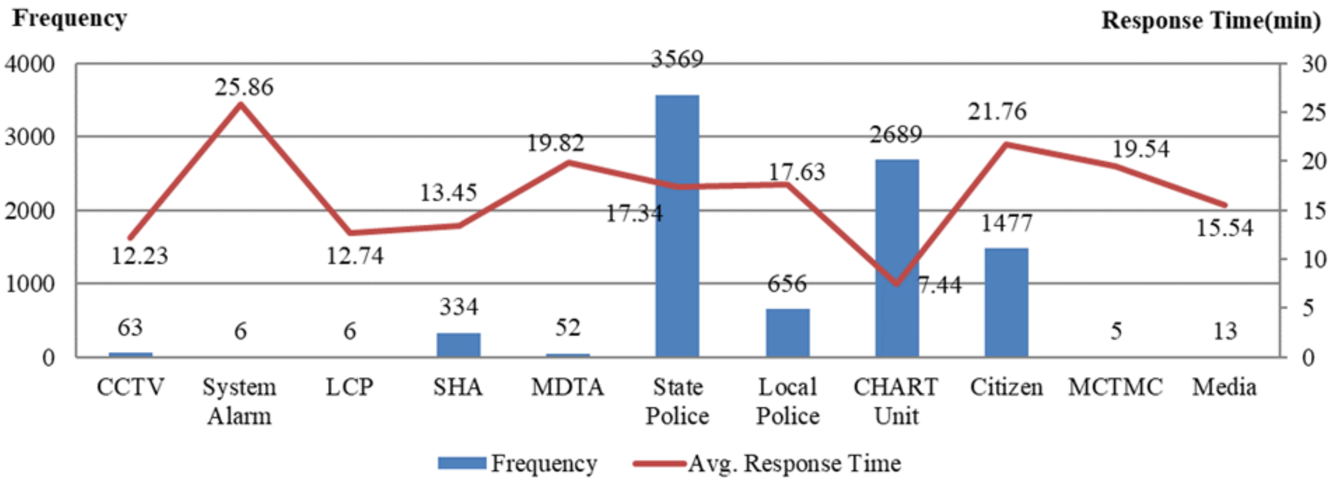


Figure 4.16 Average Response Times for SOC by Detection Source in 2024

4.2 ANALYSIS OF RESPONSE EFFICIENCY

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

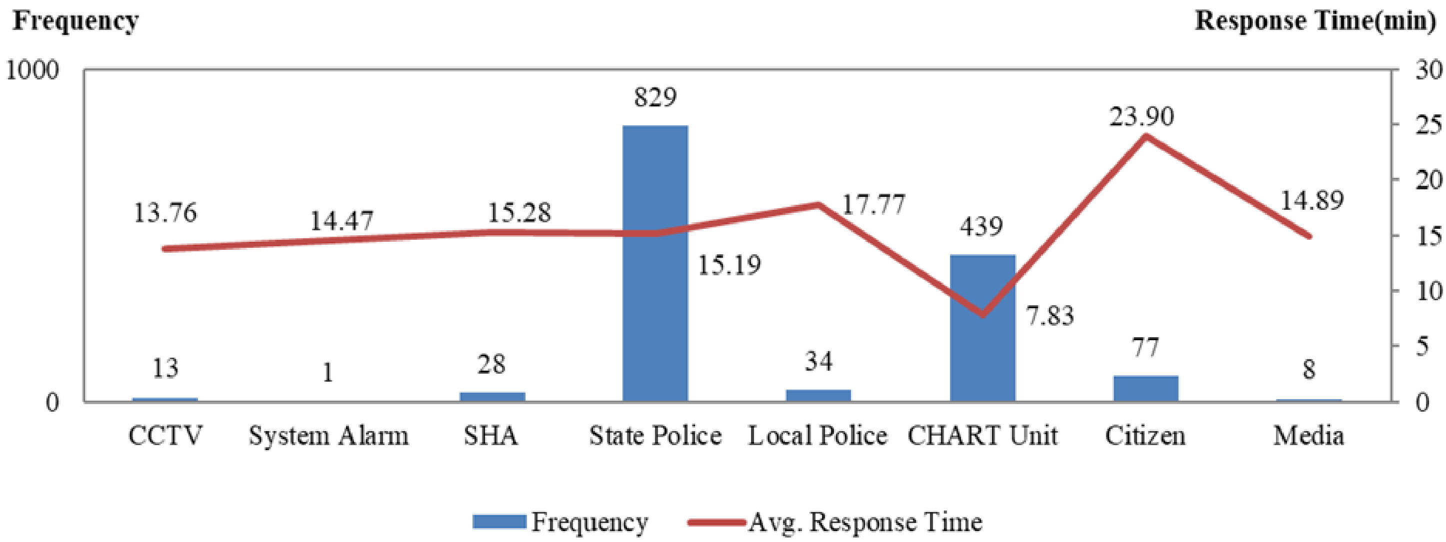


Figure 4.17 Average Response Times for TOC 3 by Detection Source in 2024

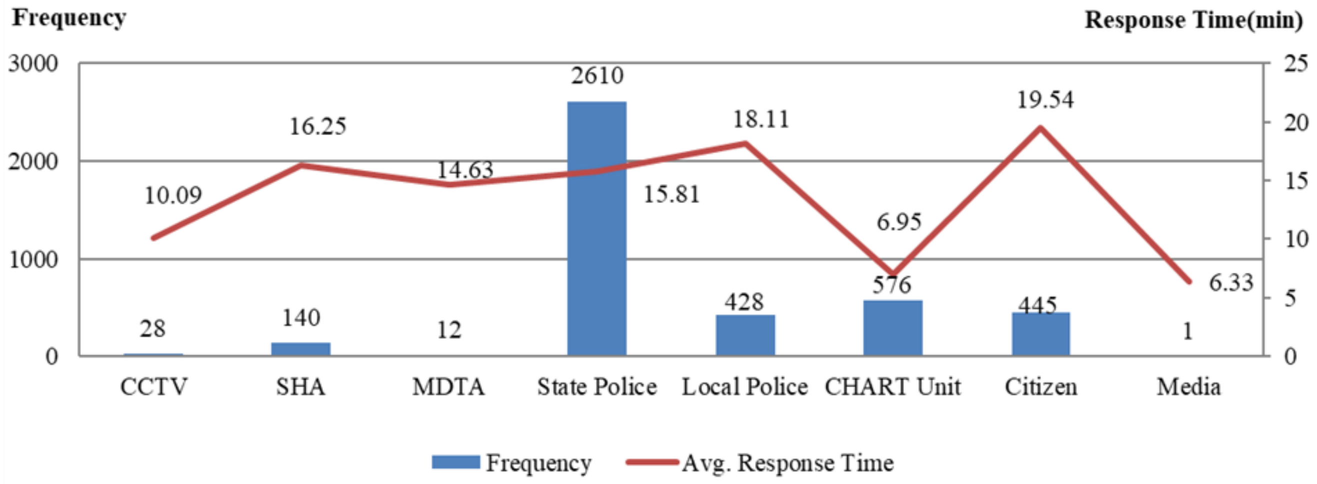


Figure 4.18 Average Response Times for TOC 4 by Detection Source in 2024

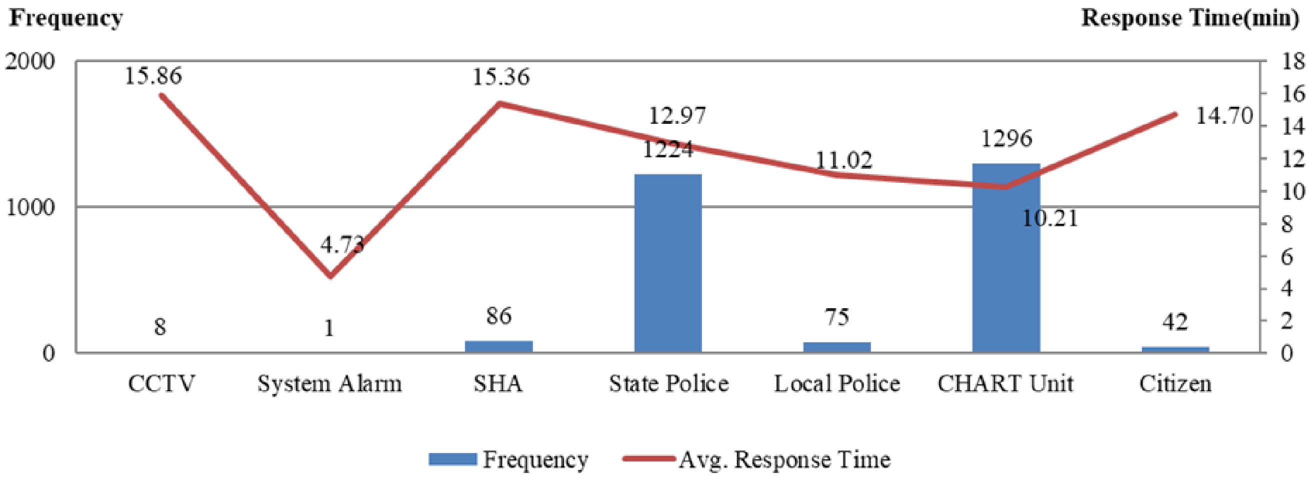
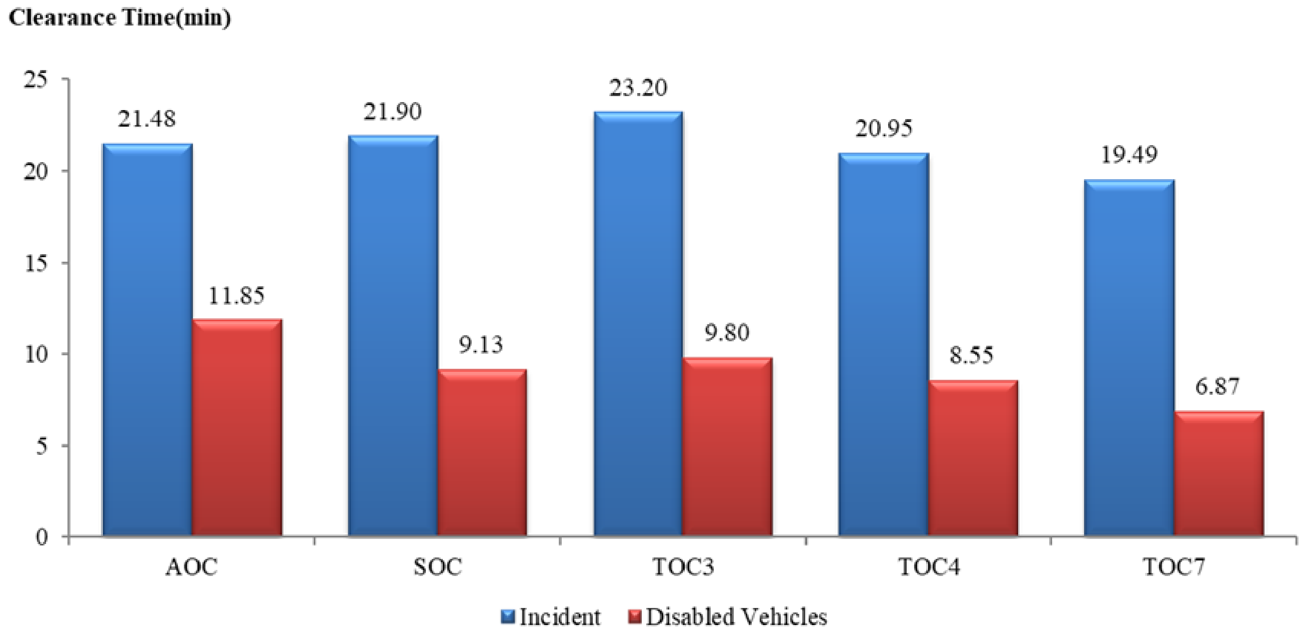


Figure 4.19 Average Response Times for TOC 7 by Detection Source in 2024

4.3 ANALYSIS OF CLEARANCE EFFICIENCY

As is well recognized, the efficiency of incident clearance could be varied by many factors. Figure 4.20 summarizes the performance of CHART incident clearance operations by operation center. The average clearance time by TOC3 is longer than any other for incidents, while AOC has a longer average clearance time than any other for disabled vehicles. On the other hand, TOC 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: 1. Data only for incident duration between 1 minute and 120 minutes are used for this analysis.
2. TOC 3 relocated back to their center on July 24th, 2024.

Figure 4.20 Average Clearance Times by Operation Center in 2024

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 2024 for non-responded incidents and those to which CHART responded. Since CHART's incident management team responded to most incidents in 2024, 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 26.01 minutes and 34.34 minutes in 2024. 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 2024 contributed to a reduction in blockage duration of about 24 percent, which has certainly contributed significantly to savings in travel times, fuel consumption, and related socioeconomic costs. Note that only about 82 percent of incident reports contain all the required information (i.e., received time and cleared time) for incident duration computation.

4.4 REDUCTION IN INCIDENT DURATION

Table 4.1 Comparisons of Incident Durations for Various Types of Lane Blockages in 2024 (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	21.07	6,090	31.38	473	1,521	24.98%
1 lane	23.03	12,161	32.87	654	3,119	25.64%
2 lanes	40.56	2,688	45.31	113	374	13.91%
3 lanes	49.55	716	58.16	42	251	35.06%
>=4 lanes	53.25	383	44.10	12	221	57.70%
Weighted Average	**26.01 (25.41)**	**22,038 (21,170)**	**34.34 (36.29)**	**1,294 (1,497)**		
Unknown	15.47	6,569	28.12	624		

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 2023

CHAPTER 5

ANALYSIS OF RESPONSE TIMES

5.1 Distribution of Average Response Times by Time of Day

5.2 Distribution of Average Response Times by Incident Nature

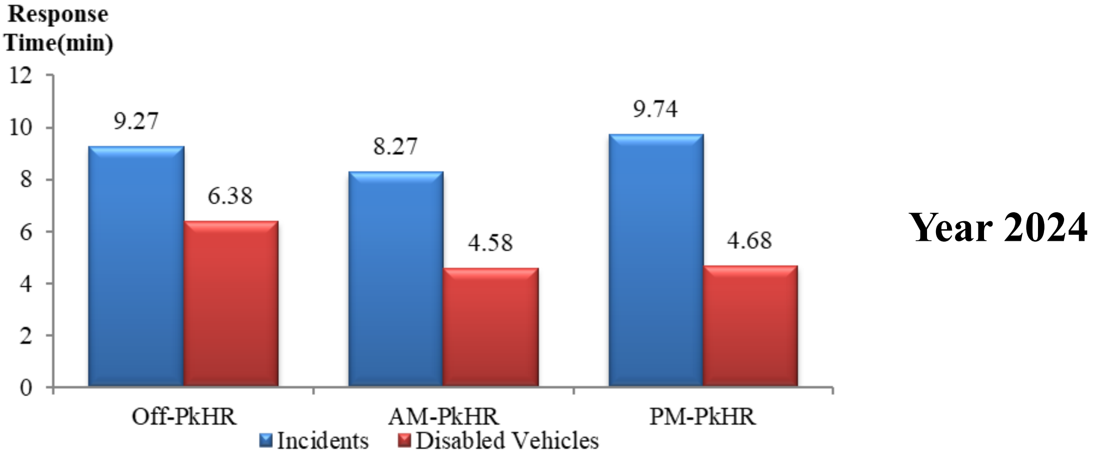
5.3 Distribution of Average Response Times by Various Factors

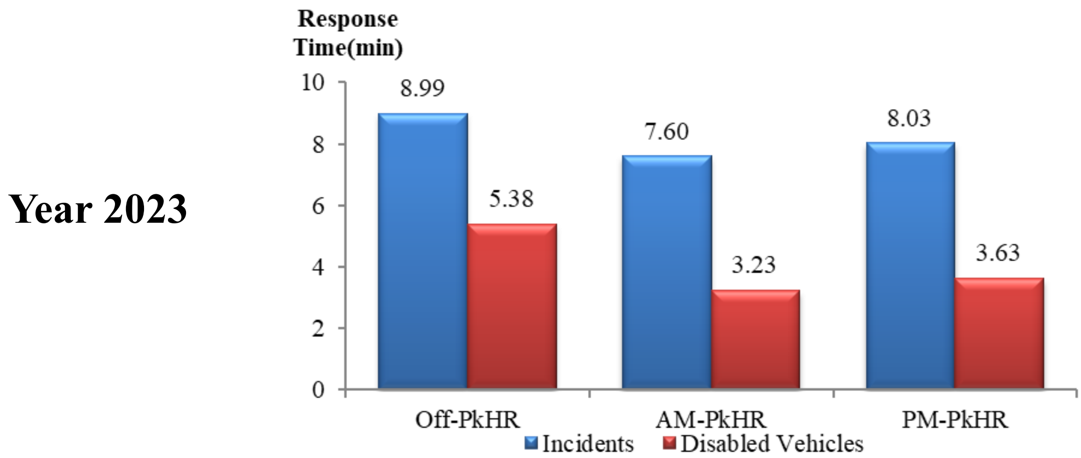
5

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

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

5.1 DISTRIBUTION OF AVERAGE RESPONSE TIMES BY TIME OF DAY





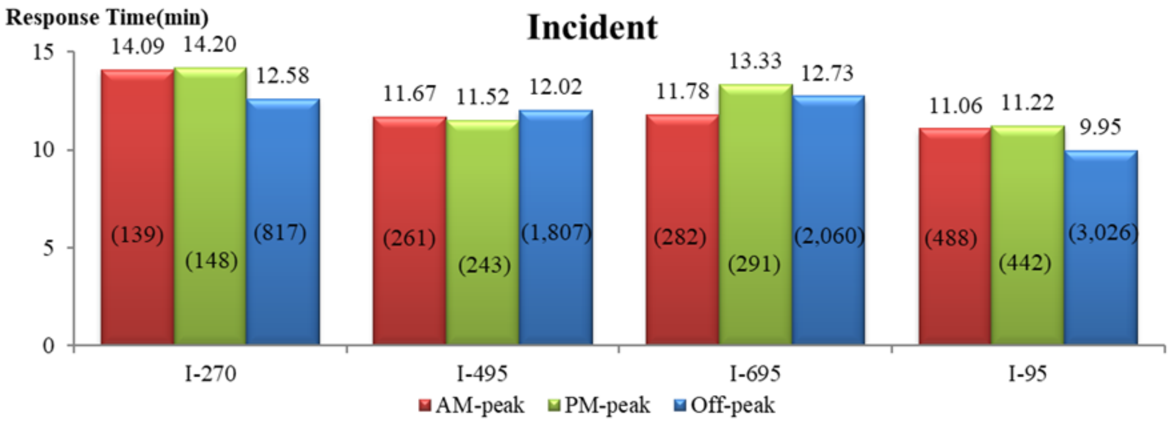
Note: Off-peak Hours include night times.

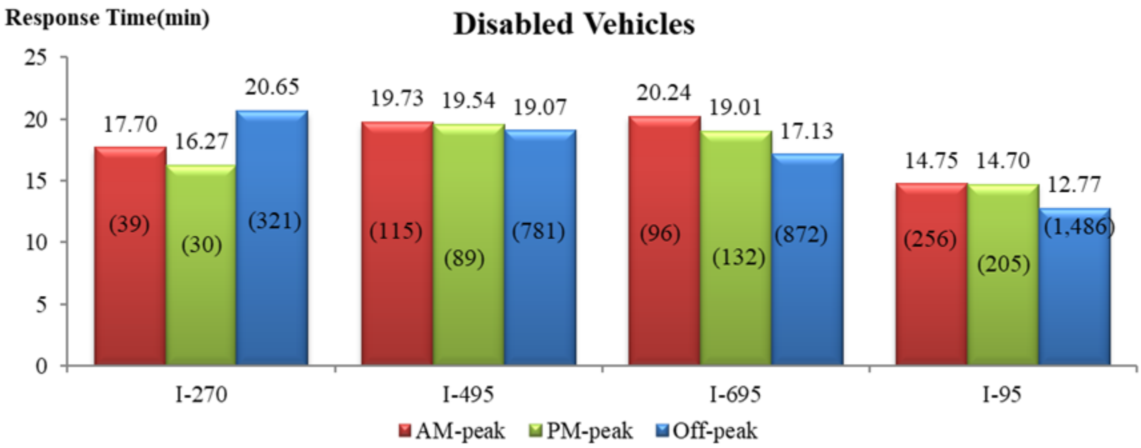
Figure 5.1 Distributions of Average Response Times by Time of Day in 2024 and 2023

Figure 5.1 compares response times by time of day in 2024 and 2023. In 2024, 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 a.m. peak hours were also shorter than those during off-peak hours in 2024.

DISTRIBUTION OF AVERAGE RESPONSE TIMES BY TIME OF DAY

5.1





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 2024

Figure 5.2 shows the average response times by different times of day through the major roads. The incidents on I-270 and I-95 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 off-peak hours were longest, whereas disabled vehicles on I-495 had a shortest response time during p.m. peak hours.

5.2 DISTRIBUTION OF AVERAGE RESPONSE TIMES BY INCIDENT NATURE

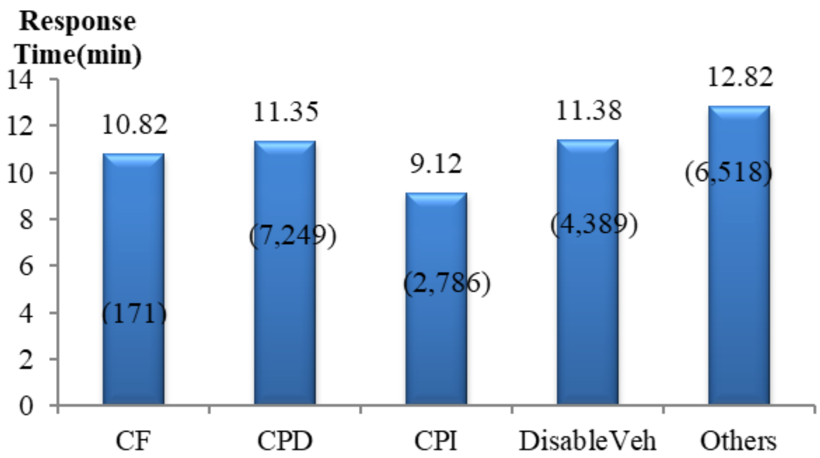
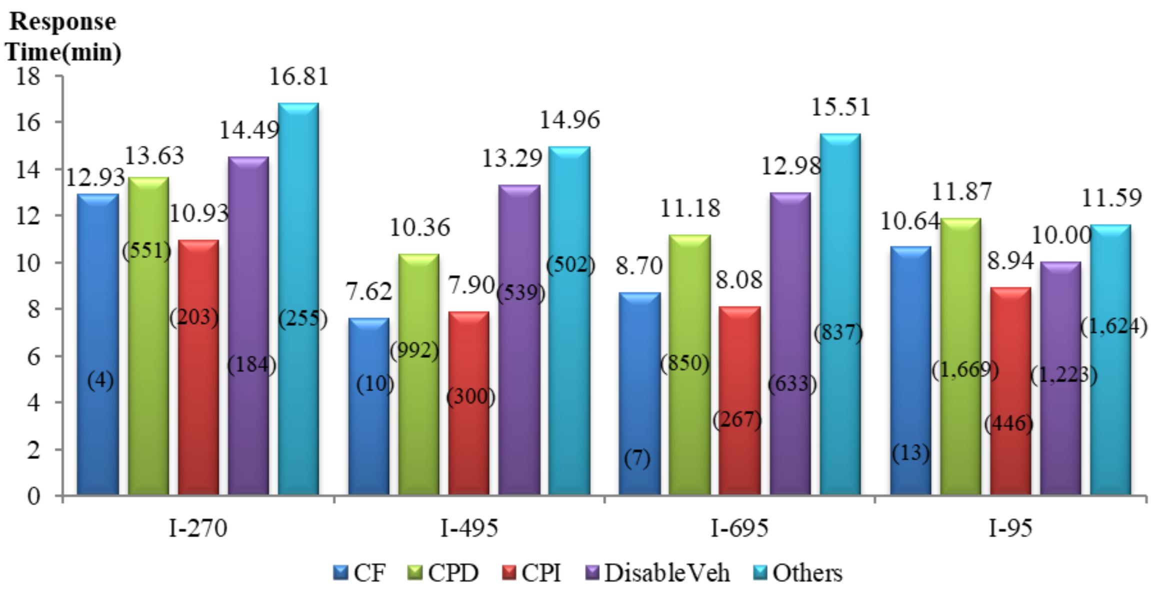


Figure 5.3 shows that the response times are likely to decrease as a detected incident becomes severe. For instance, the collision types of incidents, causing any fatality and injuries (CF and CPI), usually lead to quicker responses than other types of incidents.

Figure 5.3 Average Response Time by Incident Nature in 2024

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 2024

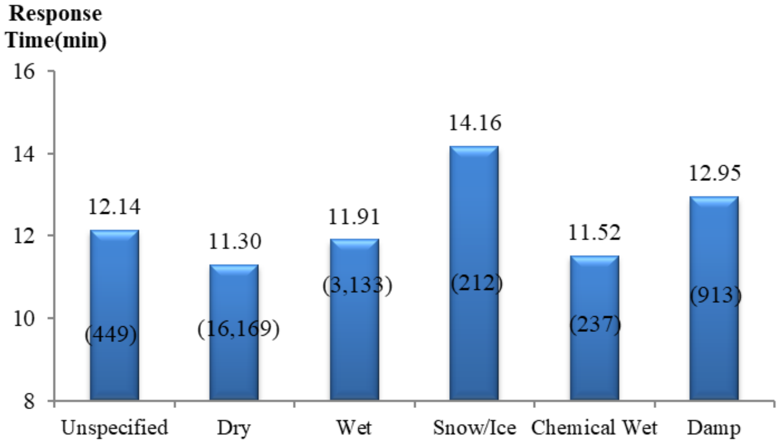
A similar pattern of decreased response times as the incident becomes severe appears on four major corridors, especially on I-695 and I-495, as shown in Figure 5.4.

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 dry, the response time is likely to be shorter.



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

Figure 5.5 Average Response Time by Pavement Condition in 2024

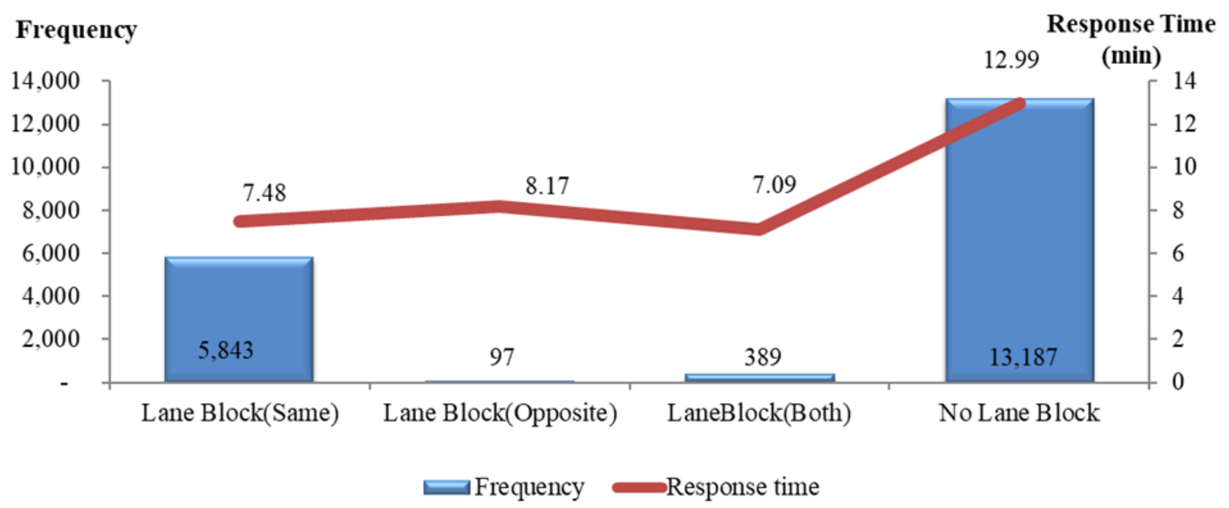
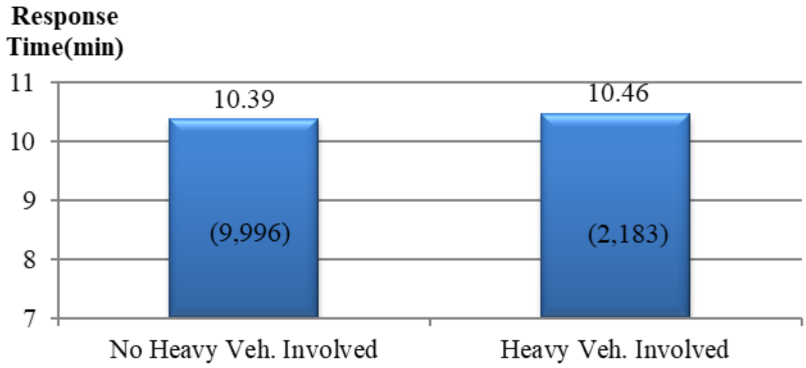


Figure 5.6 Average Response Time by Lane Blockage in 2024

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

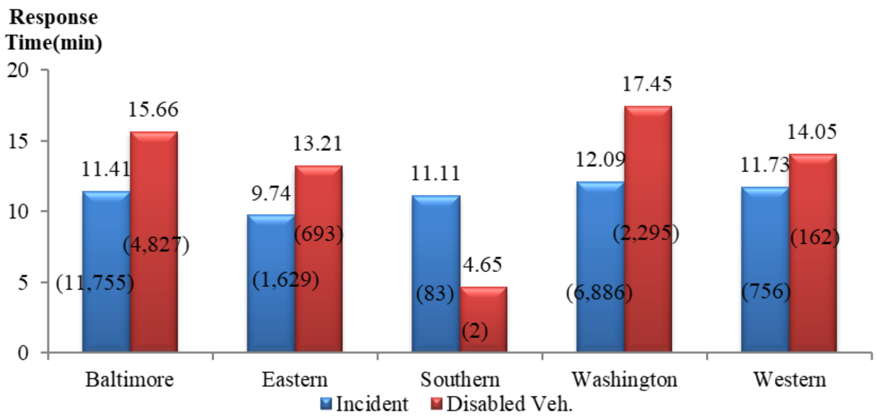
When a detected incident is involved with any heavy vehicles such as vans, SUVs, pick-up trucks, single-unit trucks, or tractor-trailers, the response is similar to the incidents which heavy vehicles are not involved in, as shown in Figure 5.7.



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 2024

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 response times for incidents are quicker than those for disabled vehicles in all regions except the Southern region.



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 2024

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 2024, about 41 percent of incidents without collisions were caused by Disabled Vehicles. A similar pattern was also observed in 2023, when about 39 percent of non- collision incidents occurred due to Disabled Vehicles. In contrast, the other types of non-collision incidents occurred in relatively low frequencies; therefore, the study classifies all such incident types as one category, i.e., Others, as shown in Table 6.1.

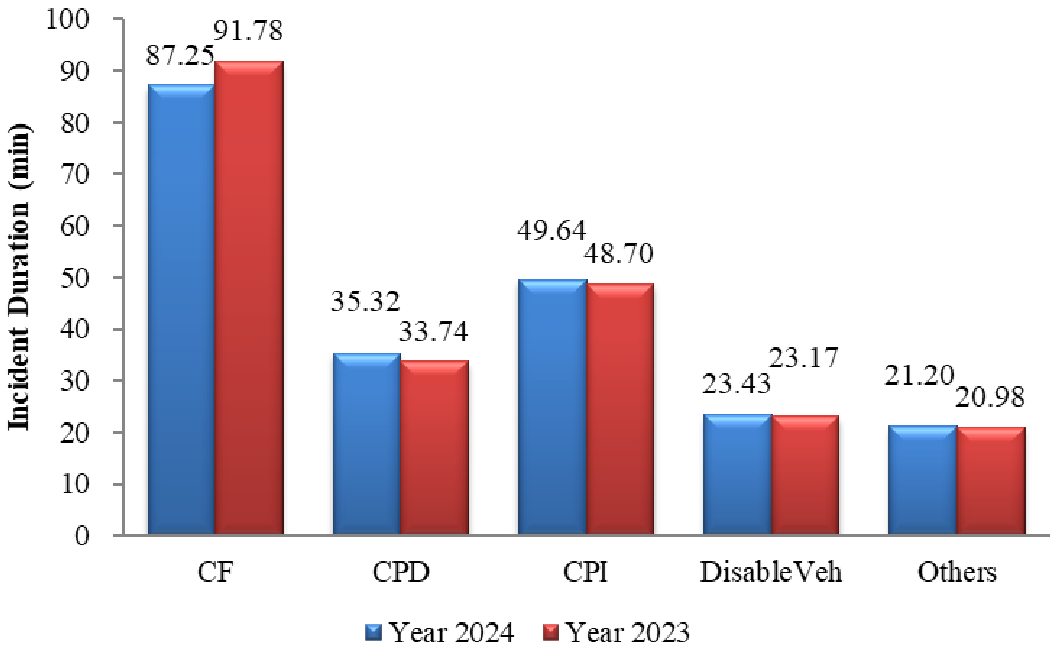
Table 6.1 Categories of Incident Nature

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

DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY NATURE

6.1

Figure 6.1 summarizes the average incident duration for each type in year 2024. 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.

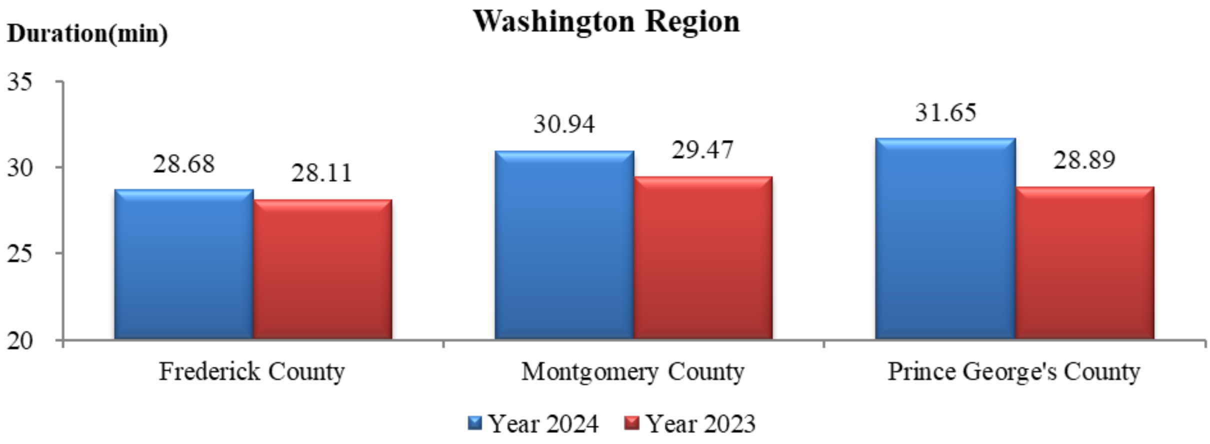


Note: 1. Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis
2. CF, CPD, and CPI represent collision-fatality, collision-property damage, and collision-personal injury, respectively.

Figure 6.1 Distribution of Average Incident Duration by Nature in 2024 and 2023

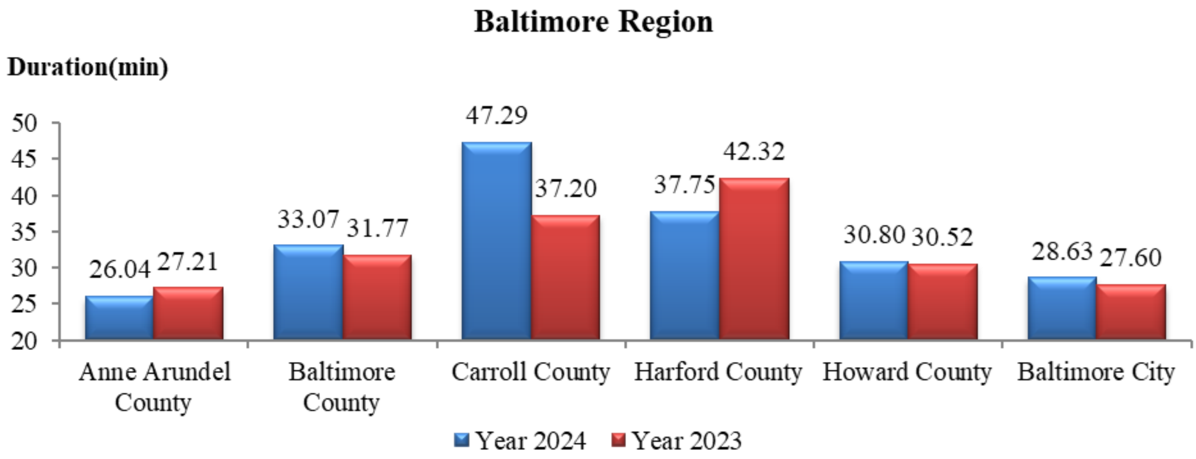
6.2 DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY COUNTY AND REGION

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 longer incident duration then Frederick County, as shown in Figure 6.2. Figure 6.3 shows that the incidents especially around Carroll and Harford Counties had longer durations, (i.e., longer than 35 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 2024 and 2023



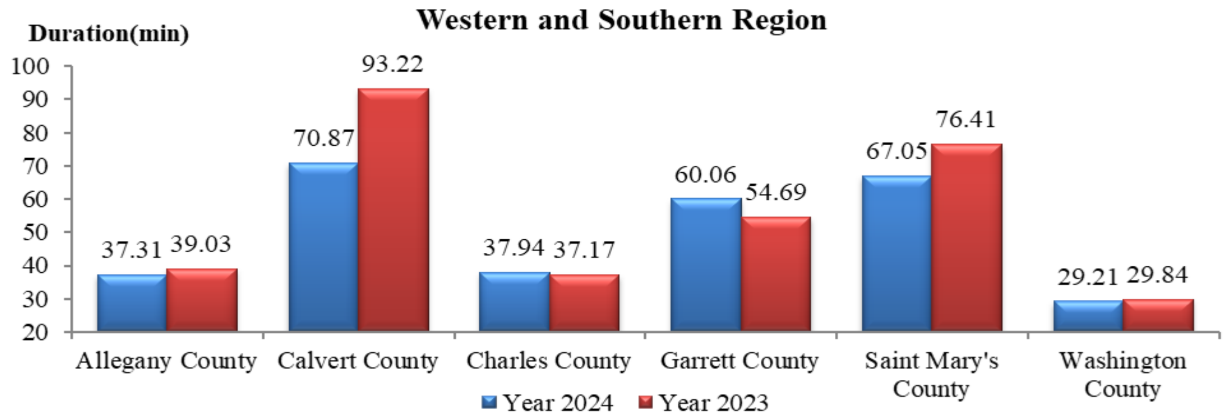
Note: Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis.

Figure 6.3 Distribution of Average Incident Duration by County in Baltimore Region in 2024 and 2023

DISTRIBUTION OF AVERAGE INCIDENT DURATIONS BY COUNTY AND REGION

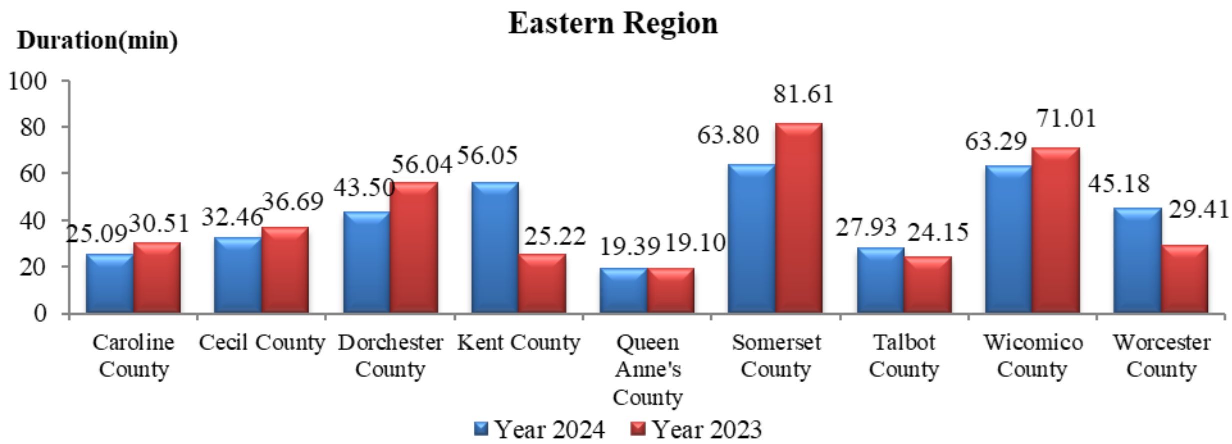
6.2

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 2024. The incidents occurring in Somerest 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 19 minutes on average to be cleared.



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

Figure 6.4 Distribution of Average Incident Duration by County in Western and Southern Regions in 2024 and 2023



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 2024 and 2023

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 Western 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 2024.

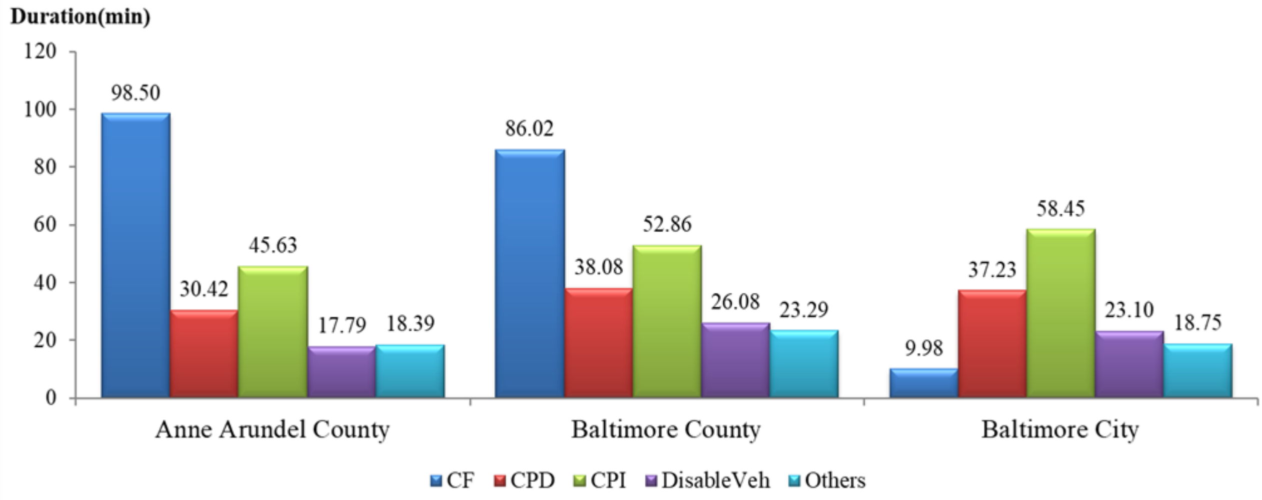
Table 6.2 Summary of Incident Duration Components by Region

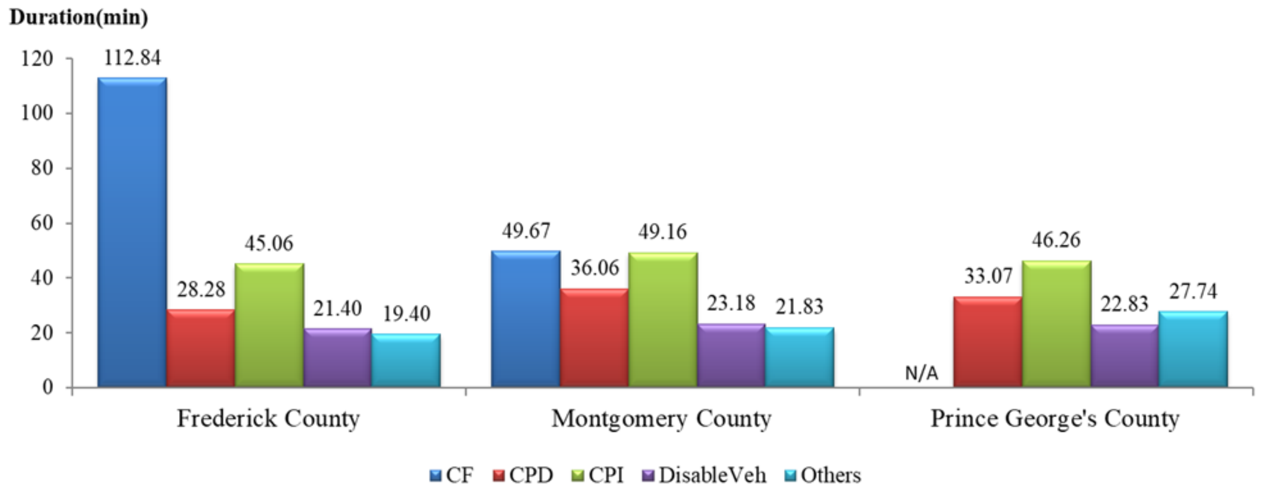
Region	Sample Frequency*	Avg. Response Time (mins)	Avg. Clearance Time (mins)	Avg. Incident Duration (mins)
Baltimore	12,180	8.59	22.30	30.88
Eastern	1,728	7.06	18.94	26.00
Southern	70	13.10	31.40	44.50
Washington	7,679	8.85	21.63	30.48
Western	872	8.81	20.72	29.53

** 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 Montgomery County was shorter than in any other area. On the other hand, CF-related incidents in Frederick 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.

3. No valid CF incidents (i.e., incidents with durations between 1 and 120 minutes) were found in PG's County. Therefore, the average incident duration is not available.

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 2024 have about 26 second's difference, while the average clearance time for weekends was significantly 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	2024	17,563	8.48	21.12	29.60
	2023	17,159	8.03	20.57	28.60
Weekends	2024	4,972	8.92	24.13	33.06
	2023	5,008	9.55	23.60	33.15

**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	2024	16,784	8.59	22.24	30.83
	2023	16,563	8.56	21.68	30.24
Peak	2024	5,751	8.55	20.47	29.02
	2023	5,604	7.80	20.01	27.81

**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.

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

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

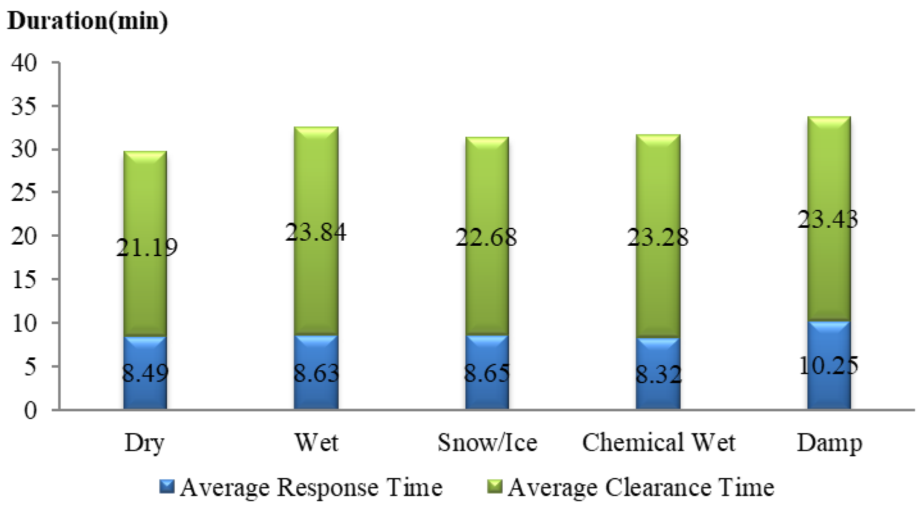
Table 6.5 Distribution of Average Incident Duration without and with CHART

	Year	Sample* Frequency	Avg. Response Time (min)	Avg. Clearance Time (min)	Avg. Incident Duration (min)
w/o CHART	2024	727	18.97	29.98	48.96
	2023	921	20.39	31.03	51.42
w/ CHART	2024	21,808	8.23	21.51	29.75
	2023	21,246	7.85	20.83	28.68

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.

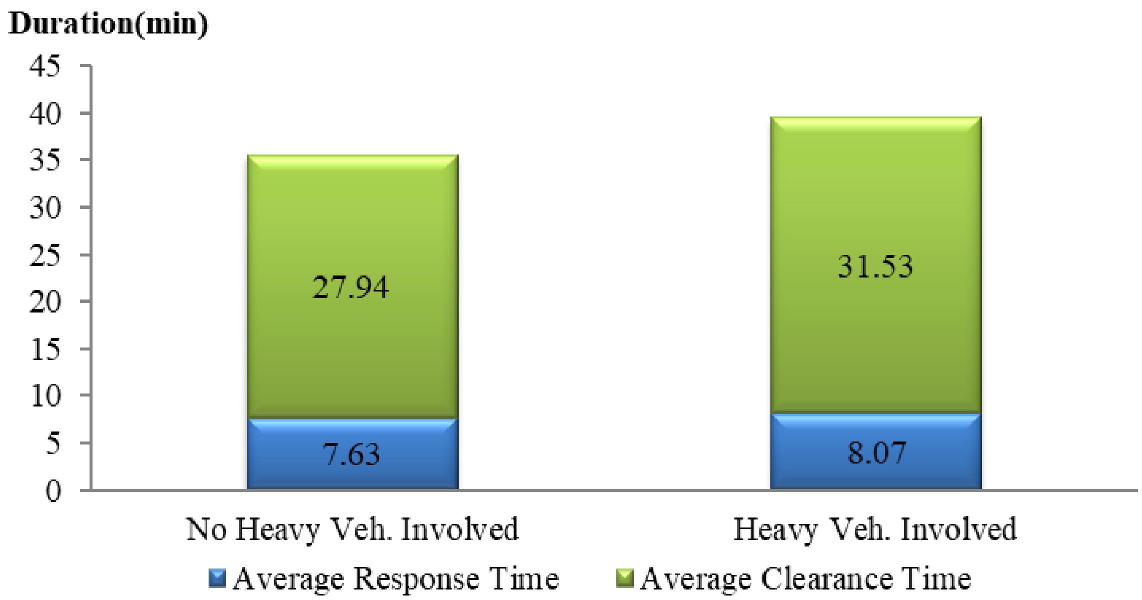
The response time and clearance time of incidents could vary with the pavement conditions, based on the pavement conditions. Figure 6.7 shows that chemical wet conditions (e.g., oil spill) may result in a faster response , but its average clearance time is likely to be longer.



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

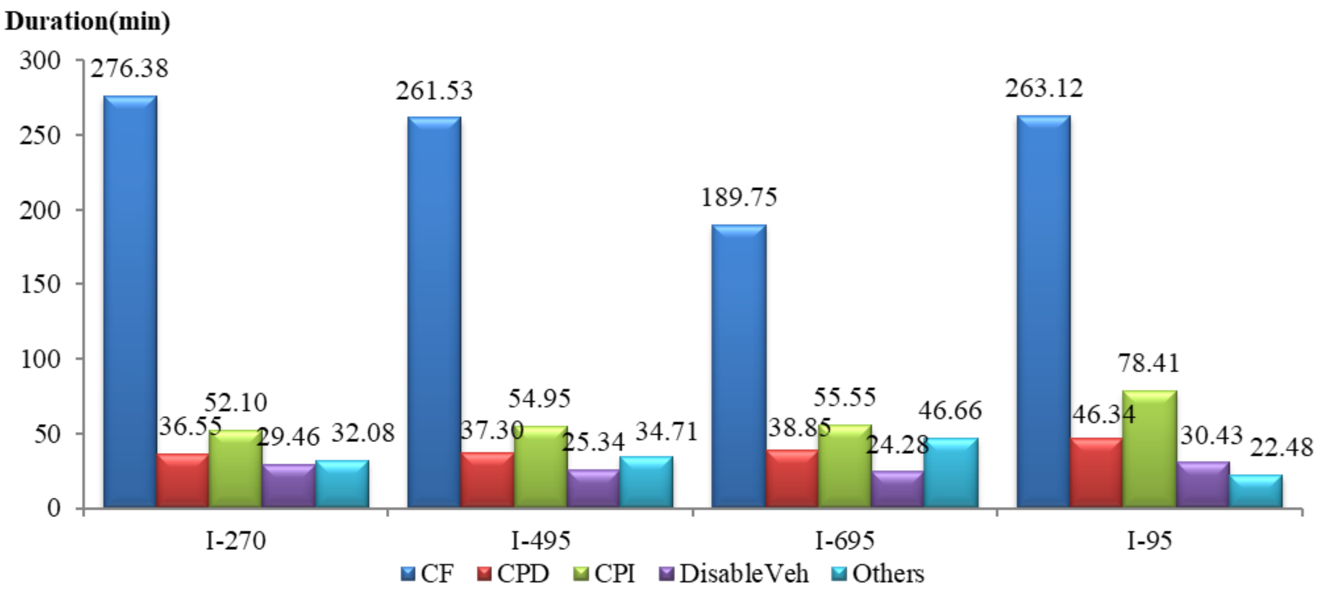
Figure 6.8 illustrates how a heavy vehicle influences the incident durations. In 2024, the response and clearance times for incidents involved with a heavy vehicle were likely to be longer than those without a heavy vehicle due to their incident severity.



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-270 seemed to exhibit the longest average duration (i.e., 276.38 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

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 2024 and Year 2023 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. Note that since TOC 3 was not available in 2023, a comparison involving TOC 3 is not included in 2024's report.

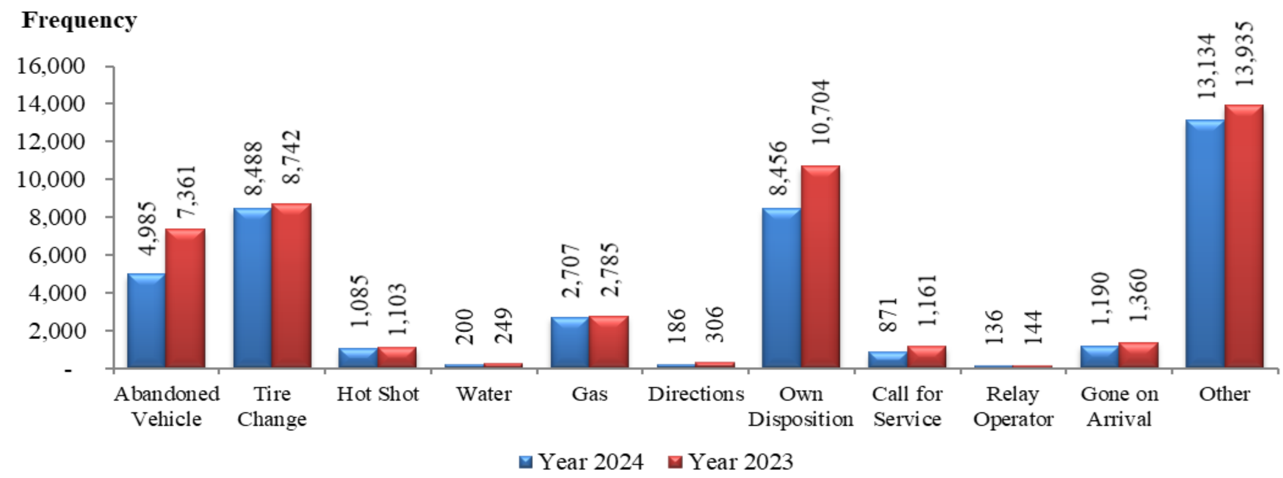


Figure 7.1 Classification of Driver Assistance Requests by Nature in 2024 and 2023

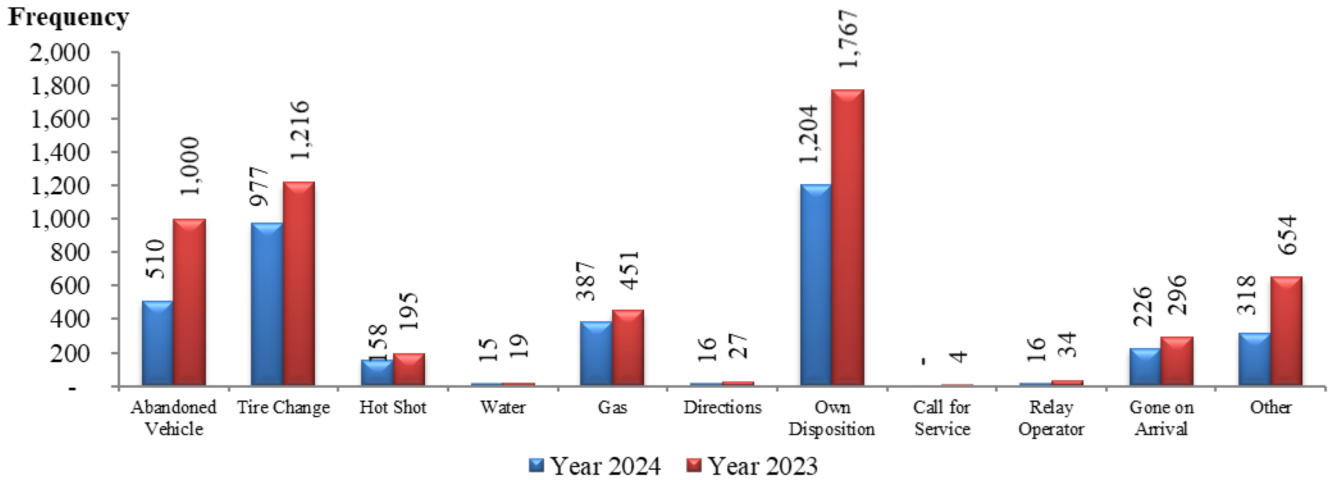


Figure 7.2 Classification of Driver Assistance Requests by Nature for TOC 4

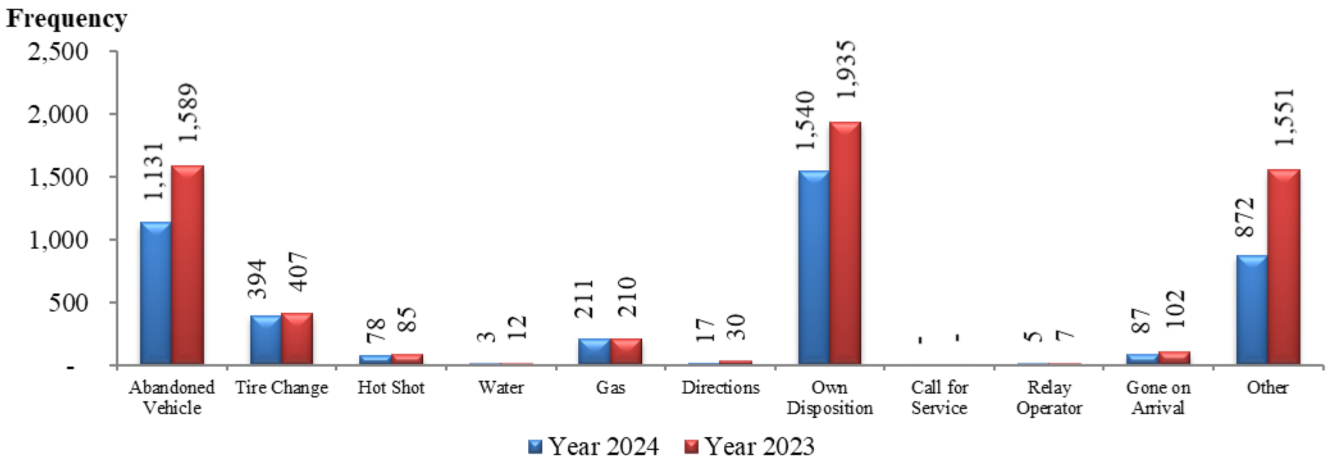


Figure 7.3 Classification of Driver Assistance Requests by Nature for TOC 7

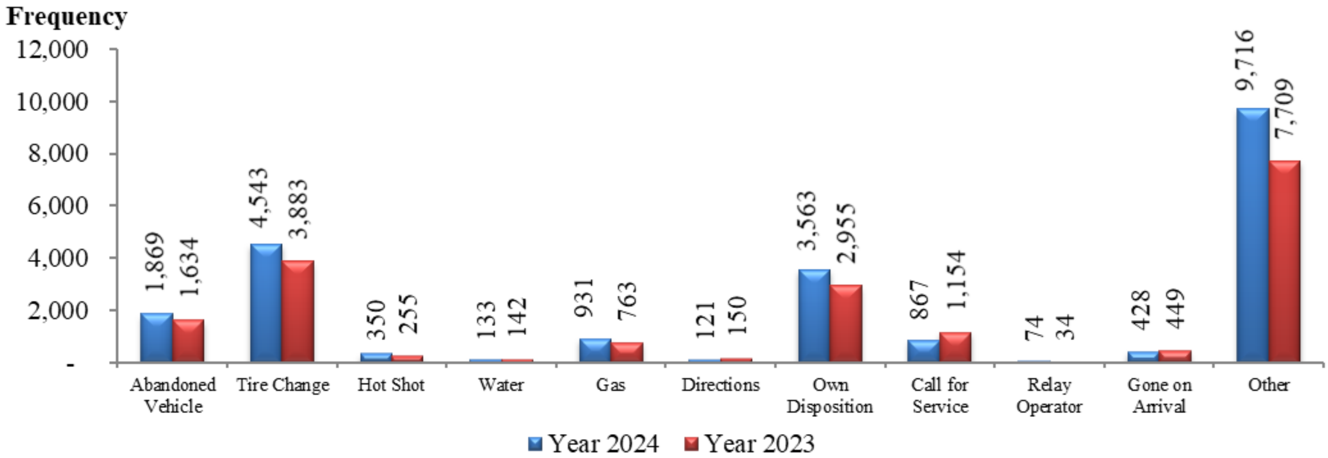


Figure 7.4 Classification of Driver Assistance Requests by Nature for AOC

These types of driver assistance in 2024 include flat tires, shortages of gas, or mechanical problems. Out of the 36,918 assistance requests, 11,195 assists were related to “out of gas” or “tire changes”, less than the number in 2023 (11,527 cases).

7.2 POTENTIAL REDUCTION IN SECONDARY INCIDENTS

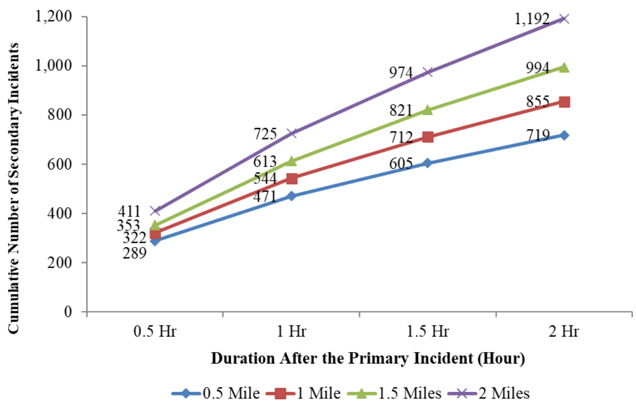
Major accidents are known to induce a number of relatively minor secondary incidents. These may occur as a result of dramatic changes in traffic conditions, such as rapidly spreading queue lengths or substantial drops in traffic speed. Some incidents are caused by rubbernecking effects. Hence, the efficient 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 2023. Notably, 1,192 secondary incidents occurred in 2024. 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: 1,192
- Estimated number of secondary incidents without CHART, which reduced incident duration by 22.58 percent, calculated as: 1,192/(1-0.2258) = 1,540 incidents
- The number of incidents potentially reduced due to CHART/MSHA operations: 1,540-1,192 = 348 secondary incidents .



Note that the 348 secondary incidents might have further prolonged the primary incident duration, increasing congestion, fuel consumption, and travel times. These associated benefits are not computed in this report due to data limitations but will be investigated in future studies.

Figure 7.5 Distributions of Reported Secondary Incidents

ESTIMATED BENEFITS DUE TO EFFICIENT REMOVAL OF STATIONARY VEHICLES

7.3

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

The estimated results with respect to the reduction in potential incidents for selected freeways are reported in Table 7.1. Note that this estimation was made using peak period data. Off-peak data were omitted because they are known to have negligible correlations with the lane-changing maneuvers and accidents. A detailed description of the estimation methodology can be found in the previous CHART performance evaluation reports (chartinput.umd.edu).

Table 7.1 Reduction in Potential Incidents due to CHART Operations

Road Name		I-495/95	I-95	I-270	I-695	I-70	I-83	I/MD-295	US-50	Total
Mileage		41	63	32	44	13	34	30	42	
No. of Potential Incidents Reduced	2024	160	416	55	131	62	40	29	68	961
	2023	201	402	32	170	89	47	44	81	1,066
	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

**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 (2024) and the Energy Information Administration (2024). Figure 7.6 also shows the difference in benefits between 2023 and 2024.

The evaluation for 2024 has adopted delay reduction for cars and trucks to convert the delays to fuel consumption. Please refer to Note 5 under Table 7.2 for details.

Starting from the 2024 report, new emission parameters have been adopted to reflect recent advancements in vehicle emission standards. The results shown as “2024a” use the original emission parameters, while the statistics in “2024b” adopt the new parameters for benefit estimation. Volatile Organic Compounds (VOCs) have been introduced to replace Hydrocarbons (HCs), as VOCs encompass a broader range of pollutants than HCs. These parameters are mainly from Environmental Protection Agency (EPA, 2008; EPA, 2025).

Recognized as a primary contributor to global warming, CO_2 is also accounted for in the estimated emission reduction, based on factors provided by the Environmental Protection Agency (EPA, 2023). Using the cost parameters shown in Table 7.2, the reduction in emissions resulted in total savings of $44.71 million with the 2024a parameters and $15.12 million with the 2024b parameters.

Thus, CHART operations in 2024 generated total savings of $2,148.69 million with the 2024a parameters, or $2,119.10 million if with the 2024b parameters.

DIRECT BENEFITS TO HIGHWAY USERS 7.4

Table 7.2(a) Total Direct Benefits to Highway Users in 2024a

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	Truck	2.31 (2.27)	Driver *$25.31/hour (24.06)* [1]	58.46 (54.57)
			Cargo *$55.00/hour (45.40)* [2]	127.03 (102.99)
	Car	36.78 (40.20)	*$51.42/hour (49.59)* [3]	1,891.36 (1,993.57)
Fuel Consumption (M gallon)		7.73 [5] (8.20)	Gasoline *$3.43/gal (3.63)* [4]	27.13 (30.91)
			Diesel *$3.76/gal (4.21)* [4]	
Emissions	HC (ton)	511.05 (555.17)	$6,700/ton	44.71 (48.53)
	CO (ton)	5,739.95 (6,235.41)	$6,360/ton	
	NO (ton)	244.76 (265.88)	$12,875/ton	
	CO_2 (metric ton)	70,838.38 (75,232.13)	$23/metric ton[6]	
Total		$ 2,148.69 (2,230.57)		

<Note>
** The number in each parenthesis is the estimate in year 2023.*
** All values are rounded to the nearest hundredth in this table only for the presentation purpose, since actual values need more spaces to be presented. For example, the benefit from truck drivers = 2, 309, 572.33… veh-hr * $25.31hr = $58,455,275.8…*
<Source>

1. *The truck driver's unit cost is based on the information from the Bureau of Labor Statistics in year 2024*
2. *The cargo unit cost is based on the information from the literature "Examining the Value of Travel Time Reliability for Freight Transportation to Support Freight Planning and Decision-Making" by Xia et al. (2016).*
3. *The car driver's unit cost is based on household income by the U.S. Census Bureau (2024).*
4. *The gasoline and diesel unit costs are from the Energy Information Administration in year 2024.*
5. *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. (2004) and the Environmental Protection Agency (EPA).*
6. *This value is computed based on the unit rates of 19.56 lbs CO2/gallon of gasoline, 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.*

7.4 DIRECT BENEFITS TO HIGHWAY USERS

Table 7.2(b) Total Direct Benefits to Highway Users in 2024b

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	Truck	2.31 (2.27)	Driver *$25.31/hour (24.06)* [1]	58.46 (54.57)
			Cargo *$55.00/hour (45.40)* [2]	127.03 (102.99)
	Car	36.78 (40.20)	*$51.42/hour (49.59)* [3]	1,891.36 (1,993.57)
Fuel Consumption (M gallon)		7.73 [5] (8.20)	Gasoline *$3.43/gal (3.63)* [4]	27.13 (30.91)
			Diesel *$3.76/gal (4.21)* [4]	
Emissions	VOC (ton)	158.05 [9] (n/a)	$1,840/ton[6]	15.12 (48.53)
	CO (ton)	233.32 [10] (6,235.41)	$1,465/ton[7]	
	NO (ton)	41.43 [11] (265.88)	$8,140/ton[6]	
	CO_2 (metric ton)	74,500.49 (75,232.13)	$190/metric ton[8]	
Total		**$ 2,119.10 (2,230.57)**		

<Note>
** The number in each parenthesis is the estimate in year 2023.*
** All values are rounded to the nearest hundredth in this table only for the presentation purpose, since actual values need more spaces to be presented. For example, the benefit from truck drivers = 2, 309, 572.33… veh-hr * $25.31hr = $58,455,275.8…*
<Source>

1. *The truck driver's unit cost is based on the information from the Bureau of Labor Statistics in year 2024*
2. *The cargo unit cost is based on the information from the literature "Examining the Value of Travel Time Reliability for Freight Transportation to Support Freight Planning and Decision-Making" by Xia et al. (2016).*
3. *The car driver's unit cost is based on household income by the U.S. Census Bureau (2024).*
4. *The gasoline and diesel unit costs are from the Energy Information Administration in Year 2024.*
5. *The fuel consumption is computed based on the rate of average emissions for passenger cars and trucks. The rate for passenger cars is 0.16 gallons of gas per hour, and for trucks is 0.8 gallon per hour, both reported by the Department of Energy (2015).*
6. *These values are based on the report "Sector-based PM2.5 and Ozone Benefit Per Ton Estimates" from the Environmental Protection Agency in Year 2025.*
7. *This value is based on the report "Achieving a Zero Emission Truck Fleet: Final Report" from California Air Resources Board in Year 2024.*
8. *This value is computed based on the unit rates of 20.86 lbs CO2/gallon of gasoline and 22.45 lbs CO2/gallon of diesel from the Energy Information Administration in Year 2024 and $190 /metric ton of CO2 by the Environmental Protection Agency (2023).*
9. *This value is computed based on the unit rates of 4.043 grams VOC/hr reported by the EPA (2008).*
10. *This value is calculated using unit emission rates of 10.7 grams of CO per kilogram of fuel, as reported by the California Environmental Protection Agency (2019).*
11. *The value is computed based on the unit rates of grams 1.9 grams of NO per kilogram of fuel by Dallmann, T. R. (2012).*

7.4 DIRECT BENEFITS TO HIGHWAY USERS

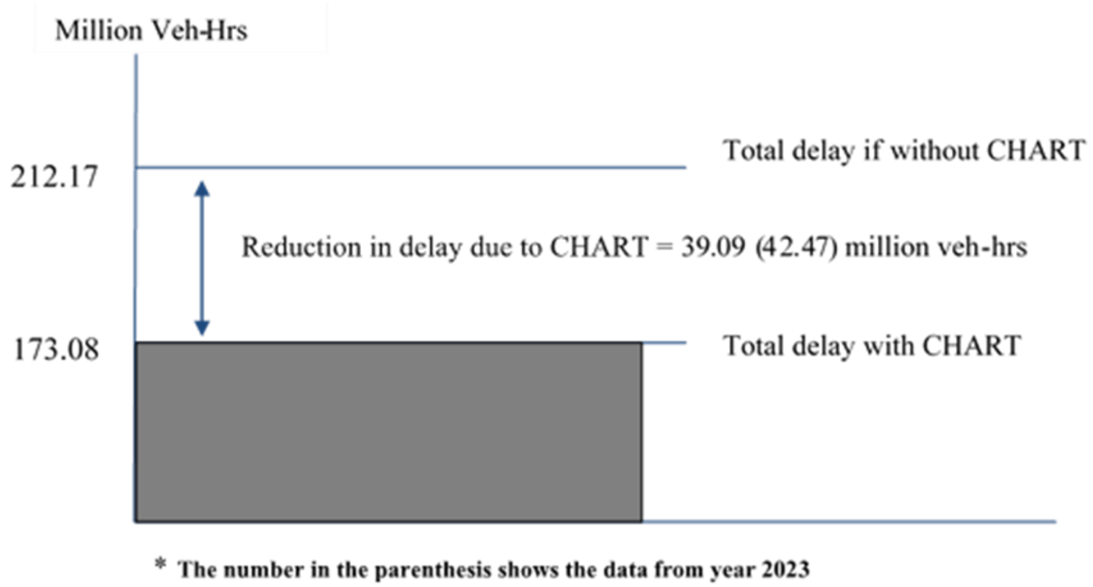


Figure 7.6 Reduction in Delay due to CHART in Year 2024

The total benefits decreased from 2,230.57 million dollars in 2023 to $2,148.69 million dollars (with original emission parameters), or $2,119.10 (with new emission parameters), in 2024. The main factors contributing to the change in benefits are listed and tabulated below:

- The total number of incidents used for the benefit estimate increased by about 2.55 percent from year 2023 to year 2024, as shown in Table 7.3.
- The ratio, reflecting the difference between incident durations with CHART and those without CHART, decreased from 27.09 percent in 2023 to 22.59 percent in 2024, as shown in Table 7.4.
- Table 7.5 shows that the adjusted AADT in 2024 decreased by 1.22 percent on the major roads in Maryland compared to 2023.
- Table 7.6 shows that the average truck percentage decreased in year 2024 over all major roads in Maryland, by 0.1 percent on average.
- The monetary unit of time value increased by 4.44 percent from 2023 to 2024.

Table 7.3 Total Number of Incidents Eligible for the Benefit Estimate

	2023	2024	Δ(' 23 ~ '24) [2]
No. of Incidents	33,297	34,145	2.55%

Note: 1. Only incidents causing main lanes blockage are included. Those incidents causing only shoulder lanes blockage are excluded for the benefit analysis.

2. The percentage change in No. of incidents (X) from Year 2023 to Year 2024 is calculated as follows: $\Delta X(\%)=(X_{2024}-X_{2023})/X_{2023}*100$

Table 7.4 Comparison of Incident Duration Reduction between 2023 and 2024

	With CHART (mins)	Without CHART (mins)	Difference (mins)	Ratio in Difference
2023	27.42	37.61	10.19	27.09%
2024 All year	27.90	36.04	8.14	22.59%
2024 Jan to June	27.38	36.25	8.87	24.47%
Δ(23 ~ '24 all year) [2]	1.75	-4.17	-20.12	-16.61%
Δ(23 ~ '24 Jan to June) [3]	-0.15	-3.62	-12.95	-9.67%

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

2.The percentage change in incident duration (X) from Year 2023 to Year 2024 is calculated as follows: $\Delta X(\%)=(X_{2024}-X_{2023})/X_{2023}*100$

3. The percentage change in incident duration (X) from Year 2023 to the period of January-June in Year 2024 is calculated as follows: As of July 2024, ERTs were no longer actively patrolling and staged only in areas of high call volume, i.e., waiting until receiving calls for assistance.

Table 7.5 Changes in adjusted AADT (with peak hour factor) for Major Roads from Year 2023 to Year 2024

	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	**2023**	12,079	7,905	7,612	10,453	4,086	2,404	4,333	2,487	3,400	**54,756**
	2024	11,908	7,954	7,223	10,471	4,013	2,378	4,320	2,481	3,340	**54,088**
Δ(23 ~ '24)		-1.42%	0.62%	-5.11%	0.17%	-1.79%	-1.08%	-0.30%	-0.24%	-1.76%	-1.22%

Note: The percentage change in the adjusted AADT(X) from Year 2023 to Year 2024 is calculated as follows: $\Delta X(\%)=(X_{2024}-X_{2023})/X_{2023}*100$

Table 7.6 Changes in Truck Percentage for Major Roads from Year 2023 to Year 2024

	Year	I-495	I-95	I-270	I-695	MD 295	US 50	US 1	I-83	I-70	Average
Truck Percentage (%)	**2023**	7.96	9.77	3.48	6.50	1.77	5.26	3.85	10.43	9.65	**6.52**
	2024	7.08	11.23	3.67	6.37	1.86	4.66	3.88	10.49	9.37	**6.51**
Δ(23 ~ '24)		-11.06%	14.94%	5.46%	-2.00%	5.08%	-11.41%	0.78%	0.58%	-2.90%	-0.10%

Note: The percentage change in the truck percentage from Year 2023 to Year 2024 is calculated as follows: $\Delta X(\%)=(X_{2024}-X_{2023})/X_{2023}*100$

DIRECT BENEFITS TO HIGHWAY USERS

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 (2023)				2,230.57
Key Factor			**Δ('23~ '24)[1]**	**Estimated Benefits[2]**
Sensitivity Analysis	Adjusted AADT		▼ 1.22%	2,152.88 (▼3.48%)
	Number of Incidents		▲ 2.55%	2,275.46 (▲2.01%)
	Incident duration percentage difference between w/ and w/o CHART	'24 All year	▼ 20.12%	1,859.79 (▼16.62%)
		'24 Jan. to June	▼ 12.95%	2,014.84 (▼9.67%)
	Truck percentage		▼ 0.1%	2,231.14 (▲0.03%)
	Monetary unit of gas price		▼ 5.83%	2,228.42 (▼0.1%)
	Monetary unit of time value		▲ 4.44%	2,306.83 (▲3.42%)
Benefit of the Current Year (2024a)[3]				**2,148.69** (▼3.67%)
Benefit of the Current Year (2024b)[3]				**2,119.10** (▼5.00%)

Note:1. This field is showing the difference in percentage between 2023 and 2024.
2. The numbers in each parenthesis show the percentage of the benefit change from year 2023.
3. Starting from the 2024 report, a new set of parameters for computing the emission benefit is introduced to reflect recent advancements in vehicle emission standards. The results in 2024a show the benefits computed with the original emission parameters, while the statistics 2024b reflect the same measurements with the new parameters.

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 each selected factor, using its 2024 value, but setting all other factors identical to those in 2023; and

• Following the same procedures to analyze the sensitivity of the total 2024 benefits with respect to each key factor.

The results of sensitivity analysis for each factor are shown in the Table 7.7. The decrease in the average adjusted AADT by 1.22 percent in 2024 contributed to a decrease of 3.48 percent in the total benefit. The number of lane-blockage incidents increased by 2.55 percent in 2024, resulting in the benefit increase of 2.01 percent. Note that the ratio with respect to the performance difference between incident durations with- and without-CHART involvement decreased by 20.12 percent, and thus directly resulted in decrease of 16.62 percent in the total benefit. This is likely due to the policy change in July 2024, when ERTs stopped patrolling and staged in areas of high call volume, i.e., waiting for receiving calls for assistance. If without the policy change, the performance difference between incident durations with- and without-CHART would have only decreased by 12.95 percent.

An increase of 3.42 percent in the total benefit is due solely to the raise of 4.44 percent in the average income for the MD driving populations (i.e., a proxy for time value).

DIRECT BENEFITS TO HIGHWAY USERS 7.4

This chapter summarizes the benefits for major freeway corridors in 2024 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 11.74, 3.65, 1.28, 4.33, 1.80, and 0.86 million vehicle-hours, respectively, in 2024.

The total benefits resulting from the reductions in delays, fuel consumption, and emissions for each major roadway in 2024 are summarized in Tables 7.9(a) to 7.9 (l). The total benefits for I-95, I-495/95, I-270, I-695, I-70, and I-83 in 2024 are estimated at $656.06 M ($664.42 M), $199.18 M ($201.90 M), $68.09 M ($69.12 M), $235.22 M ($238.57 M), $100.04 M ($101.33 M), and $48.18 M ($48.78 M), respectively. The numbers in parentheses represent benefit estimates calculated using the previous emission parameters.

Note that the benefits for those six major corridors account for 61.67% of the total CHART benefits of $2,119.10M.

Table 7.8 Number of Incidents Used for Benefit Estimate for the Six Major Corridors in 2024

Corridors	Number of Incidents	Reduction in Delay due to CHART (M vehicle-hours)
I-95	7,309	11.74
I-95/495	3,274	3.65
I-270	1,075	1.28
I-695	3,471	4.33
I-70	1,444	1.80
I-83	1042	0.86
Others	16,530	15.44

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

Table 7.9(a) Total Direct Benefits for I-95 in 2024a

<table>
<tr><th colspan="2">Reduction due to CHART</th><th>Amount</th><th>Unit rate</th><th>In M Dollar</th></tr>
<tr><td rowspan="3">Delay (M veh-hr)</td><td rowspan="2">Truck</td><td rowspan="2">1.30</td><td>Driver
$25.31/hour</td><td>32.79</td></tr>
<tr><td>Cargo
$55.00/hour</td><td>71.25</td></tr>
<tr><td>Car</td><td>10.45</td><td>$51.42/hour</td><td>537.13</td></tr>
<tr><td colspan="2" rowspan="2">Fuel Consumption (M gallon)</td><td rowspan="2">2.73</td><td>Gasoline
$3.43/gal</td><td rowspan="2">9.73</td></tr>
<tr><td>Diesel
$3.76/gal</td></tr>
<tr><td rowspan="4">Emissions</td><td>HC (ton)</td><td>153.50</td><td>$6,700/ton</td><td rowspan="4">13.53</td></tr>
<tr><td>CO (ton)</td><td>1,724.00</td><td>$6,360/ton</td></tr>
<tr><td>NO (ton)</td><td>73.51</td><td>$12,875/ton</td></tr>
<tr><td>CO_2 (metric ton)</td><td>25,635.43</td><td>$23/metric ton</td></tr>
<tr><td colspan="2">Total</td><td colspan="3">$664.42 M</td></tr>
</table>

Table 7.9(b) Total Direct Benefits for I-95 in 2024b

<table>
<tr><th colspan="2">Reduction due to CHART</th><th>Amount</th><th>Unit rate</th><th>In M Dollar</th></tr>
<tr><td rowspan="3">Delay (M veh-hr)</td><td rowspan="2">Truck</td><td rowspan="2">1.30</td><td>Driver
$25.31/hour</td><td>32.79</td></tr>
<tr><td>Cargo
$55.00/hour</td><td>71.25</td></tr>
<tr><td>Car</td><td>10.45</td><td>$51.42/hour</td><td>537.13</td></tr>
<tr><td colspan="2" rowspan="2">Fuel Consumption (M gallon)</td><td rowspan="2">2.71</td><td>Gasoline
$3.43/gal</td><td rowspan="2">9.63</td></tr>
<tr><td>Diesel
$3.76/gal</td></tr>
<tr><td rowspan="4">Emissions</td><td>VOC (ton)</td><td>47.47</td><td>$1,840/ton</td><td rowspan="4">5.26</td></tr>
<tr><td>CO (ton)</td><td>56.68</td><td>$1,465/ton</td></tr>
<tr><td>NO (ton)</td><td>10.07</td><td>$8,140/ton</td></tr>
<tr><td>CO_2 (metric ton)</td><td>26,367.11</td><td>$190/metric ton</td></tr>
<tr><td colspan="2">Total</td><td colspan="3">$656.06 M</td></tr>
</table>

7.4 DIRECT BENEFITS TO HIGHWAY USERS

Table 7.9(c) Total Direct Benefits for I-95/495 in 2024a

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	Truck	0.26	Driver *$25.31/hour*	6.67
			Cargo *$55.00/hour*	14.49
	Car	3.38	*$51.42/hour*	173.91
Fuel Consumption (M gallon)		0.75	Gasoline *$3.43/gal*	2.65
			Diesel *$3.76/gal*	
Emissions	HC (ton)	47.66	$6,700/ton	4.18
	CO (ton)	535.30	$6,360/ton	
	NO (ton)	22.83	$12,875/ton	
	CO_2 (metric ton)	6,955.13	$23/metric ton	
Total		**$201.90 M**		

Table 7.9(d) Total Direct Benefits for I-95/495 in 2024b

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	Truck	0.26	Driver *$25.31/hour*	6.67
			Cargo $55.00/hour	14.49
	Car	3.38	*$51.42/hour*	173.91
Fuel Consumption (M gallon)		0.75	Gasoline *$3.43/gal*	2.65
			Diesel *$3.76/gal*	
Emissions	VOC (ton)	14.74	$1,840/ton	1.46
	CO (ton)	17.60	$1,465/ton	
	NO (ton)	3.13	$8,140/ton	
	CO_2 (metric ton)	7,267.19	$190/metric ton	
Total		**$199.18 M**		

Table 7.9(e) Total Direct Benefits for I-270 in 2024a

Reduction due to CHART		**Amount**	**Unit rate**	**In M Dollar**
Delay (M veh-hr)	**Truck**	0.04	Driver *$25.31/hour*	1.00
			Cargo *$55.00/hour*	2.17
	Car	1.24	*$51.42/hour*	63.71
Fuel Consumption (M gallon)		0.23	Gasoline *$3.43/gal*	0.8
			Diesel *$3.76/gal*	
Emissions	**HC (ton)**	16.71	$6,700/ton	1.46
	CO (ton)	187.71	$6,360/ton	
	NO (ton)	8.00	$12,875/ton	
	CO_2 (metric ton)	2,054.67	$23/metric ton	
Total		**$69.12 M**		

Table 7.9(f) Total Direct Benefits for I-270 in 2024b

Reduction due to CHART		**Amount**	**Unit rate**	**In M Dollar**
Delay (M veh-hr)	**Truck**	0.04	Driver *$25.31/hour*	1.00
			Cargo *$55.00/hour*	2.17
	Car	1.24	*$51.42/hour*	63.71
Fuel Consumption (M gallon)		0.23	Gasoline *$3.43/gal*	0.8
			Diesel *$3.76/gal*	
Emissions	**VOC (ton)**	5.17	$1,840/ton	0.42
	CO (ton)	6.17	$1,465/ton	
	NO (ton)	1.10	$8,140/ton	
	CO_2 (metric ton)	2,055.25	$190/metric ton	
Total		**$68.09 M**		

7.4 DIRECT BENEFITS TO HIGHWAY USERS

Table 7.9(g) Total Direct Benefits for I-695 in 2024a

<table>
<tr><th colspan="2">Reduction due to CHART</th><th>Amount</th><th>Unit rate</th><th>In M Dollar</th></tr>
<tr><td rowspan="3">Delay (M veh-hr)</td><td rowspan="2">Truck</td><td rowspan="2">0.27</td><td>Driver
$25.31/hour</td><td>6.80</td></tr>
<tr><td>Cargo
$55.00/hour</td><td>14.77</td></tr>
<tr><td>Car</td><td>4.06</td><td>*$51.42/hour*</td><td>209.01</td></tr>
<tr><td colspan="2" rowspan="2">Fuel Consumption (M gallon)</td><td rowspan="2">0.86</td><td>Gasoline
$3.43/gal</td><td rowspan="2">3.03</td></tr>
<tr><td>Diesel
$3.76/gal</td></tr>
<tr><td rowspan="4">Emissions</td><td>HC (ton)</td><td>56.65</td><td>$6,700/ton</td><td rowspan="4">4.96</td></tr>
<tr><td>CO (ton)</td><td>636.27</td><td>$6,360/ton</td></tr>
<tr><td>NO (ton)</td><td>27.13</td><td>$12,875/ton</td></tr>
<tr><td>CO_2 (metric ton)</td><td>7,942.98</td><td>$23/metric ton</td></tr>
<tr><td colspan="2">Total</td><td colspan="3">$238.57 M</td></tr>
</table>

Table 7.9(h) Total Direct Benefits for I-695 in 2024b

<table>
<tr><th colspan="2">Reduction due to CHART</th><th>Amount</th><th>Unit rate</th><th>In M Dollar</th></tr>
<tr><td rowspan="3">Delay (M veh-hr)</td><td rowspan="2">Truck</td><td rowspan="2">0.27</td><td>Driver
$25.31/hour</td><td>6.80</td></tr>
<tr><td>Cargo
$55.00/hour</td><td>14.77</td></tr>
<tr><td>Car</td><td>4.06</td><td>*$51.42/hour*</td><td>209.01</td></tr>
<tr><td colspan="2" rowspan="2">Fuel Consumption (M gallon)</td><td rowspan="2">0.87</td><td>Gasoline
$3.43/gal</td><td rowspan="2">3.04</td></tr>
<tr><td>Diesel
$3.76/gal</td></tr>
<tr><td rowspan="4">Emissions</td><td>VOC (ton)</td><td>17.52</td><td>$1,840/ton</td><td rowspan="4">1.60</td></tr>
<tr><td>CO (ton)</td><td>20.92</td><td>$1,465/ton</td></tr>
<tr><td>NO (ton)</td><td>3.71</td><td>$8,140/ton</td></tr>
<tr><td>CO_2 (metric ton)</td><td>7,945.23</td><td>$190/metric ton</td></tr>
<tr><td colspan="2">Total</td><td colspan="3">$235.22 M</td></tr>
</table>

7.4 DIRECT BENEFITS TO HIGHWAY USERS

Table 7.9(i) Total Direct Benefits for I-70 in 2024a

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	Truck	0.19	Driver *$25.31/hour*	4.77
			Cargo *$55.00/hour*	10.36
	Car	1.61	*$51.42/hour*	82.66
Fuel Consumption (M gallon)		0.41	Gasoline *$3.43/gal* Diesel *$3.76/gal*	1.46
Emissions	HC (ton)	23.48	$6,700/ton	2.07
	CO (ton)	263.72	$6,360/ton	
	NO (ton)	11.25	$12,875/ton	
	CO_2 (metric ton)	3,851.16	$23/metric ton	
Total		$101.33 M		

Table 7.9(j) Total Direct Benefits for I-70 in 2024b

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	Truck	0.19	Driver *$25.31/hour*	4.77
			Cargo $55.00/hour	10.36
	Car	1.61	*$51.42/hour*	82.66
Fuel Consumption (M gallon)		0.41	Gasoline *$3.43/gal* Diesel *$3.76/gal*	1.45
Emissions	VOC (ton)	7.26	$1,840/ton	0.79
	CO (ton)	8.67	$1,465/ton	
	NO (ton)	1.54	$8,140/ton	
	CO_2 (metric ton)	3,969.02	$190/metric ton	
Total		$100.04 M		

7.4 DIRECT BENEFITS TO HIGHWAY USERS

Table 7.9(k) Total Direct Benefits for I-83 in 2024a

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	**Truck**	0.10	Driver *$25.31/hour*	2.59
			Cargo $55.00/hour	5.63
	Car	0.76	*$51.42/hour*	38.84
Fuel Consumption (M gallon)		0.20	Gasoline *$3.43/gal*	0.73
			Diesel *$3.76/gal*	
Emissions	**HC (ton)**	11.21	$6,700/ton	0.99
	CO (ton)	125.94	$6,360/ton	
	NO (ton)	5.37	$12,875/ton	
	CO_2 (metric ton)	1,928.84	$23/metric ton	
Total		**$48.78M**		

Table 7.9(l) Total Direct Benefits for I-83 in 2024b

Reduction due to CHART		Amount	Unit rate	In M Dollar
Delay (M veh-hr)	**Truck**	0.10	Driver *$25.31/hour*	2.59
			Cargo $55.00/hour	5.63
	Car	0.76	*$51.42/hour*	38.84
Fuel Consumption (M gallon)		0.20	Gasoline *$3.43/gal*	0.72
			Diesel *$3.76/gal*	
Emissions	**VOC (ton)**	3.47	$1,840/ton	0.39
	CO (ton)	4.14	$1,465/ton	
	NO (ton)	0.74	$8,140/ton	
	CO_2 (metric ton)	1,977.55	$190/metric ton	
Total		**$48.18 M**		

DIRECT BENEFITS TO HIGHWAY USERS

7.4

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 2024 were 1,570 hours/day and 39,634 hours/day for trucks and cars, respectively, compared with the 1,701 hours/day for trucks and 47,462 hours/day for cars in 2023. The delay reduction for trucks in the Baltimore region increased from 7,024 hours/day in 2023 to 7,313 hours/day in 2024, and decreased from 27,857,957 hours/day in 2023 to 26,477,714 hours/day in 2024 for passenger cars.

The overall reductions in emissions (i.e., by cars and trucks) for the entire region were $186,655/day for the year 2023. In the year 2024, the overall reductions in emissions with the original parameters (2024a) is $204,663/day, and with the new parameters (2024b) is $57,673/day.

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		
		2024a	2024b	2023	2024a	2024b	2023	2024a	2024b	2023
Annual Delay Reduction	hour	2,309,572	2,309,572	2,268,452	408,281	408,281	442,181	1,901,291	1,901,291	1,826,271
Daily Delay Reduction	hour	8,883	8,883	8,725	1,570	1,570	1,701	7,313	7,313	7,024
Emission Reduction										
HC reduction	ton/day	0.12	-	0.11	0.04	-	0.04	0.08	-	0.07
	$/day	778.05	-	764.20	256.22	-	262.92	521.83	-	501.28
VOC reduction	ton/day	-	0.036	-	-	0.012	-	-	0.024	-
	$/day	-	66.08	-	-	21.76	-	-	44.32	-
CO reduction	ton/day	1.30	0.043	1.28	0.43	0.014	0.44	0.87	0.029	0.84
	$/day	8,295.32	62.82	8,147.63	2,731.77	20.689	2,803.19	5,563.54	41.57	5,344.44
NO reduction	ton/day	0.056	0.008	0.055	0.018	0.003	0.019	0.037	0.005	0.036
	$/day	716.06	61.98	703.31	235.81	20.41	241.97	480.25	128.03	461.34
CO2 reduction	ton/day	76.65	72.37	75.30	25.24	23.83	25.91	51.41	48.53	49.40
	$/day	1,762.91	13,749.39	1,732.01	4795.88	4,527.88	595.90	9,767.30	9,221.51	1,136.11
Total	$/day	11,552.34	13,940.28	11,347.15	8,019.68	4,590.75	3,903.99	16,332.97	9,435.43	7,443.16

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		
		2024a	2024b	2023	2024a	2024b	2023	2024a	2024b	2023
Annual Delay Reduction	hr	36,782,621	36,782,621	40,198,092	10,304,906	10,304,906	12,340,134	26,477,714	26,477,714	27,857,957
Daily Delay Reduction	hr	141,471	141,471	154,608	39,634	39,634	47,462	101,837	101,837	107,145
Emission Reduction										
HC reduction	ton/ day	1.849	-	2.021	0.609	-	0.695	1.240	-	1.326
	$/ day	12,391.37	-	13,541.98	4,080.67	-	4,659.12	8,310.70	-	8,882.86
VOC reduction	ton/ day	-	0.57	-	-	0.19	-	-	0.38	-
	$/ day	-	1,052.42	-	-	346.58	-	-	705.85	-
CO reduction	ton/ day	20.78	0.68	22.70	6.84	0.23	7.81	13.93	0.46	14.89
	$/ day	132,112.59	1,000.54	144,379.98	43,506.68	329.49	49,673.94	88,605.90	671.04	94,706.04
NO reduction	ton/ day	0.89	0.12	0.97	0.29	0.04	0.33	0.60	0.08	0.64
	$/ day	11,404.08	987.16	12,463.01	3,755.54	325.09	4,287.90	7,648.54	662.08	8,175.11
CO2 reduction	ton/ day	195.81	214.18	214.05	64.48	70.53	73.64	131.32	143.64	140.41
	$/ day	37,203.33	40,693.27	4,923.14	12,251.62	13,400.91	1,693.80	24,951.70	27,292.36	3,229.33
Total	$/ day	193,111.36	43,733.40	175,308.10	63.594.51	14,402.07	60,314.76	129,516.86	29,331.32	114,993.34

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 2024 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 2024 was 12.73 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 2024 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 2024, 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 staff 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 to employ 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.

APPENDIX A – ADDITIONAL ANALYSIS TO INCIDENTS /DISABLED VEHICLES

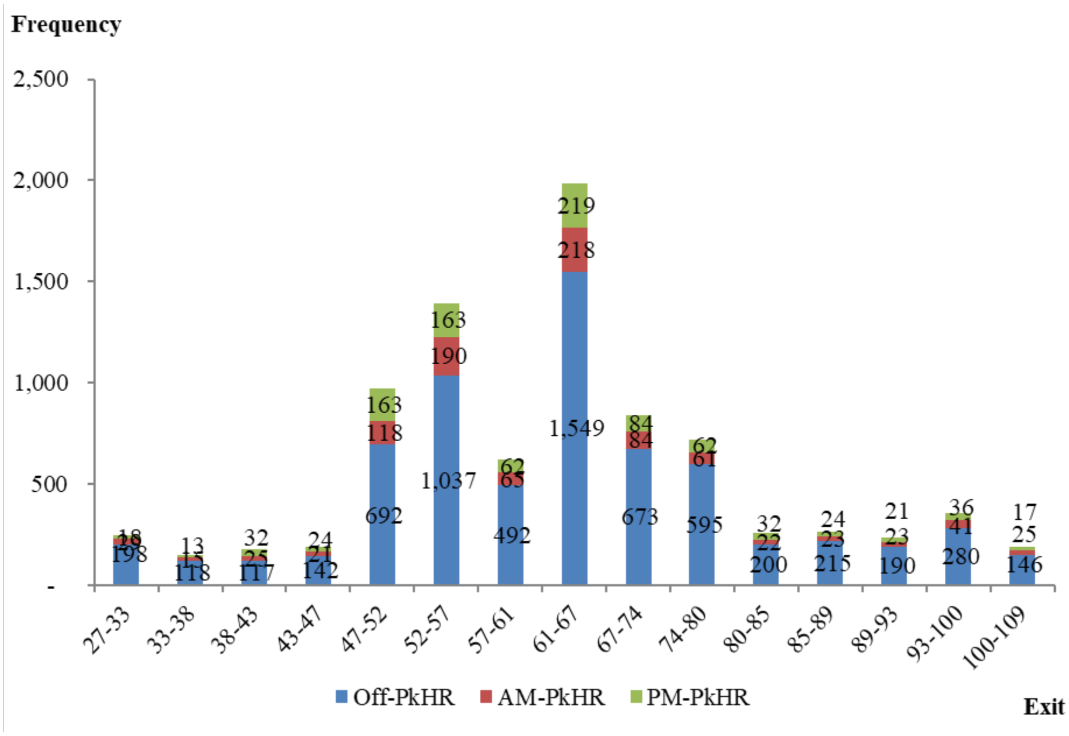


Figure A.1 Distribution of Incidents by Time of Day on I-95 in Year 2024

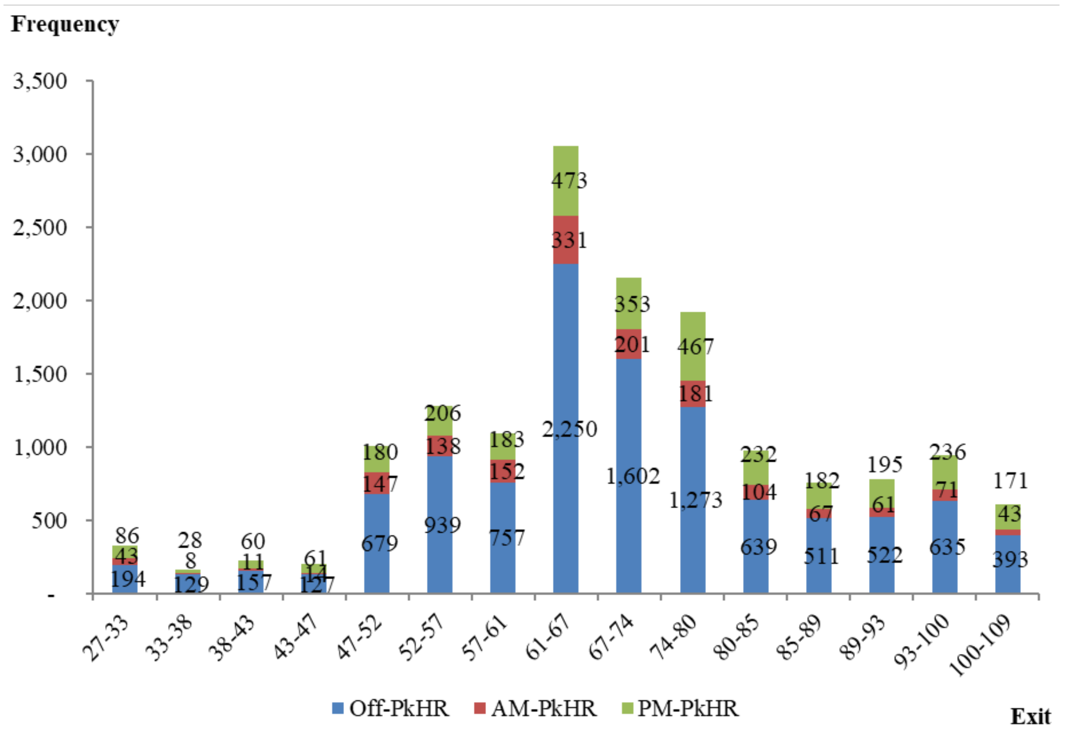


Figure A.2 Distribution of Disabled Vehicles by Time of Day on I-95 in Year 2024

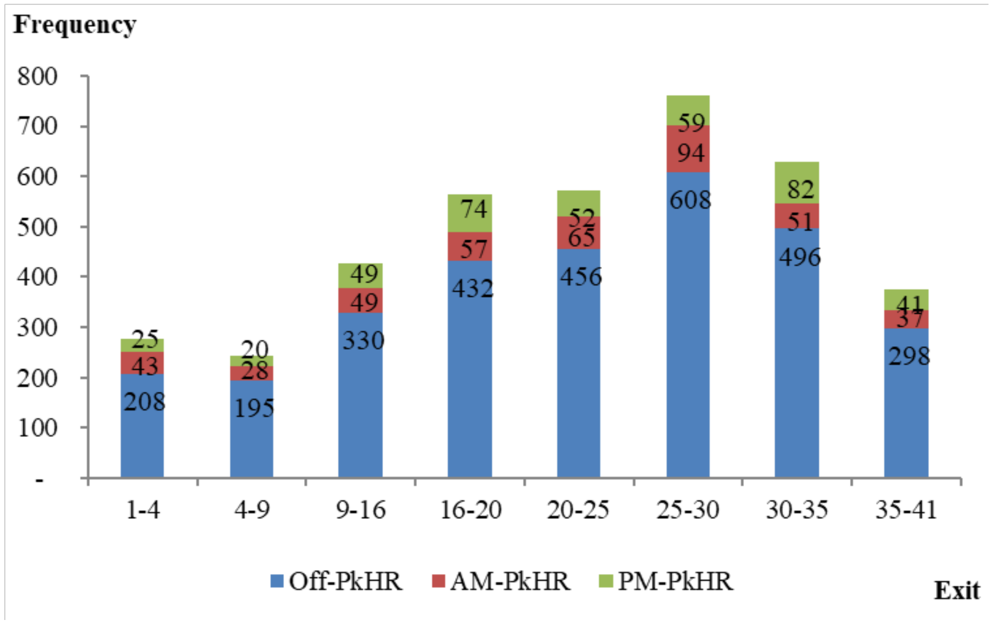


Figure A.3 Distribution of Incidents by Time of Day on I-495 in Year 2024

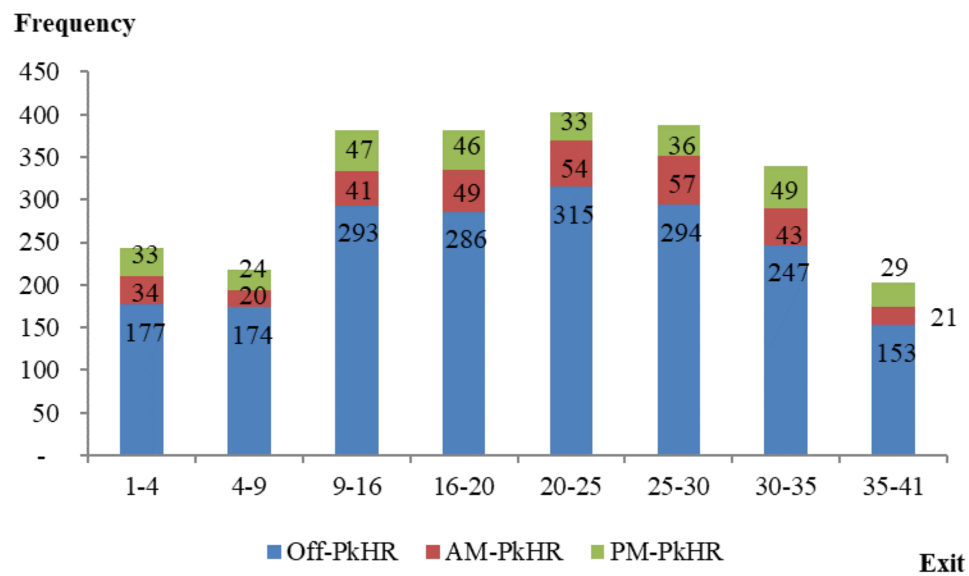


Figure A.4 Distribution of Disabled Vehicles by Time of Day on I-495 in Year 2024

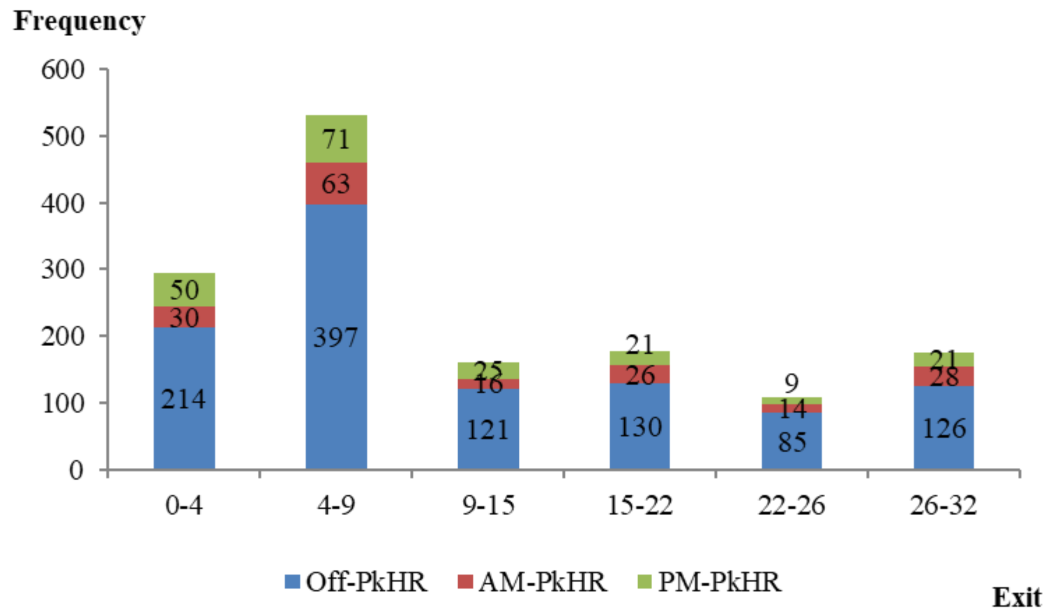


Figure A.5 Distribution of Incidents by Time of Day on I-270 in Year 2024

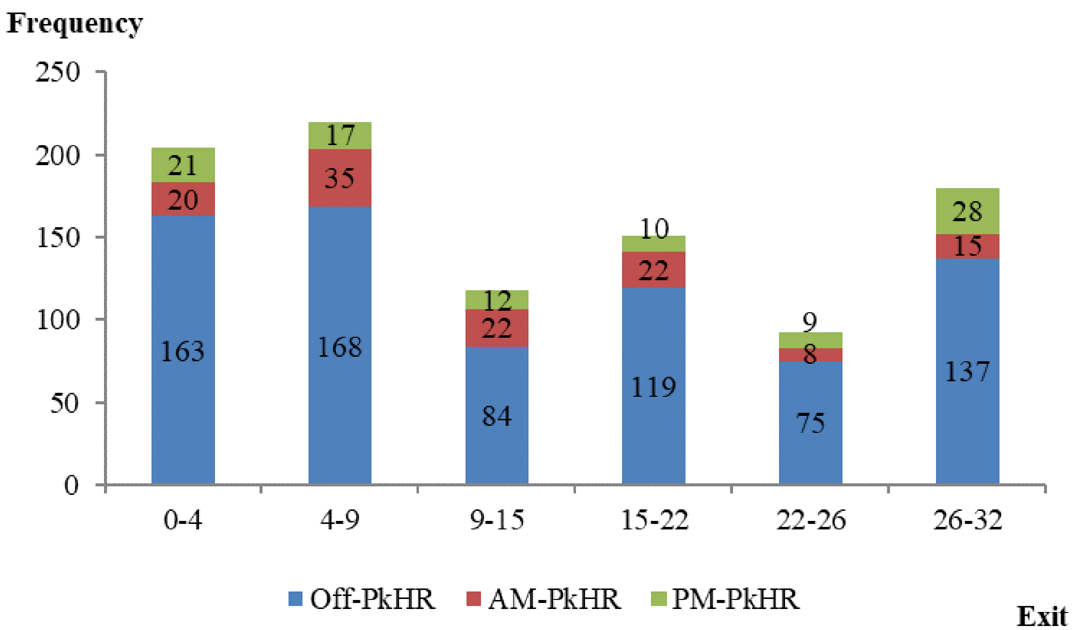


Figure A.6 Distribution of Disabled Vehicles by Time of Day on I-270 in Year 2024

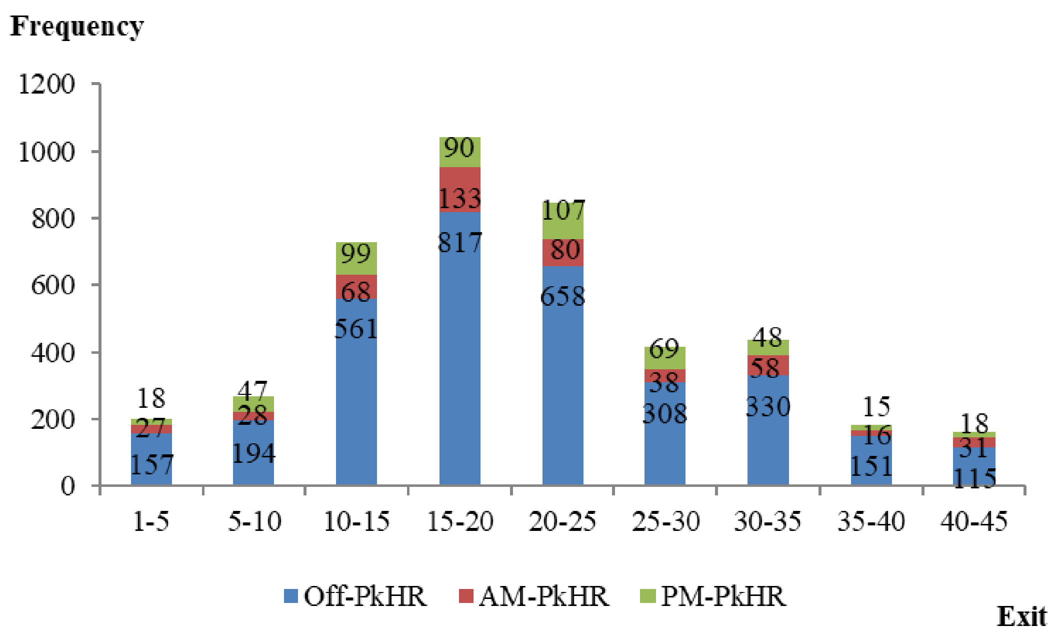


Figure A.7 Distribution of Incidents by Time of Day on I-695 in Year 2024

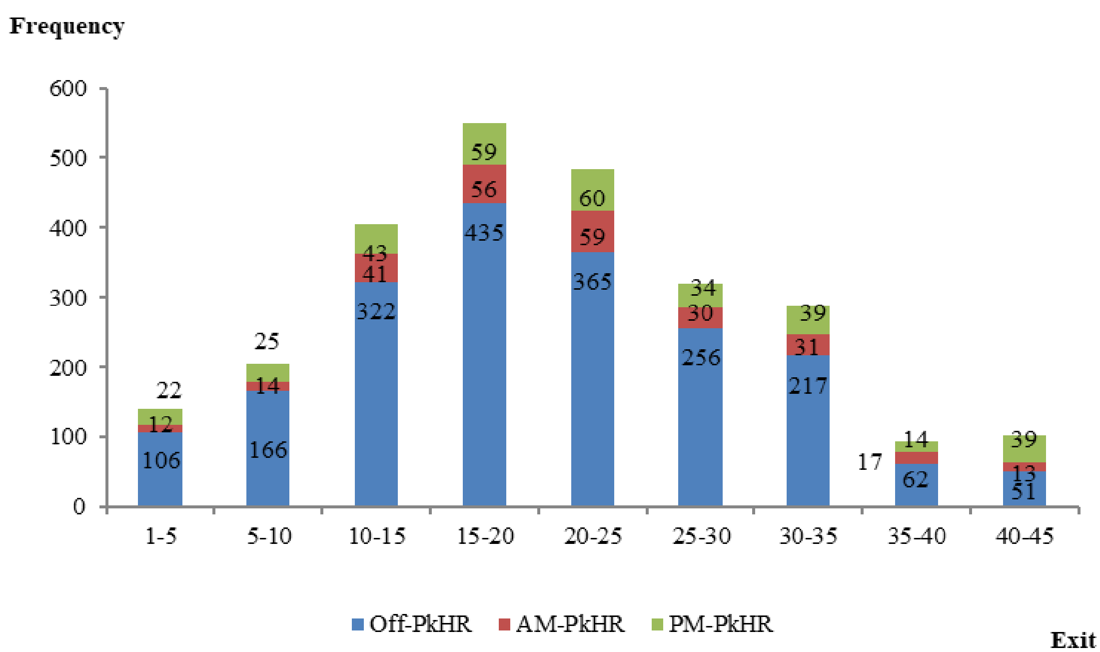


Figure A.8 Distribution of Disabled Vehicles by Time of Day on I-695 in Year 2024

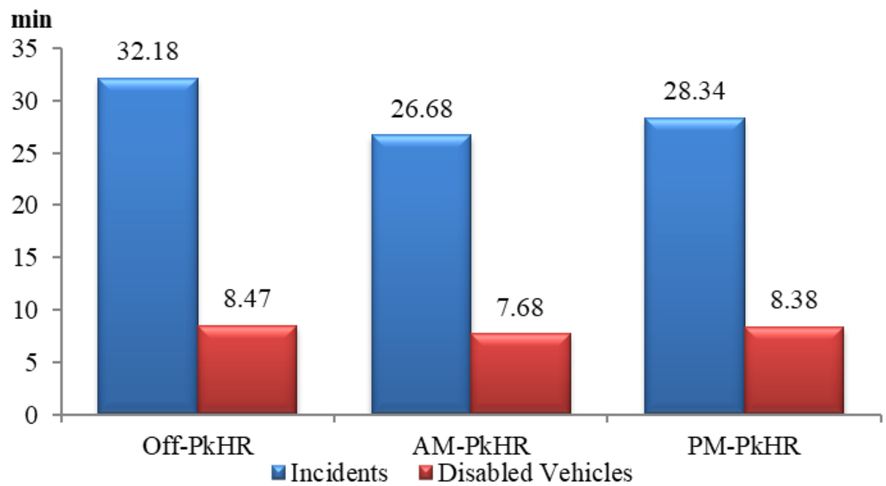


Figure A.9 Distribution of Clearance Time by Time of Day in Year 2024

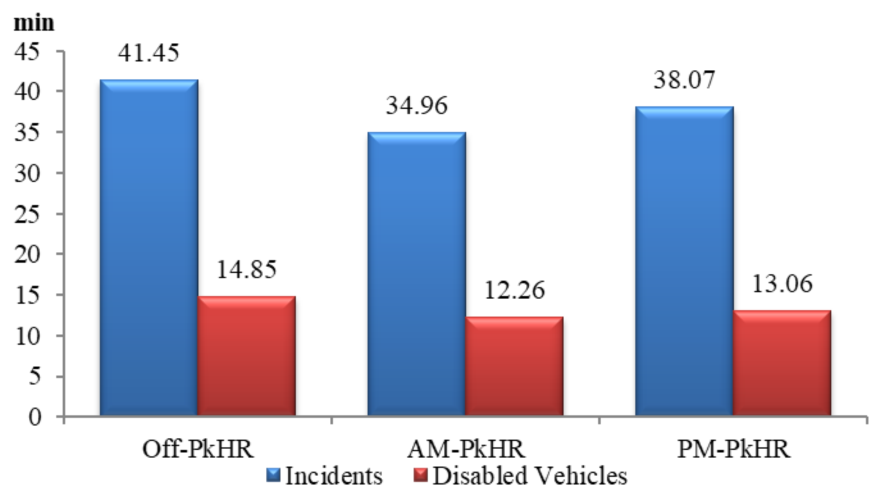


Figure A.10 Distribution of Incident Duration by Time of Day in Year 2024

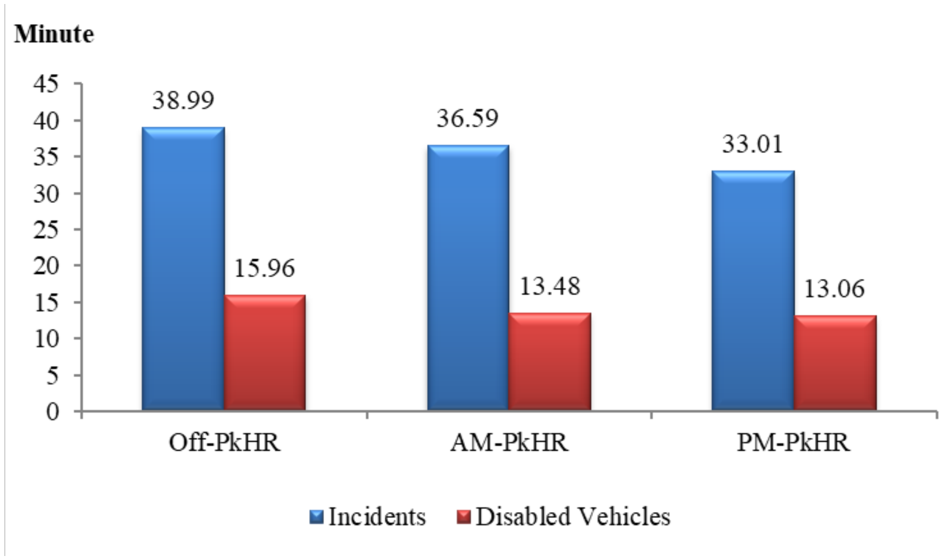


Figure A.11 Distribution of Incident Duration by Time of Day on I-95 in Year 2024

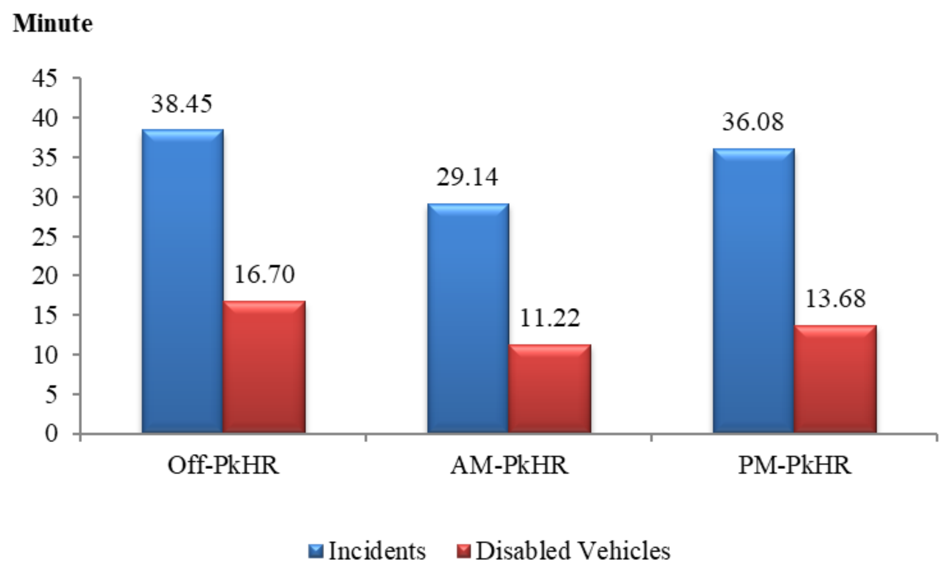


Figure A.12 Distribution of Incident Duration by Time of Day on I-495 in Year 2024

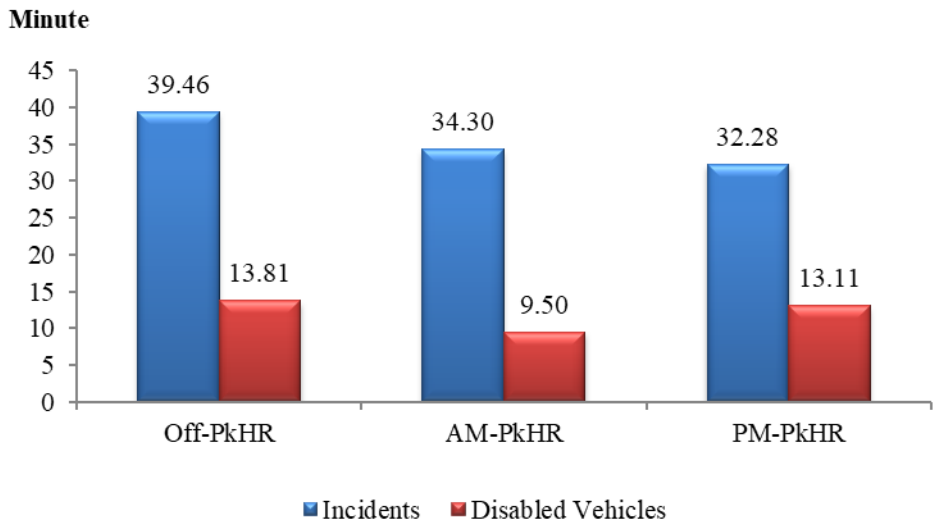


Figure A.13 Distribution of Incident Duration by Time of Day on I-270 in Year 2024

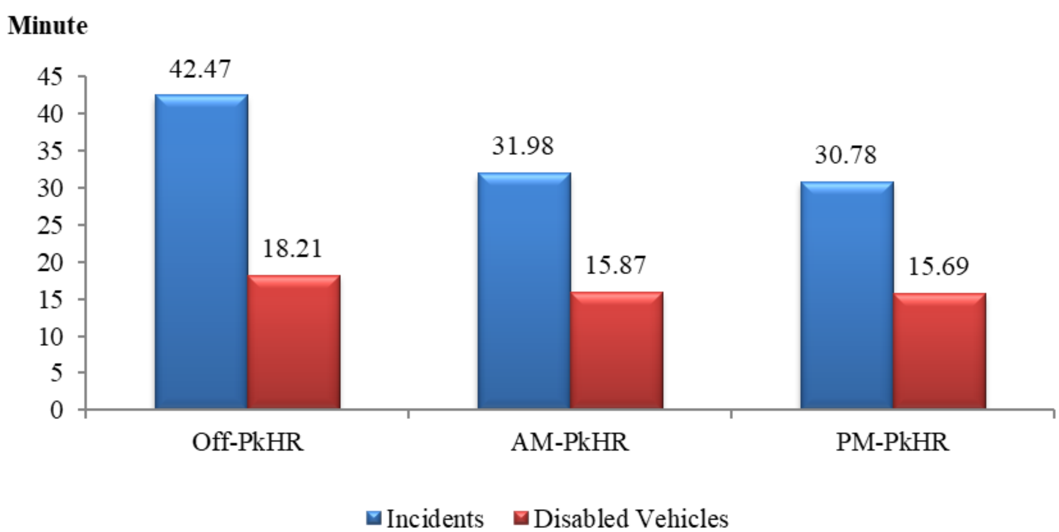


Figure A.14 Distribution of Incident Duration by Time of Day on I-695 in Year 2024

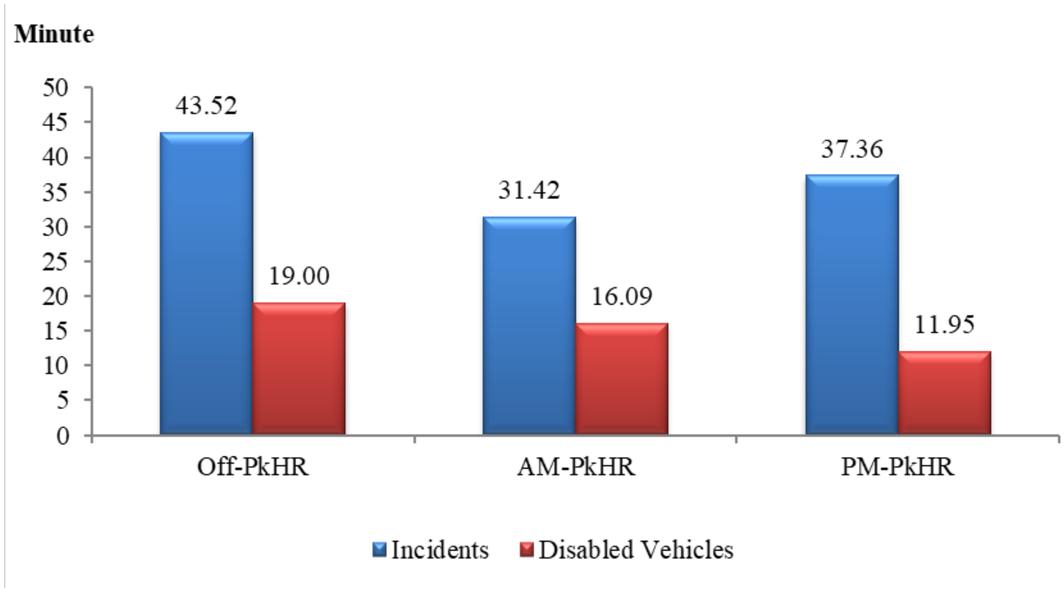


Figure A.15 Distribution of Incident Duration by Time of Day on I/MD-295 in Year 2024

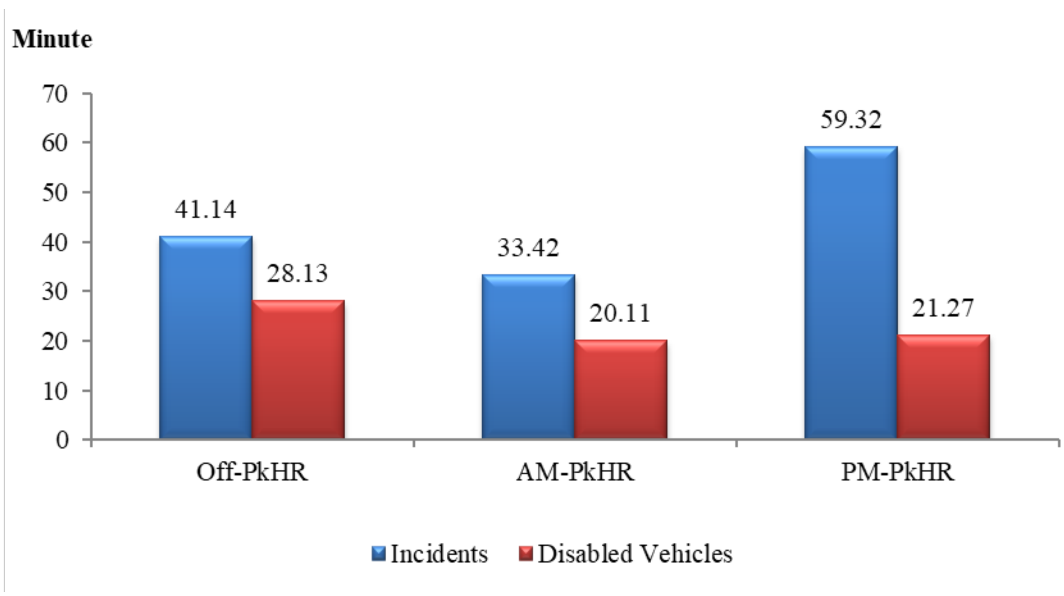
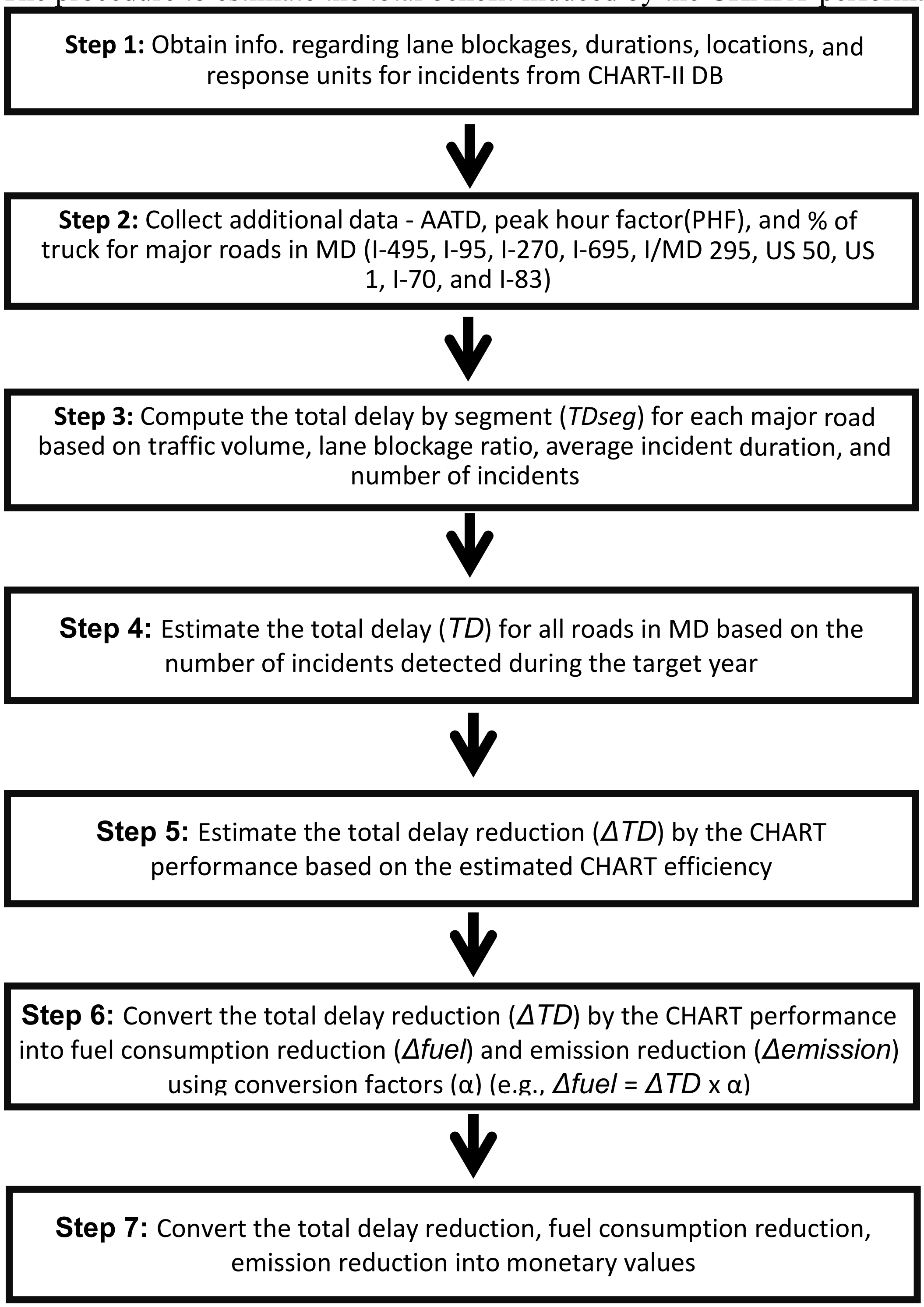


Figure A.16 Distribution of Incident Duration by Time of Day on I-83 in Year 2024

APPENDIX B - Benefit Estimation Procedure and Sensitivity Analysis

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



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