



# Performance Evaluation and Benefit Analysis for CHART in Year 2021 – Coordinated Highways Action Response Team –

November 2022

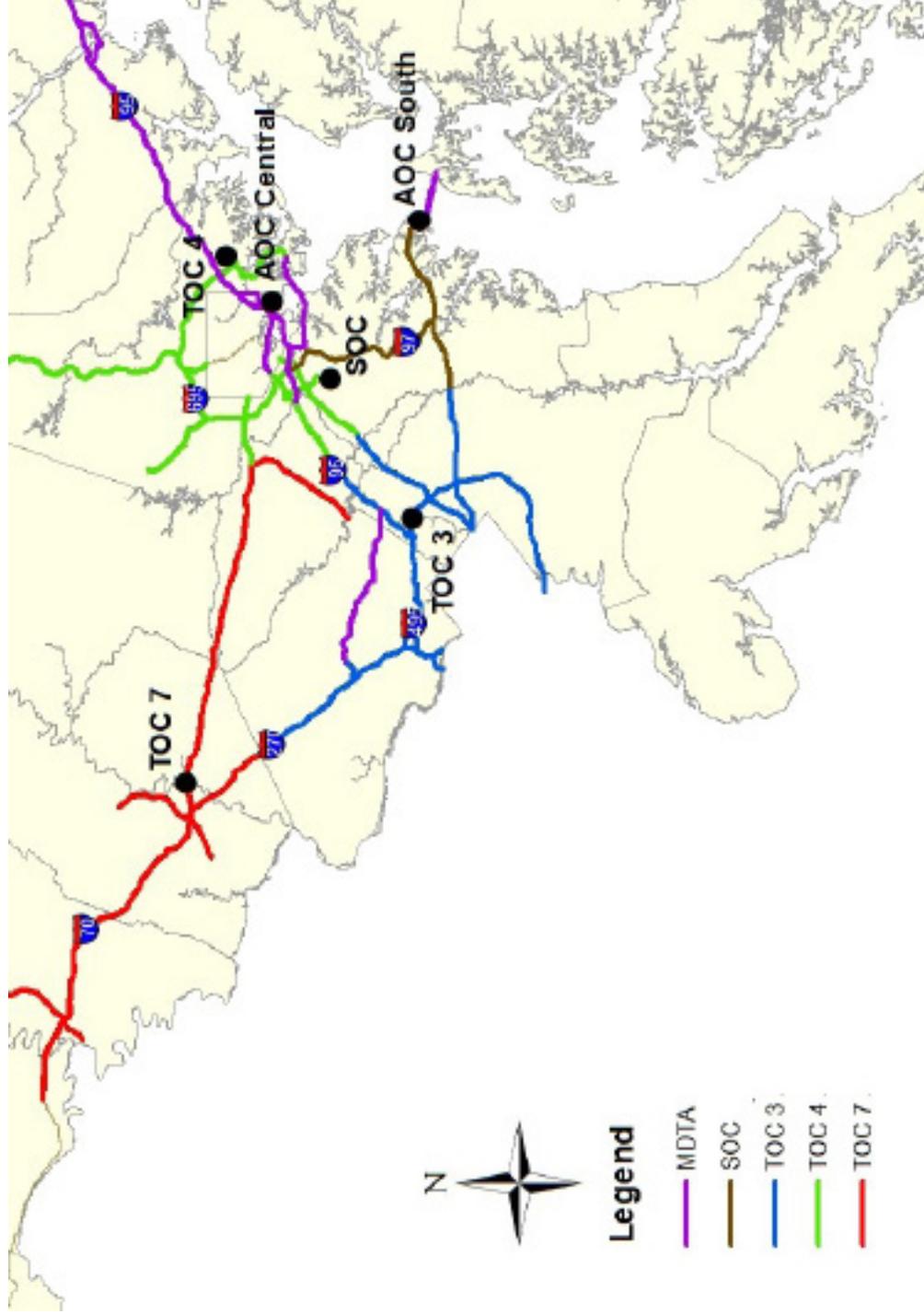


Department of Civil and Environmental Engineering  
The University of Maryland, College Park



Office of Transportation Mobility and Operations  
Maryland Department of Transportation  
State Highway Administration

Performance Evaluation of CHART  
The Real-Time Incident Management System (Year 2021)



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# EXECUTIVE SUMMARY

## Objectives

This report presents the performance evaluation study of the Coordinated Highways Action Response Team (CHART) for the Year 2021, including its operational efficiency and resulting benefits. The research team at the Civil and Environmental Engineering Department of the University of Maryland, College Park (UM), has conducted the annual CHART performance analysis over the past 24 years for the Maryland State Highway Administration (MDOT SHA).

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

The study consisted of two phases. Phase 1 focused on defining objectives, identifying the available data, and developing the methodology. The core of the second phase involved assessing the efficiency of the incident management program and estimating the resulting benefits using the 2021 CHART incident operations data. As some information essential for efficiency and benefit assessment was not available in the CHART-II database, this study presents only those evaluation results that can be directly computed from the incident management data or derived with statistical methods.

## Available Data for Analysis

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

To better the evaluation quality and also in view of the fact that the Statewide Operations Center (SOC) has been opened in August of 1995, those associated with the evaluation study concluded that the analysis should be based on actual performance data from the CHART program. Hence, in 1996, the UM research team (Chang and Point-Du-Jour, 1998) was contracted to work jointly with MDOT SHA staff to compile and conduct the research with respect to CHART performance using the available data.

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

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

Unlike previous studies, the quality and quantity of data available for performance evaluation have been increased considerably since 1999. This results from CHART reflect the need to keep an extensive operational record in order to justify its costs to operate the emergency incident response program and estimate the resulting benefits. Due to CHART's efficient data collection, the documentation of lane-closure-related incidents increased from 2,567 in 1997 to 38,275 in 2021.

Table E.1 shows the total number of emergency response operations assiduously documented from 2017 to 2021:

**Table E.1 Total Number\* of Emergency Response Records from 2017 to 2021**

	2017	2018	2019	2020	2021	Δ (2021-2020)
<b>Incidents only</b>	37,100 (30,335)	41,247 (34,692)	38,383 (31,750)	34,590 (26,702)	38,275 (29,546)	10.65% (10.65%)
<b>Total</b>	81,299 (72,381)	88,138 (79,956)	79,506 (71,233)	70,115 (60,665)	76,722 (65,839)	9.42% (8.53%)

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

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

It should be noticed that CHART has responded to more incidents this year than last year. This may be due to an increase in the networkwide incidents.

## Evolution of the Evaluation Work

CHART has consistently worked to improve its data recording for both major and minor incidents over the past two decades, achieving substantial improvements in data quality and quantity. The evaluation work has also been advanced by the increased level of data availability. Since the quality of available data is critical to a reliable estimate of CHART's performance and contributing benefits, the performance evaluation reports have included data quality analysis from 1999 to ensure continued advancement in the quality of incident-related data.

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

## Distribution of Incidents/Disabled Vehicles

The evaluation methodology was created to use all available data sets of acceptable quality. An analysis of incident/disabled vehicle characteristics by its duration and number of blocked lanes was firstly conducted in this annual CHART benefit analysis study.

As shown in Table E.2, the results of 2021 incident data indicate that there were a total of 3,290 incidents resulting in one-lane blockage, 9,328 incidents causing two-lane closures, and 5,534 incidents blocking three or more lanes. Either disabled vehicles or minor incidents caused a total of 45,258 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<sup>1</sup> of Incidents/Disabled vehicles by Lane Blockage Type**

	2017	2018	2019	2020	2021	Δ (2021-2020)
<b>Shoulder<sup>2</sup></b>	51,115	54,630	48,485	41,409	45,258	9.30%
<b>1 lane</b>	3,727	3,948	3,480	3,221	3,290	2.14%
<b>2 lanes<sup>3</sup></b>	8,383	9,589	8,823	8,205	9,328	13.69%
<b>3 lanes<sup>3</sup></b>	2,859	3,086	2,965	2,780	3,062	10.14%
<b>≥ 4 lanes<sup>3</sup></b>	2,114	2,458	2,301	2,331	2,472	6.05%

\* Note: 1. This analysis is based only on the samples with complete information for identifying 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 12,068 incidents/disabled vehicles in 2021; I-695, I-95, US-50, I/MD-295, and I-270 with 8,585, 12,838, 7,807, 3,120, and 4,484 incidents/disabled vehicles, respectively. The distributions of incidents/disabled vehicles on those major commuting corridors between 2017 and 2021 are shown in Table E.3:

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

	2017	2018	2019	2020	2021	Δ (2021 - 2020)
<b>I-495/95</b>	12,570	11,807	10,589	10,339	12,068	16.72%
<b>I-695</b>	12,249	11,752	10,705	8,025	8,585	6.98%
<b>I-95</b>	11,259	15,619	14,729	12,937	12,838	-0.77%
<b>US-50</b>	8,053	7,940	7,208	6,492	7,807	20.26%
<b>I/MD-295</b>	3,459	3,578	3,152	2,694	3,120	15.81%
<b>I-270</b>	4,998	5,086	4,892	4,058	4,484	10.50%

\* 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 2021 are shown in Table E.4. The highest frequency of incidents occurred on the I-95 southbound segment between Exits 56 and 57, and the I-95 northbound segment between Exits 55 and 56 in AM and PM peaks, respectively. The inner loop of I-495 between Exits 13 and 15 and the inner loop of I-495 between Exits 34 and 36 ranked the first with the respect to the number of disabled vehicle assists in 2021 in AM and PM peak hours.

**Table E.4 Top 10 Freeway Sections with the Most Incidents/Disabled Vehicles in 2021**

	Incidents				Disabled vehicles			
	AM Peak		PM Peak		AM Peak		PM Peak	
<b>1</b>	I-95 S	Exits 56&57	I-95 N	Exits 55&56	I-495 IL	Exits 13&15	I-495 IL	Exits 34&36
<b>2</b>	I-95 N	Exits 55&56	I-95 N	Exits 67&74	I-495 OL	Exits 3&4	I-95 N	Exits 67&74
<b>3</b>	I-695 IL	Exits 43&44	I-95 S	Exits 56&57	I-95 N	Exits 61&62	I-495 OL	Exits 4&7
<b>4</b>	I-495 OL	Exits 27&28	I-695 IL	Exits 11&12	I-95 S	Exits 67&74	I-495 IL	Exits 13&15
<b>5</b>	I-95 N	Exits 67&74	I-95 S	Exits 67&74	I-95 N	Exits 67&74	I-495 OL	Exits 16&17
<b>6</b>	I-95 S	Exits 67&74	I-70 E	Exits 87&91	I-495 IL	Exits 22&23	I-495 OL	Exits 3&4
<b>7</b>	I-95 S	Exits 50&52	I-695 IL	Exits 43&1	I-495 OL	Exits 11&13	I-95 S	Exits 67&74
<b>8</b>	I-95 N	Exits 74&77	I-695 IL	Exits 25&26	I-495 OL	Exits 16&17	US 50 E	Exits 16&22
<b>9</b>	I-95 N	Exits 64&67	I-95 S	Exits 50&52	I-495 OL	Exits 25&28	I-695 IL	Exits 11&12
<b>10</b>	I-495 OL	Exits 17&20	I-95 N	Exits 74&77	I-495 OL	Exits 4&7	I-495 IL	Exits 7&9

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

It should be mentioned that most incidents/disabled vehicles on major commuting freeways did not block traffic for more than one hour. For instance, about 72 percent of incidents/disabled vehicles had durations shorter than 30 minutes in 2021. 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 2017 to 2021 are summarized in Table E.5:

**Table E.5 Distribution\* of Incidents/Disabled Vehicle Duration from 2017 to 2021**

Duration(Hrs)	2017	2018	2019	2020	2021
<b>D &lt; 0.5</b>	76%	74%	73%	73%	72%
<b>0.5 ≤ D &lt; 1</b>	14%	15%	16%	15%	15%
<b>1 ≤ D &lt; 2</b>	6%	6%	7%	7%	8%
<b>2 ≤ D</b>	4%	5%	5%	5%	5%

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

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

## Efficiency of Operations

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

The average response time is defined as the average time from receiving an emergency request to the arrival of an emergency response unit. Table E.6 shows the average response times of 12.64, 14.03, 11.83, 14.67 and 9.45 minutes for TOC-3, TOC-4, TOC-7, SOC and Authority Operations Center (AOC), respectively, in 2021. The results indicate that TOC-3, TOC-4, and TOC-7 took slightly longer response times in 2021 than in 2020. 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 by Center from 2017 to 2021**

Response Time (mins)	2017	2018	2019	2020	2021		
					During OH	After OH	Overall
TOC-3	12.33	13.00	12.99	12.17	12.64 (3,960)	12.33 (15)	12.64 (3,975)
TOC-4	13.17	14.01	13.40	12.98	14.01 (4,911)	17.39 (28)	14.03 (4,939)
TOC-7	10.24	11.46	11.38	11.42	11.72 (3,020)	12.43 (551)	11.83 (3,571)
ESTO	6.95	7.12	6.84	N/A	N/A	N/A	N/A
SOC	13.34	13.78	13.93	14.32	14.67 (5,724)	N/A	14.67 (5,724)
AOC	7.66	8.74	8.99	9.03	9.45 (8,057)	N/A	9.45 (8,057)
OTHER	6.84	8.91	11.68	2.53	3.52 (2)	9.71 (9)	8.58 (11)
<b>Weighted Average</b>	<b>11.44</b>	<b>11.99</b>	<b>11.88</b>	<b>11.64</b>	<b>12.24 (25,674)</b>	<b>12.62 (603)</b>	<b>12.25 (26,277)</b>

\* Note: The number in each parenthesis indicates the available samples with acceptable quality for analysis.

1. This analysis is based on the data of incidents and disabled vehicles (i.e., assists to drivers) which have indicated the responsible operation center and response times.
2. This analysis includes those sample data which have response times between 1 minute and 60 minutes.
3. Events included in this analysis were responded by various units, including CHART, fire boards, state/local polices, private towing companies, etc.
4. OH stands for Operational Hours: TOCs operate 5 a.m. – 9 p.m. Monday through Friday. TOC-3 and TOC-4 began operating seven days a week (5 a.m. - 9 p.m.) as of August 30th, 2017. SOC and AOC operate on a 24 hour/seven-days-a-week basis.
5. ESTO's response records are absorbed by SOC as of Oct 6th, 2019.

The results in Table E.7 reveal that incidents are likely to be responded more promptly than disabled vehicles during both operational and non-operational hours by most operation centers.

**Table E.7 Comparisons of CHART Response Performance during and after Operational Hours**

Response Time (mins)	Operational Hours		Non-operational Hours		Total		
	Incident	Disabled Vehicle	Incident	Disabled Vehicle	Incident	Disabled Vehicle	Sub-total
TOC-3	12.14 (2,878)	15.52 (1,104)	10.30 (10)	14.08 (5)	12.13 (2,888)	15.52 (1,109)	13.07 (3,997)
TOC-4	13.84 (3,585)	17.46 (1,422)	14.69 (16)	18.97 (9)	13.84 (3,601)	17.47 (1,431)	14.88 (5,032)
TOC-7	12.28 (2,377)	12.03 (626)	12.58 (411)	13.63 (137)	12.33 (2,788)	12.32 (763)	12.32 (3,551)
SOC	14.25 (4,949)	19.77 (1,681)	N/A	N/A	14.25 (3,724)	19.77 (1,681)	15.97 (5,405)
AOC	7.60 (5,476)	12.22 (2,221)	N/A	N/A	7.60 (5,476)	12.22 (2,221)	8.93 (7,697)
OTHER	3.52 (2)	N/A	6.03 (8)	39.08 (1)	5.53 (10)	39.08 (1)	8.58 (11)
<b>Weighted Average</b>	<b>11.55 (18,042)</b>	<b>15.26 (9,337)</b>	<b>12.49 (445)</b>	<b>14.12 (152)</b>	<b>11.57 (18,487)</b>	<b>15.55 (7,206)</b>	<b>12.69 (25,693)</b>

\* Note: The number in each parenthesis indicates the data availability.

1. This analysis is based on the records of incidents and disabled vehicles (assistance to drivers) which have the information of the 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: TOCs operate 5 a.m. – 9 p.m. Monday through Friday, TOC-3 and TOC-4 began operating seven days a week (5 a.m. - 9 p.m.) as of August 30, 2017, SOC and AOC operate on a 24 hour/seven-days-a-week basis.

Also, the 2021 data show that CHART's response operations are more efficient when incidents are more severe and cause lane blockages. In general, more severe incidents, especially involving in fatalities or heavy vehicles, demand longer clearance times.

## Analysis of Incident Durations

To better understand the contributions of the incident management program, this study compared the average duration of incidents to which CHART responded with those managed by other agencies. For example, the difference on the average duration for one-lane-blockage incidents between with and without CHART involvement is about 11.47 minutes. (See Table 4.1)

The average duration of incidents managed by CHART response units in 2021 was 26.31 minutes, shorter than the average duration of 37.82 minutes for those incidents by other agencies. Such a difference of about 30.45 percent in 2021, is slightly lower than the same statistics computed with the data in previous year. Performance comparisons of CHART operations from years 2017 to 2021 are summarized in Table E.8:

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

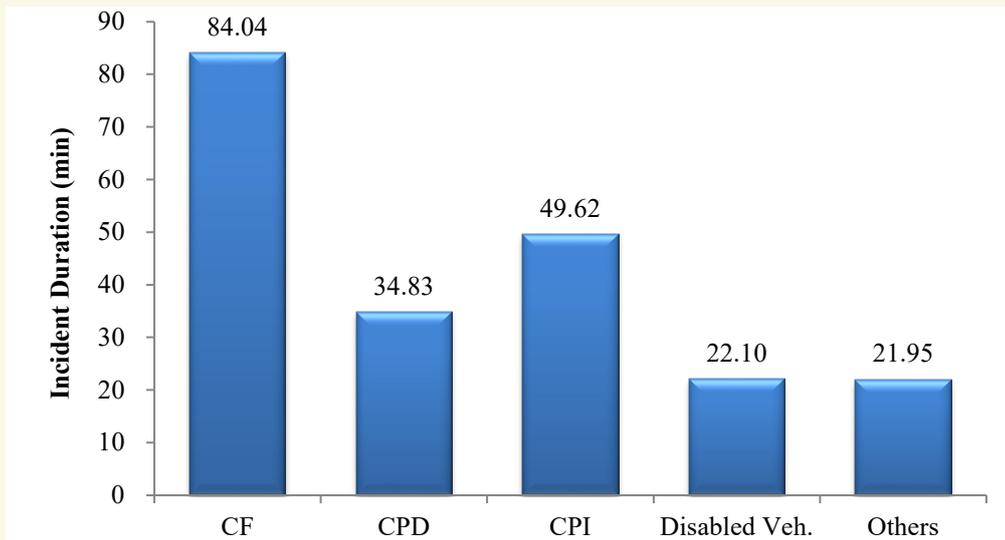
Year	With CHART (mins)	Without CHART (mins)
2017	24.01	34.88
2018	25.42	33.08
2019	25.75	33.91
2020	25.35	37.02
2021	26.31	37.82

- \* Note: 1. This analysis is based on incident records which have included the information of event duration, lane blockage, and response units.  
 2. This analysis includes those sample events which have incident durations between 1 minute and 120 minutes.  
 3. The numbers are the weighted average of incidents with different lane blockages, including shoulder only blockage.

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

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

The average duration of incidents involving fatalities (CF) was 84 minutes, shorter than the average of 92 minutes in year 2020. Incidents with property damage (CPD) and personal injuries (CPI) lasted, on average, 35 and 50 minutes, respectively (see Figure E.1). The average duration of disabled vehicle incidents was 22 minutes, like those classified as “Others” (e.g., debris, vehicles on fire, police activities, etc.) which experienced an average duration of approximately 22 minutes.



\* Notes:

1. This analysis is based on incidents which have included the information of event duration and nature.
2. This analysis includes those sample data which have incident durations between 1 minute and 120 minutes.

**Figure E.1 Distribution of the Average Incident Durations by Nature**

## Resulting Benefits

The benefits due to CHART operations were estimated directly from the available data, including assists to drivers and reductions in delay times, fuel consumption, emissions, and secondary incidents. In 2021, CHART responded to a total of 29,546 (out of 38,275) lane blockage incidents, and assisted 36,293 (out of 38,447) 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 984 potential lane-changing-related collisions in 2021, 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, and it was discovered that various factors may affect the resulting delay, including traffic and heavy vehicle volumes, the number of lane closures, the number of incident responses, and incident durations (see Chapter 7 for further information on benefits estimate). For instance, several primary factors (such as AADT and gas price) have increased in 2021. The ratio in difference between incident durations of with and without CHART and the number of incidents eligible for benefit estimate exhibit a slight reduction in 2021. Overall, the delay reduction due to CHART's services in 2021 (39.74 million vehicle-hours) increased by 68.96 percent, compared to the performance in 2020 (23.52 million vehicle-hours). The collective impacts of all those key contributing factors have resulted in a net benefit increase, i.e., from \$1,080.83M in 2020 to \$1,875.25M in 2021. Comparison results of the direct benefits, estimated from the reduction in delay times, fuel consumptions, and emissions from 2017 to 2021, are summarized in Table E.9:

**Table E.9 Comparison of Direct Benefits from 2017 to 2021**

	<b>Total Direct Benefits (million)<sup>1,2,3,4</sup></b>	<b># of Incidents Eligible for the Benefit Estimate<sup>5</sup></b>
2017	\$1,465.62	29,986
2018	\$1,311.89	33,243
2019	\$1,393.38	30,793
2020	\$1,080.83	28,513
2021	\$1,875.25	31,253

\* Note:

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

Most benefits were produced from delay reductions due to CHART’s efficient incident response and management, especially along the major corridors which are the primary contributors to traffic congestion in Maryland. The estimated delay reduction due to CHART’s services on I-95, I-495, I-270, I-695, I-70, and I-83 are 7.87, 4.34, 1.40, 5.64, 2.40, and 0.84 million vehicle-hours, respectively, in 2021. Such direct benefits for each major road in 2021 are summarized in Table E.10:

**Table E.10 Direct Benefits for Major Roads in 2021 due to CHART operations**

<b>Roads</b>	<b>Total Direct Benefits (million)<sup>1,2,3</sup></b>	<b># of Incidents Eligible for the Benefit Estimate<sup>4</sup></b>
I-95	\$381.26	5,203
I-495/95	\$207.70	3,273
I-270	\$65.63	969
I-695	\$267.64	3,486
I-70	\$116.06	1,601
I-83	\$41.34	725
Others	\$795.61	15,996
<b>Total</b>	<b>\$1,875.25</b>	<b>31,253</b>

\* Note:

1. Results are based on the data from the U.S Census Bureau and Energy Information Administration.
2. The direct benefits are estimated from the reductions in car/truck delay times, fuel consumptions, and emissions due to CHART’s 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 estimated direct benefits are based only on those incidents causing travel lane closure(s).

The main contributing factors used for estimating benefits are listed and tabulated below:

- The total number of incidents used for the benefit estimate increased by about 9.61 percent from year 2020 to year 2021 as shown in Table E.11.
- The ratio, reflecting the difference between incident durations with CHART and those without CHART, decreased from 28.41 percent in 2020 to 28.04 percent in 2021 as shown in Table E.12.
- Table E.13 shows that the adjusted AADT in 2021 increased on all major roads compared to 2020.
- Table E.14 shows that truck percentage decreased in year 2021 over most major roads in Maryland, on average by 4.63 percent.

**Table E.11 The Total Number of Incidents Eligible for the Benefit Estimate from Year 2020 to Year 2021**

	2020	2021	$\Delta('20 \sim '21)^2$
No. of Incidents <sup>1</sup>	28,513	31,253	9.61%

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

2. The percentage change in No. of Incidents (X) from Year 2020 to Year 2021 is calculated as follows:  $\Delta X(\%) = (X_{2021} - X_{2020}) / X_{2020} * 100$

**Table E.12 Average Incident Duration with and without CHART from Year 2020 to Year 2021<sup>1</sup>**

	With CHART (mins) (A)	Without CHART (mins) (B)	Difference (mins) (B-A)	Ratio in Difference ((B-A)/B)
2020	27.06	37.80	10.74	28.41%
2021	27.99	38.89	10.90	28.04%
$\Delta('20 \sim '21)^2$	3.44%	2.88%	1.53%	-1.31%

Note: 1. The analysis is based on those incidents causing main lane blockage, but not with those for shoulder lane blockage only.

2. The percentage change in incident duration (X) from Year 2020 to Year 2021 is calculated as follows:  $\Delta X(\%) = (X_{2021} - X_{2020}) / X_{2020} * 100$

**Table E.13 The adjusted AADT for Major Roads from Year 2020 to Year 2021**

	Year	I-495	I-95	I-270	I-695	MD 295	US 50	US 1	I-83	I-70	Total
$\Sigma$ AADT(vplph)*PHF	2020	10,502	6,827	6,127	9,316	3,600	2,082	4,115	2,293	2,843	47,706
	2021	11,912	7,981	6,987	10,586	4,087	2,342	4,746	2,434	3,162	54,237
$\Delta('20 \sim '21) (\%)*$		13.43	16.90	14.04	13.63	13.53	12.49	15.33	6.15	11.22	13.69

Note: The percentage change in the adjusted AADT (X) from Year 2020 to Year 2021 is calculated as follows:  $\Delta X(\%) = (X_{2021} - X_{2020}) / X_{2020} * 100$

**Table E.14 Truck percentage for Major Roads from Year 2020 to Year 2021**

	Year	I-495	I-95	I-270	I-695	MD 295	US 50	US 1	I-83	I-70	Total
Truck %	2020	9.08	15.62	6.96	8.32	3.03	9.82	4.85	10.54	10.73	8.77
	2021	7.76	11.98	5.41	7.57	2.72	11.30	4.84	13.25	10.47	8.37
$\Delta('20 \sim '21) (\%)*$		-14.50	-23.31	-22.35	-9.01	-10.24	15.08	-0.23	25.68	-2.46	-4.63

Note: The percentage change in the truck percentage (X) from Year 2020 to Year 2021 is calculated as follows:  $\Delta X(\%) = (X_{2021} - X_{2020}) / X_{2020} * 100$

The following procedures are used for performing sensitivity analyses:

- 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 2021 value, but setting all other factors identical to those in 2020; and
- Following the same procedures to analyze the sensitivity of the total 2020 benefits with respect to each key factor.

The results of sensitivity analysis for each factor are shown in the Table E.15. The increase in the average adjusted AADT by 13.69 percent in 2021 contributed to an increase of 43.30 percent in the total benefit. The number of eligible incidents increased by 9.61 percent in 2021, resulting in the benefit increase of 6.54 percent. Note that a decrease of 1.31 percent in the performance difference between incident durations with CHART and those without CHART resulted in a 1.31 percent decrease in the total benefit. The total benefits increase by 2.97 percent due solely to an average increase of 5.14 percent in drivers' income (i.e., a proxy for time value).

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

Benefits of the Previous Year (2020)			1,080.83
Key Factor		$\Delta$ ('20 ~ '21)	Estimated Benefits
Sensitivity Analysis	Adjusted AADT	↑ 13.69 %	1,548.85(↑43.30 %)
	Number of incidents	↑ 9.61 %	1,151.53(↑6.54 %)
	Incident duration percentage difference between w/ and w/o CHART	↓ 1.31 %	1,066.68(↓1.31 %)
	Truck percentage	↓ 4.63 %	1,075.55(↓0.49 %)
	Monetary unit of gas price	↑ 32.65 %	1,084.61(↑0.35%)
	Monetary unit of time value	↑ 5.14 %	1,112.88(↑2.97%)
Benefits of the Current Year (2021)			1,875.25(↑73.50%)

Note: The number in each parenthesis shows the percentage of benefit change from year 2020.

## Conclusions and Recommendations

Grounded in the lessons from the earlier studies, this study has conducted a rigorous evaluation of CHART's performance in 2021 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 the progress of operations for 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 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 incident response time in Year 2021 was 12.25 minutes (See Figure 4.5). In view of the worsening congestion and the increasing number of incidents in the Washington-Baltimore region, it is commendable that CHART can maintain its performance efficiency with approximately the same level of resources.

This study's main recommendations, based on the performance of CHART in 2021, are listed below:

- 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 roads, and include data collection as well as performance benefits in the annual CHART review.
- Make CHART's data quality evaluation report available to the centers' operators for their continuous improvement on data recording and documentation.
- Implement training sessions to educate/re-educate operators on the importance of high-quality data, and discuss how to effectively record critical performance-related information.
- Improve the data structure used in the CHART-II system for recording incident locations to eliminate the current laborious and complex procedures.
- Document and re-investigate the database structure on a regular basis to improve the efficiency and quality of collected data.
- Document possible explanations for extremely short or long response and/or clearance times so that the results of performance analysis can be more reliable.
- Integrate police accident data efficiently with the CHART-II incident response database to have a complete representation of statewide incident records.
- Incorporate the delay and fuel consumption benefits from the reduced potential secondary incidents in the CHART benefit evaluation.

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

## **Summary of Key Findings from the 2021 CHART Performance Evaluation**

- Both the number of statewide emergency responses and CHART responses increased significantly from Year 2020 to Year 2021 (9.42% and 8.53%, respectively), due likely to the recovery from the impact of COVID19.
- TOCs, AOC and SOC on average took slightly longer response times in 2021 than in 2020 to clear reported incidents.
- In 2021, the average incident duration with CHART was 26.31 minutes, shorter than the average of 37.82 minutes for those incidents responded by other agencies. The reduction in the average incident duration is about 30 percent. The average incident duration with CHART slightly increased from 25.35 minutes in 2020 to 26.31 minutes in 2021.
- Among major corridors, US-50 experienced the most significant increase in its incidents/disabled vehicle frequency in 2021, compared to 2020 (about 20%). The total incidents/disabled vehicles frequency on I-495/95 and I/MD-295 also increased by 16.72% and 15.81%, respectively.