Performance Evaluation and Benefit Analysis for CHART – Coordinated Highways Action Response Team – in Year 2014

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Performance Evaluation of CHART
The Real-Time Incident Management System (Year 2014)
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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 2014, 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 sixteen years for the Maryland State Highway Administration (MSHA).

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

The study consisted of two phases. Phase 1 focused on defining objectives, identifying the available data, and developing the methodology. The core of the second phase involved assessing the efficiency of the incident management program and estimating the resulting benefits using the 2014 CHART incident operations data. As some information essential for efficiency and benefit assessment was not available in the CHART-II database, this study presents only those evaluation results that can be directly computed from the incident management data or derived with statistical methods.

**Available Data for Analysis**

Upon a request made by MSHA, COSMIS began evaluating CHART operations performance in 1996. During the initial evaluation, the 1994 incident management data from the Traffic Operations Center (TOC) were reviewed but for various reasons were not used. Thus, the conclusions drawn were based mostly on information either from other states or from nationwide averaged data published by the Federal Highway Administration. To better the evaluation quality and also in view of the fact that the Statewide Operations Center (SOC) has been opened in August of 1995, those associated with the evaluation study concluded that the analysis should be based on actual performance data from the CHART program. Hence, in 1996, the UM research team (Chang and Point-Du-Jour, 1998) was contracted to work jointly with MSHA staff to collect, and subsequently research item to analyze incident management data.

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

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

Unlike previous studies, the quality and quantity of data available for performance evaluation have been increased considerably since 1999. This results from CHART reflect the need to keep an extensive operational record in order to justify its costs and to evaluate the benefits of the emergency response operations. Due to CHART’s efficient data collection, the documentation of lane-closure-related incidents increased from 2,567 in 1997 to 31,535 in 2014.

Table E.1 shows the total number of emergency response operations assiduously documented from 2010 to 2014:
Table E.1 Summary of the Total Number of Emergency Responses from 2010 to 2014

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidents only</td>
<td>19,309</td>
<td>22,534</td>
<td>22,328</td>
<td>24,738</td>
<td>31,535</td>
<td>27.5%</td>
</tr>
<tr>
<td>Total *</td>
<td>49,008</td>
<td>60,105</td>
<td>63,571</td>
<td>60,519</td>
<td>77,865</td>
<td>28.7%</td>
</tr>
</tbody>
</table>

* Total includes incidents and disabled vehicles (assists to drivers)

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

Evolution of the Evaluation Work

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

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

Distribution of Incidents

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

As shown in Table E.2, the results of 2014 incident data indicate that there were a total of 3,831 incidents resulting in one-lane blockage, 6,816 incidents causing two-lane closures, and 4,245 incidents blocking three or more lanes. These lane-blockage data confirm the surge of severe incidents in Year 2014. In addition, either disabled vehicles or minor incidents caused a total of 50,581 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 of Incidents/Disabled vehicles by Lane Blockage Type

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder2</td>
<td>31,322</td>
<td>40,290</td>
<td>43,728</td>
<td>38,818</td>
<td>50,581</td>
<td>30.3%</td>
</tr>
<tr>
<td>1 lane</td>
<td>2,023</td>
<td>2,881</td>
<td>2,514</td>
<td>2,948</td>
<td>3,831</td>
<td>29.9%</td>
</tr>
<tr>
<td>2 lanes3</td>
<td>2,167</td>
<td>3,745</td>
<td>3,424</td>
<td>4,599</td>
<td>6,816</td>
<td>48.2%</td>
</tr>
<tr>
<td>3 lanes3</td>
<td>711</td>
<td>1,322</td>
<td>1,215</td>
<td>1,612</td>
<td>2,341</td>
<td>45.1%</td>
</tr>
<tr>
<td>≥ 4 lanes3</td>
<td>578</td>
<td>1,065</td>
<td>1,010</td>
<td>1,322</td>
<td>1,904</td>
<td>44.1%</td>
</tr>
</tbody>
</table>

* Note: 1. This analysis is based only on the samples with complete information for the lane blockage status.
2. Shoulder Lane Blockages include events that have disabled vehicles (i.e., assists to drivers)
3. A shoulder lane blockage is counted as one lane blockage (e.g., 2-lane blockage can either be two travel lanes or one travel lane and one shoulder blockage).
Most of those incidents/disabled vehicles were distributed along six major commuting corridors: I-495/95, which experienced a total of 11,821 incidents/disabled vehicles in 2014; I-695, I-95, US-50, I/MD-295, and I-270 with 10,056, 13,958, 7,188, 3,951, and 4,288 incidents/disabled vehicles, respectively. Significant increases in the number of incidents/disabled vehicles have been shown on I-495/95 and I-270. CHART managed an average of 38 emergency requests per day on I-95 alone, and 32, 28, 20, 11 and 12 responses per day for I-495/95, I-695, US-50, I/MD-295, and I-270, respectively. The distributions of incidents/disabled vehicles on those major commuting corridors between 2010 and 2014 are shown in Table E.3:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I-495/95</td>
<td>5,362</td>
<td>5,702</td>
<td>5,383</td>
<td>6,013</td>
<td>11,821</td>
<td>93.7%</td>
</tr>
<tr>
<td>I-695</td>
<td>6,294</td>
<td>8,088</td>
<td>8,345</td>
<td>7,875</td>
<td>10,056</td>
<td>27.7%</td>
</tr>
<tr>
<td>I-270</td>
<td>2,378</td>
<td>3,059</td>
<td>3,261</td>
<td>3,024</td>
<td>4,288</td>
<td>41.8%</td>
</tr>
<tr>
<td>I-95</td>
<td>17,551</td>
<td>19,411</td>
<td>19,594</td>
<td>13,699</td>
<td>13,958</td>
<td>2.9%</td>
</tr>
<tr>
<td>US-50</td>
<td>4,600</td>
<td>5,069</td>
<td>5,209</td>
<td>6,541</td>
<td>7,188</td>
<td>10.3%</td>
</tr>
<tr>
<td>I/MD-295</td>
<td>1,441</td>
<td>1,815</td>
<td>3,315</td>
<td>2,960</td>
<td>3,951</td>
<td>33.5%</td>
</tr>
</tbody>
</table>

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

However, it should be mentioned that most incidents/disabled vehicles on major commuting freeways did not block traffic for more than one hour. For instance, about 79 percent of incidents/disabled vehicles had durations shorter than 30 minutes in 2014. 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 2010 to 2014 are summarized in Table E.4:

<table>
<thead>
<tr>
<th>Duration(Hrs)</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>D &lt; 0.5</td>
<td>83%</td>
<td>83%</td>
<td>84%</td>
<td>81%</td>
<td>79%</td>
</tr>
<tr>
<td>0.5 ≤ D &lt; 1</td>
<td>10%</td>
<td>9%</td>
<td>9%</td>
<td>11%</td>
<td>12%</td>
</tr>
<tr>
<td>1 ≤ D &lt; 2</td>
<td>4%</td>
<td>5%</td>
<td>4%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>2 ≤ D</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>4%</td>
</tr>
</tbody>
</table>

* 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 still plagued by a high frequency of incidents with durations ranging from 10 to over 120 minutes. Those incidents were the primary contributors to traffic congestion in the entire region, especially on the major commuting highway corridors, such as I-95, I-270, I-495/95, and I-695.
Efficiency of Operations

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

The average response time is defined as the average time from receiving an emergency request to the arrival of an emergency response unit. Table E.5 shows the average response times of 12.52, 12.86, 7.42, 3.33, 12.16, 11.63, and 7.62 minutes for TOC-3, TOC-4, TOC-5, TOC-6, TOC-7, SOC and AOC, respectively, in 2014. They indicate that most traffic operation centers provided less prompt response services in 2014 than in 2013. However, TOC-6 and TOC-7 demonstrated faster responses in 2014 than in 2013. Note that incidents/disabled vehicles included in this analysis were responded by various units, including CHART and non-CHART agencies:

Table E.5 Evolution of Response Times* by Center from 2010 to 2014

<table>
<thead>
<tr>
<th>Response Time (mins)</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>During OH</td>
<td>After OH</td>
<td>Overall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOC-3</td>
<td>11.43</td>
<td>11.70</td>
<td>12.22</td>
<td>11.91</td>
<td>12.55</td>
</tr>
<tr>
<td></td>
<td>(5,199)</td>
<td>(139)</td>
<td>(5,338)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOC-4</td>
<td>14.38</td>
<td>12.83</td>
<td>12.67</td>
<td>12.05</td>
<td>12.89</td>
</tr>
<tr>
<td></td>
<td>(4,905)</td>
<td>(116)</td>
<td>(5,021)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOC-5</td>
<td>N/A</td>
<td>2.67</td>
<td>5.64</td>
<td>7.03</td>
<td>8.20</td>
</tr>
<tr>
<td></td>
<td>(43)</td>
<td>(115)</td>
<td>(158)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOC-6</td>
<td>5.94</td>
<td>4.43</td>
<td>16.40</td>
<td>6.99</td>
<td>3.16</td>
</tr>
<tr>
<td></td>
<td>(99)</td>
<td>(2)</td>
<td>(101)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOC-7</td>
<td>12.23</td>
<td>12.17</td>
<td>12.87</td>
<td>12.40</td>
<td>12.15</td>
</tr>
<tr>
<td></td>
<td>(2,397)</td>
<td>(83)</td>
<td>(2,480)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOC</td>
<td>7.01</td>
<td>6.73</td>
<td>6.72</td>
<td>7.41</td>
<td>9.06</td>
</tr>
<tr>
<td></td>
<td>(1,643)</td>
<td>(4,248)</td>
<td>(5,891)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AOC</td>
<td>6.41</td>
<td>6.55</td>
<td>6.43</td>
<td>6.90</td>
<td>7.85</td>
</tr>
<tr>
<td></td>
<td>(4,495)</td>
<td>(2,075)</td>
<td>(6,570)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OTHER</td>
<td>5.23</td>
<td>4.42</td>
<td>6.15</td>
<td>6.40</td>
<td>5.59</td>
</tr>
<tr>
<td></td>
<td>(11)</td>
<td>(41)</td>
<td>(52)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weighted Average</td>
<td>10.15</td>
<td>9.87</td>
<td>9.92</td>
<td>9.84</td>
<td>11.09</td>
</tr>
<tr>
<td></td>
<td>(18,792)</td>
<td>(6,819)</td>
<td>(25,611)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Note:
1. This analysis is based on the data of incidents and disabled vehicles (i.e., assists to drivers) which have indicated the responsible operation center and response times.
2. This analysis includes those sample data which have response times between 1 minute and 60 minutes.
3. Events included in this analysis were responded by various units, including CHART, fire boards, state/local polices, private towing companies, etc.
4. OH stands for Operational Hours, 5 a.m. – 9 p.m. Monday through Friday.
5. The number in each parenthesis indicates the available samples with acceptable quality for analysis.
6. TOC-5 and TOC-6 operate on a seasonal basis.
Note that CHART currently operates during 5 a.m. – 9 p.m. from Monday through Friday. Table E.6 presents that incidents are likely to be responded more promptly than disabled vehicles during both operational and non-operational hours.

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

<table>
<thead>
<tr>
<th>Response Time (mins)</th>
<th>Operational Hours</th>
<th>Non-operational Hours</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident</td>
<td>Disabled Vehicle</td>
<td>Incident</td>
<td>Disabled Vehicle</td>
</tr>
<tr>
<td>TOC-3</td>
<td>11.03 (3,466)</td>
<td>15.58 (1,733)</td>
<td>9.89 (93)</td>
</tr>
<tr>
<td>TOC-4</td>
<td>10.84 (2,987)</td>
<td>16.09 (1,918)</td>
<td>10.41 (74)</td>
</tr>
<tr>
<td>TOC-5</td>
<td>8.77 (31)</td>
<td>6.73 (12)</td>
<td>7.13 (65)</td>
</tr>
<tr>
<td>TOC-6</td>
<td>3.16 (98)</td>
<td>2.95 (12)</td>
<td>12.02 (2)</td>
</tr>
<tr>
<td>TOC-7</td>
<td>11.52 (1,851)</td>
<td>14.30 (546)</td>
<td>12.48 (70)</td>
</tr>
<tr>
<td>SOC</td>
<td>8.61 (1,195)</td>
<td>10.26 (448)</td>
<td>10.57 (2,650)</td>
</tr>
<tr>
<td>AOC</td>
<td>6.67 (2,725)</td>
<td>9.64 (1,770)</td>
<td>5.81 (1,241)</td>
</tr>
<tr>
<td>OTHER</td>
<td>6.59 (8)</td>
<td>2.92 (3)</td>
<td>9.95 (29)</td>
</tr>
<tr>
<td>Weighted Average</td>
<td>9.79 (12,361)</td>
<td>13.59 (6,431)</td>
<td>9.10 (4,224)</td>
</tr>
</tbody>
</table>

*Note:
1. This analysis is based on the dataset of incidents and disabled vehicles (assistance to drivers) which have indicated responsible operation center and response times.
2. This analysis includes those sample data which have response times between 1 minute and 60 minutes.
3. Events included in this analysis were responded by CHART
4. Operational Hours are 5 a.m. – 9 p.m. Monday through Friday.
5. The number in each parenthesis indicates the data availability.
6. TOC-5 and TOC-6 operate on a seasonal basis.

Also, the 2014 data show that CHART’s response operations are more efficient when incidents are more severe and cause lane blockages. In general, more severe incidents, especially involving in fatalities or heavy vehicles, demand longer clearance times.
To better understand the contributions of the incident management program, this 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 12 minutes.

The duration of incidents managed by CHART response units in 2014 averaged 23.32 minutes, shorter than the average duration of 34.82 minutes for those incidents by other agencies. On average, CHART operations in Year 2014 reduced the average incident duration by about 33 percent.

Performance improvement of CHART operations from years 2010 to 2014 is summarized in Table E.7:

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

<table>
<thead>
<tr>
<th>Year</th>
<th>With CHART (mins)</th>
<th>Without CHART (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>27.60</td>
<td>47.06</td>
</tr>
<tr>
<td>2011</td>
<td>22.14</td>
<td>29.44</td>
</tr>
<tr>
<td>2012</td>
<td>21.95</td>
<td>28.95</td>
</tr>
<tr>
<td>2013</td>
<td>21.64</td>
<td>31.54</td>
</tr>
<tr>
<td>2014</td>
<td>23.32</td>
<td>34.82</td>
</tr>
</tbody>
</table>

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

**Analysis of Incident Durations**

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

Hence, this study conducted a statistical analysis of incident duration, 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 90 minutes, while incidents with property damage (CPD) and personal injuries (CPI) lasted, on average, 30 and 41 minutes, respectively (see Figure E.1). The average duration of disabled vehicle incidents was 20 minutes, shorter than those classified as “Others” (e.g., debris, vehicles on fire, police activities, etc.), which have an average duration of approximately 24 minutes.
**Resulting Benefits**

The benefits due to CHART operations were estimated directly from the available data, including assistance to drivers, reductions in driver delay times, fuel consumption, emissions, and secondary incidents. In 2014, CHART responded to a total of 31,535 lane blockage incidents, and assisted 46,330 highway drivers who may otherwise have caused incidents or rubbernecks delays to highway traffic. CHART’s contribution to shortening incident duration also reduced potential secondary incidents by 458. In addition, the efficient removal of stationary vehicles and large debris from travel lanes by CHART patrol units may have prevented 848 potential lane-changing-related collisions in 2014, 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 Appendix B for further information on benefits estimate). For instance, in 2014 several primary factors, such as incident duration difference between w/ and w/o CHART, the number of incident responses, and the incident duration by CHART’s operations, have been noticeably increased, compared with Year 2013. The reduction in delay due to CHART’s services in 2014 (36.31 million vehicle-hours) has been increased by 11 percent in comparison with the performance in 2013 (32.65 million vehicle-hours). The performance improvement consequently results in an increase of the total benefits by approximately 9 percent from $1,162.97 million to $1,264.53 million. A comparison of the direct benefits from reduced delay times, fuel consumptions, and emissions, from 2010 to 2014, is summarized in Table E.8:
Table E.8 Comparison of Direct Benefits from 2010 to 2014

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Direct Benefits (million)</th>
<th># of Incidents Eligible for the Benefit Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>$1,375.52</td>
<td>18,045</td>
</tr>
<tr>
<td>2011</td>
<td>$1,096.61</td>
<td>20,547</td>
</tr>
<tr>
<td>2012</td>
<td>$961.69</td>
<td>19,920</td>
</tr>
<tr>
<td>2013</td>
<td>$1,162.97</td>
<td>23,706</td>
</tr>
<tr>
<td>2014</td>
<td>$1,264.53</td>
<td>27,014</td>
</tr>
</tbody>
</table>

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

Conclusions and Recommendations

Grounded on the lessons from the earlier studies, this study has conducted a rigorous evaluation of CHART’s performance in 2014 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 2014 was 11.01 minutes. In view of the worsening congestion and the increasing number of incidents in the Washington-Baltimore region, it is commendable that CHART can maintain its performance efficiency with approximately the same level of resources.
This study’s main recommendations, based on the performance of CHART in 2014, 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 routes, and include data collection as well as performance benefits in the annual CHART review.
- Make CHART's data quality evaluation report available to the centers’ operators for their continuous improvement of data recording and documentation.
- Implement training sessions to educate/re-educate operators on the importance of high-quality data, and discuss how to effectively record critical performance-related information.
- Improve the data structure used in the CHART-II system for recording incident locations to eliminate the current laborious and complex procedures.
- Document and re-investigate the database structure on a regular basis to improve the efficiency and quality of collected data.
- Document possible explanations for extremely short or long response and/or clearance times so that the results of performance analysis can be more reliable.
- Integrate police accident data efficiently with the CHART-II incident response database to have a complete representation of statewide incident records.
- Incorporate the delay and fuel consumption benefits from the reduced potential secondary incidents in the CHART benefit evaluation.

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

Summary of Key Findings from the 2014 CHART Performance Evaluation

- A significant increase (about 29 percent) in the emergency response frequency, and a significant increase (about 28 percent) in the number of incident responses. This cause a 12% increase of benefits in 2014.
- A significant increase (about 47 percent) in the response frequency of incidents which caused more than two lanes blockage.
- A significant decrease (about 33 percent) in incident duration between with and without CHART involvement. It is similar as that in 2013. This is one of major factors contributing to an increase in the direct benefits by CHART in 2014.
- A significant decrease (about 22 percent) in the percentage of heavy vehicles, which is a contributing factor to the benefits.

The aforementioned changes along with other factors contributed to the substantial increase (about 9 percent) on the direct benefits by CHART performance in 2014.
Chapter 1

INTRODUCTION
CHART (Coordinated Highways Action Response Team) is the highway incident management system of the Maryland State Highway Administration (MSHA). Initiated in the mid-80s as “Reach the Beach Program,” it was subsequently expanded as a statewide program. The Statewide Operations Center (SOC), an integrated traffic control center for the state of Maryland, has its headquarters in Hanover, Maryland. The SOC is supported by four satellite Traffic Operations Centers (TOCs), of which one is seasonal. CHART’s current network coverage consists of statewide freeways and major arterials.

CHART has five major functions: traffic monitoring, incident response, traveler information, traffic management, severe weather and emergency operations. Incident response and traveler information systems have received increasing attention from the general public, media, and transportation experts.

In 1996, incident data were collected and used in the pilot evaluation analysis conducted by the University of Maryland in conjunction with MSHA staff (Chang and Point-Du-Jour, 1998). As this was the first time that previous records were to be analyzed, researchers were inevitably faced with the difficulty of having a database with insufficient information.
CHAPTER 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 evaluations have improved significantly since 1999 because CHART recognized the need to keep an extensive operational record in order to justify the costs and estimate the benefits from the emergency response operations. The data available for analysis of lane-closure incidents increased from 5,000 reports in 1999 to 46,330 reports in 2014. A summary of total emergency response operations documented from 2010 to 2014 is presented in Table 1.1.

<table>
<thead>
<tr>
<th>Records*</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidents</td>
<td>19,309</td>
<td>22,534</td>
<td>22,328</td>
<td>24,738</td>
<td>31,535</td>
</tr>
<tr>
<td>Disabled Vehicles</td>
<td>29,699</td>
<td>37,571</td>
<td>41,243</td>
<td>35,781</td>
<td>46,330</td>
</tr>
<tr>
<td>Total</td>
<td>49,008</td>
<td>60,105</td>
<td>63,571</td>
<td>60,519</td>
<td>77,865</td>
</tr>
</tbody>
</table>

*Note: “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.
The objective of this study is to evaluate the effectiveness of CHART’s incident detection, response, and traffic management operations on interstate freeways and major arterials. This assessment also includes an estimation of CHART benefits, an essential part of the study, since support of MSHA programs from the general public and state policymakers largely depends on the benefits the state obtains from its ongoing programs. In order to conduct a comprehensive analysis using available data to ensure the reliability of the evaluation results, the evaluation study has been divided into the following three principal tasks:

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

Task 2: Statistical Analysis and Comparison — entails performing comparisons based on data available in 2013 and 2014, 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.
CHAPTER 1
1. Introduction

The subsequent chapters are structured as follows:

Chapter 2 assesses the quality of data available for the 2014 CHART performance evaluation. This includes the total available incident reports, the percentage of missing data for each critical performance parameter, and a comparison of 2014 data quality with that of 2013.

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 assists. The chapter also touches on an evaluation of incident response efficiency. The efficiency rate is based on the difference between the incident report time and the arrival time of emergency response units. Also, the assessment of incident clearance efficiency is based on the difference between the arrival time of the emergency response units and the incident clearance time.

Chapter 5 discusses a statistical analysis of response times, which provides fundamental insight into the characteristics of response times under various conditions. In this analysis, the distributions of the average response time are identified by a range of categories, including the time of day, the incident nature, the pavement conditions, the lane blockage status, the involvement of heavy vehicles, and the involved regions.

Chapter 6 performs a statistical analysis of incident durations, similar to Chapter 5. In this analysis, the distributions of the average incident duration are identified by a range of categories, including nature, county, 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's 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
CHAPTER 2

2.1 Analysis of Data Availability

This chapter assesses the quality of data available for the CHART 2014 performance evaluation and compares it with the data from CHART 2013.

CHAPTER 2

2.1 Analysis of Data Availability

In 2014, CHART recorded a total of 77,865 emergency response cases. These are categorized into two groups: incidents and disabled vehicles. A summary of the total available incident reports for the years 2012, 2013, and 2014 is shown in Table 2.1.

Table 2.1 Comparison of Available Data for 2012, 2013, and 2014

<table>
<thead>
<tr>
<th>Available Records</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Records</td>
<td>Ratios(%)</td>
<td>Records</td>
</tr>
<tr>
<td>CHART II Database</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disabled Vehicles</td>
<td>41,243</td>
<td>64.9</td>
<td>35,781</td>
</tr>
<tr>
<td>Incidents</td>
<td>22,328</td>
<td>35.1</td>
<td>24,738</td>
</tr>
<tr>
<td>Total</td>
<td>63,571</td>
<td>100</td>
<td>60,519</td>
</tr>
</tbody>
</table>
CHAPTER 2
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 2013 and 2014.

Figure 2.1 Summary of Data Quality for Critical Indicators

Figure 2.2 Summary of Data Quality for Time Indicators
2.2 Analysis of Data Quality

Nature of Incidents/Disabled Vehicles

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 85 percent of emergency responses reported in 2014 recorded the nature of incidents.

Detection Sources

As Figure 2.1 shows, about 97 percent of all emergency responses recorded in 2014 contained the source of detection, which is almost the same as the previous year’s data. In 2014, about 94 percent of incidents reported and 99 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 2014 used five time parameters for performance measurements: “Received Time,” “Dispatched Time,” “Arrival Time,” “Cleared Time,” and “Confirmed Time.” Figure 2.2 illustrates the data quality analysis with respect to these performance parameters. The figure indicates that the quality of data for “Received Time” and “Confirmed Time” is sufficient for reliable analysis, while the data of “Dispatched Time,” “Arrival Time,” and “Cleared Time” still require improvement for reliable analysis.
2.2 Analysis of Data Quality

Type of Reports

The total number of incidents/disabled vehicles managed by each operation center in 2014 is summarized in Table 2.2. Overall, CHART responded to a total of 31,535 incidents in 2014. Over the same period, the response team also responded to 46,330 disabled vehicle requests.

<table>
<thead>
<tr>
<th>Operation Center</th>
<th>TOC3</th>
<th>TOC4</th>
<th>SOC</th>
<th>TOC6</th>
<th>TOC7</th>
<th>AOC</th>
<th>OTHER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disabled Vehicles</td>
<td>10,103</td>
<td>9,736</td>
<td>12,247</td>
<td>12</td>
<td>5,118</td>
<td>8,054</td>
<td>1060</td>
<td>46,330 (35,781)</td>
</tr>
<tr>
<td>Incidents</td>
<td>6,361</td>
<td>5,425</td>
<td>8,672</td>
<td>198</td>
<td>3,380</td>
<td>7,088</td>
<td>411</td>
<td>31,535 (24,738)</td>
</tr>
<tr>
<td>Total</td>
<td>16,464</td>
<td>15,161</td>
<td>20,919</td>
<td>210</td>
<td>8,498</td>
<td>15,142</td>
<td>1,471</td>
<td>77,865 (60,519)</td>
</tr>
</tbody>
</table>

Note: numbers in each parenthesis are the corresponding data from 2013

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.
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 2014. Note that about 99 percent of data have some information related to the locations (road names and exit numbers), but only about 48 percent of them can be used to clearly identify the event sites. For the remaining 52 percent of incidents/disabled vehicles, the location information is either unclear or not specified, and therefore cannot be used for reliable performance analysis.

<table>
<thead>
<tr>
<th>Data Quality</th>
<th>Incident</th>
<th>Disabled Vehicles</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>98.43%</td>
<td>98.85%</td>
<td>98.68%</td>
</tr>
<tr>
<td>Location</td>
<td>45.58%</td>
<td>50.36%</td>
<td>48.42%</td>
</tr>
<tr>
<td>Valid Data for Road &amp; Location</td>
<td>45.57%</td>
<td>50.36%</td>
<td>48.42%</td>
</tr>
</tbody>
</table>

**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 2014 shows that up to 68.63 percent of emergency response reports involved lane/shoulder blockage. This value is higher than the 60.51 percent in 2013.

In summary, in 2014, 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 contributions to mitigation of traffic congestion, driver assistance, and overall improvement of the driving environment.
Chapter 3

ANALYSIS OF DATA CHARACTERISTICS
CHAPTER 3

3.1 Distribution of Incidents and Disabled Vehicles by Day and Time

3.2 Distribution of Incidents and Disabled Vehicles by Road and Location

3.3 Distribution of Incidents and Disabled Vehicles by Lane Blockage Type

3.4 Distribution of Incidents and Disabled Vehicles by Blockage Duration

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.

CHAPTER 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 81 percent) of incidents/disabled vehicles in 2014 occurred on weekdays. Thus, more resources and personnel are required on weekdays than on weekends to manage the incidents/disabled vehicles more effectively.

Table 3.1 Distribution of Incidents/Disabled Vehicles by Day

<table>
<thead>
<tr>
<th>Center</th>
<th>TOC3</th>
<th>TOC4</th>
<th>TOC5</th>
<th>TOC6</th>
<th>TOC7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>2014</td>
<td>2013</td>
<td>2014</td>
<td>2013</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>2013</td>
<td>2014</td>
<td>2013</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>2013</td>
<td>2014</td>
<td>2013</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>2013</td>
<td>2014</td>
<td>2013</td>
<td>2014</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekdays</td>
<td>99%</td>
<td>99%</td>
<td>99%</td>
<td>99%</td>
<td>29%</td>
<td>30%</td>
</tr>
<tr>
<td>Weekends</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>71%</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>2%</td>
<td>2%</td>
</tr>
</tbody>
</table>

*Includes RAVENS TOC and REDSKINS TOC
CHAPTER 3
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 29 percent of incidents/disabled vehicles reported in 2014 occurred during peak hours, which is slightly lower than the one in 2013.

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

<table>
<thead>
<tr>
<th>Center</th>
<th>TOC3</th>
<th>TOC4</th>
<th>TOC5</th>
<th>TOC6</th>
<th>TOC7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak**</td>
<td>37%</td>
<td>38%</td>
<td>40%</td>
<td>46%</td>
<td>16%</td>
</tr>
<tr>
<td>Off-Peak</td>
<td>63%</td>
<td>62%</td>
<td>60%</td>
<td>54%</td>
<td>84%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Center</th>
<th>SOC</th>
<th>AOC</th>
<th>Other*</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak**</td>
<td>13%</td>
<td>33%</td>
<td>25%</td>
<td>24%</td>
</tr>
<tr>
<td>Off-Peak</td>
<td>87%</td>
<td>67%</td>
<td>75%</td>
<td>76%</td>
</tr>
</tbody>
</table>

* Includes RAVENS TOC and REDSKINS TOC

** 7:00 a.m. ~ 9:30 a.m. and 4:00 p.m. ~ 6:30 p.m.
CHAPTER 3
3.1 Distribution of Incidents and Disabled Vehicles by Day and Time

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. Among those, 284 incidents/disabled vehicles do not have complete information for identifying their event open timestamps in 2014. More detailed information regarding distributions by time of day is presented in the Appendix A.
CHAPTER 3
3.2 Distribution of Incidents and Disabled Vehicles by Road and Location

Figure 3.2 compares the frequency distribution by road between 2014 and 2013, and Figure 3.3 depicts the frequency distribution of incidents and disabled vehicles for 2014.

Figure 3.2 Distributions of Incidents/Disabled Vehicles by Road in 2014 and 2013

Figure 3.2 Distributions of Incidents/Disabled Vehicles by Road in 2014 and 2013
CHAPTER 3

3.2 Distribution of Incidents and Disabled Vehicles by Road and Location

Based on the statistics shown above, the roadways with high incident frequencies for 2014 were I-95 (from the Delaware border to the Capital Beltway), I-695 (Baltimore Beltway), I-495/95 (Capital Beltway), US-50, I-70 and I-270. I-95 experienced a total of 13,958 incidents/disabled vehicles in 2014, while I-695 had 10,056 incidents/disabled vehicles within the same period. I-495/95, US-50, I-70 and I-270 had 11,821, 7,188, 5,656, and 4,288 incidents/disabled vehicles, respectively. Also, notice that the CHART-II database includes 1,029 incidents/disabled vehicles detected by CHART with incomplete information for road names in 2014.
CHAPTER 3
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, somewhat more incidents occurred during a.m. peak hours than p.m. peak hours on I-95, I-270 and I-83.

Figure 3.4 Distribution of Incidents by Time of Day on Major Roads in 2014
CHAPTER 3
3.2 Distribution of Incidents and Disabled Vehicles by Road and Location

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 volume, 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 Distribution of Disabled Vehicles by Time of Day on Major Roads in 2014
CHAPTER 3

3.2 Distributions of Incident and Disabled Vehicles by Road and Location

Figure 3.6 Distribution of Incidents/Disabled Vehicles by Location on I-695
CHAPTER 3
3.2 Distributions of Incidents and Disabled Vehicles by Road and Location

Figure 3.6 Distribution of Incidents/Disabled Vehicles by Location on I-695 (cont.)
CHAPTER 3

3.2 Distributions of Incidents and Disabled Vehicles by Road and Location

Figure 3.7 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-695
CHAPTER 3

3.2 Distributions 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 2014, while Figure 3.7 compares these values with the results in 2013. The high-incident segments are from Exits 11 to 12, Exits 17 to 18, and Exit 18 to 19 (218, 188 and 188, respectively). The two high frequencies of disabled vehicles (486 and 428 cases) were recorded on the segments between Exits 11 and 12 and Exits 17 and 18, which are close to the I-95 and I-70 interchanges, respectively.

The subsequent figures present the comparison between 2014 and 2013 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 (272 cases) occurred between Exits 31 and 33 of I-495. The location with the highest frequency of disabled vehicles (541 cases) occurred between Exits 17 and 19. A comparison with the data in 2013 is illustrated in Figure 3.9.
CHAPTER 3
3.2 Distributions of Incidents and Disabled Vehicles by Road and Location

Figure 3.8 Distributions of Incidents/Disabled Vehicles by Location on I-495/I-95
CHAPTER 3
3.2 Distributions 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

Frequency

Year 2014   Year 2013
CHAPTER 3
3.2 Distributions of Incidents and Disabled Vehicles by Road and Location

Figure 3.10 shows the distribution of incidents and disabled vehicles by location on I-95, and Figure 3.11 compares such distributions computed with data in 2014 and 2013. As shown in Figure 3.10, the highest number of incidents occurred at the segment between Exits 55 and 56 (457 cases). The segments between Exits 67 and 74 experienced a highest number of disabled vehicles (834 cases).
CHAPTER 3
3.2 Distributions of Incidents and Disabled Vehicles by Road and Location

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

Figure 3.11 Comparisons of Incidents/Disabled Vehicles Distributions by Location on I-95
In 2014 the incidents and disabled vehicles recorded for the I-95 segment between Exits 67 and 74 received the maximum number of incident responses with a total frequency of 1,181. The segments on I-95 between Exits 56 and 57 sustained the second largest number of incidents/disabled vehicles requests (673) in 2014. These trends are similar to those observed in 2013.
CHAPTER 3
3.2 Distributions of Incidents and Disabled Vehicles by Road and Location

Figure 3.12 represents the spatial distribution of incidents/disabled vehicles data on I-270 in 2014. The segment between Exits 26 - 31 on I-270 experienced the highest numbers of incidents (94) and the segment between Exits 11 - 13 experienced the highest number of disabled vehicles (144).
CHAPTER 3
3.2 Distributions of Incidents and Disabled Vehicles by Road and Location

Figure 3.13 shows a comparison between 2014 and 2013 data; the 2014 data recorded more incidents/disabled vehicles than in 2013 at most locations.

![Figure 3.13 Comparisons of Incidents/Disabled Vehicles by Location on I-270](image)

**Figure 3.13 Comparisons of Incidents/Disabled Vehicles by Location on I-270**
CHAPTER 3
3.3 Distribution of Incidents and Disabled Vehicles by Lane Blockage Type

Figure 3.14 illustrates the distribution of incidents by lane blockage in 2014. A large portion of those incidents involved one-lane or two-lane blockages. The comparison of 2014 incidents/disabled vehicles distribution by lane blockage with 2013 data is illustrated in Figure 3.15. Note that all reported disabled vehicles are classified as shoulder lane blockages.

![Figure 3.14 Distributions of Incidents by Lane Blockage](image-url)
CHAPTER 3
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 3.15 Comparisons of Incidents/Disabled Vehicles Distributions by Lane Blockage
CHAPTER 3
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 2014 and 2013 for major roads in the Washington Metropolitan and Baltimore areas.

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

Note: **Also includes Shoulder Lane Blockages
CHAPTER 3

3.3 Distribution of Incidents and Disabled Vehicles by Lane Blockage Type

Note: **Also includes Shoulder Lane Blockages

**Figure 3.16 Distributions of Lane Blockages Occurring on Major Freeways in the Washington Area (cont.)**
CHAPTER 3
3.3 Distribution of Incidents and Disabled Vehicles by Lane Blockage Type

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

Note: **Also includes Shoulder Lane Blockages
CHAPTER 3
3.3 Distribution of Incidents and Disabled Vehicles by Lane Blockage Type

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.
CHAPTER 3
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.

It is quite obvious that CHART’s highway network has experienced a high frequency of incidents, ranging from ten minutes to more than one hour in duration. These incidents are clearly primary contributors to traffic congestion in the entire region, especially on the major commuting highway corridors of I-495, I-695, I-270, and I-95, making it imperative, therefore, to continuously improve traffic management and incident response systems.
CHAPTER 3
3.4 Distribution of Incidents and Disabled Vehicles by Blockage Duration

As shown below, most disabled vehicles did not block traffic for more than half an hour. About 73 percent of incidents and disabled vehicles had durations of less than 30 minutes.

Although most incidents in 2014 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.
CHAPTER 3
3.4 Distribution of Incidents and Disabled Vehicles by Blockage Duration

Figure 3.20 presents the distribution of records in 2014 and its comparison with 2013 data. About 18 percent, 15 percent, and 19 percent of reported incidents/disabled vehicles managed by TOC-3, TOC-4, and TOC-7, respectively, had blocked traffic lasting longer than 30 minutes. For SOC, about 29 percent of reported incidents lasted longer than 30 minutes. This implies that only 22 percent of reports to which CHART responded lasted more than 30 minutes in 2014.
CHAPTER 3
3.4 Distribution of Incidents and Disabled Vehicles by Blockage Duration

Figure 3.20 Comparisons of Incidents/Disabled Vehicles Distributions by Duration and Operation Center (cont.)
Chapter 4

EVALUATION OF EFFICIENCY AND EFFECTIVENESS
CHAPTER 4
4.1 Evaluation of Detection Efficiency and Effectiveness
4.2 Analysis of Response Efficiency
4.3 Analysis of Clearance Efficiency
4.4 Reduction in Incident Duration

An automatic incident detection system has yet to be implemented by CHART. Therefore, CHART has no means of evaluating the detection and false-alarm rates. Also, at this point, CHART has no way to determine the time taken by the traffic control centers to detect an incident from various sources after its onset. Therefore, this evaluation of detection efficiency and effectiveness focuses only on the incident response rate and on the distribution of detection sources.

The response rate is defined as the ratio of the total number of traffic incidents reported to the CHART control center to those managed by the CHART/MSHA emergency response teams. Based on 2014 incident management records, the overall response rate was 99.5 percent. As in the previous year, existing incident reports did not specify the reasons for ignoring some requests. It appears that most of the ignored incidents happened during very light traffic periods or were not sufficiently severe to cause any significant traffic blockage or delay. Notwithstanding the lack of an automated incident detection system, CHART has maintained an effective coordination system with state and municipal agencies that deal with traffic incidents and congestion.
4.1 Evaluation of Detection Efficiency and Effectiveness

Figures 4.1, 4.2, 4.3 and 4.4 illustrate the distributions of incidents/disabled vehicles by detection source for control centers TOC 3, TOC 4, TOC 6 and TOC 7, respectively.

Note: Numbers in [ ] show the percentages from Year 2013.

* Actual frequencies for incidents/disabled vehicles detected by No Info, system alarm and MDTA are 15, 0 and 2 in the CHART-II database of year 2014

Figure 4.1 Distributions of Incidents/Disabled Vehicles by Detection Source for TOC 3
CHAPTER 4

4.1 Evaluation of Detection Efficiency and Effectiveness

Note: Numbers in [ ] show the percentages from Year 2013

* Actual frequencies for incidents/disabled vehicles detected by MCTMC, Media, System Alarm, No Info and MDTA in 2014 are 0, 2, 0, 4, and 4 in the CHART-II database.

Figure 4.2 Distributions of Incidents/Disabled Vehicles by Detection Source for TOC 4
CHAPTER 4
4.1 Evaluation of Detection Efficiency and Effectiveness

Note: Numbers in [ ] show the percentages from Year 2013.
TOC 6 operates on a seasonal basis.
* Actual frequencies for incidents/disabled vehicles detected by MDTA, CCTV, MCTMC, Media, and System Alarm in 2014 are all zeros, except having one classified into No Info. in the CHART-II database.

Figure 4.3 Distributions of Incidents/Disabled Vehicles by Detection Source for TOC 6
CHAPTER 4
4.1 Evaluation of Detection Efficiency and Effectiveness

Note: Numbers in [ ] show the percentages from Year 2013.

* Actual frequencies for incidents/disabled vehicles detected by MCTMC, Media, System Alarm, and MDTA in 2014 are all zeros, except having two classified into No Info. in the CHART-II database.

Figure 4.4 Distributions of Incidents/Disabled Vehicles by Detection Source for TOC 7
CHAPTER 4
4.1 Evaluation of Detection Efficiency and Effectiveness

With respect to the distribution of all detection sources, the statistics in Figure 4.5 clearly show that about 56 percent of incidents in 2014 were detected by MSHA/CHART patrols, i.e., a higher percentage than in 2013. About 15 percent were reported by the MSP, similar to that in 2013. Note that these numbers in parentheses indicate the 2013 statistics.

Note: Numbers in [ ] show the percentages from Year 2013.

* The actual frequency for incidents/disabled vehicles detected by System Alarm in 2014 is 3 in the CHART-II database.

Figure 4.5 Distributions of Incidents/Disabled Vehicles by Detection Source
CHAPTER 4
4.2 Analysis of Response Efficiency

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 starting 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 2014 is given in Figure 4.6. The average response time in 2014 was 11.01 minutes, slightly higher than that of 2013 (9.84 minutes).
CHAPTER 4
4.2 Analysis of Response Efficiency

In Figure 4.7 the average response times of incidents by TOC 3, TOC 4, and TOC 7 are fairly consistent throughout the year and are between ten and fifteen minutes. AOC also shows fairly consistent response times between five and ten minutes through year 2014. On the other hand, the response times for disabled vehicles show significant fluctuations for TOC 3, TOC 4, and TOC 7 during the first six months. SOC exhibits a consistent increase in the average response time for disabled vehicles throughout the year. Overall, the average response time for AOC is shorter than for TOCs and SOC over the entire year.

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

2. TOC 5 and TOC 6 were excluded in this analysis, since they operate on a seasonal basis.

Figure 4.7 Average Response Times for Operation Centers by Month in 2014
CHAPTER 4
4.2 Analysis of Response Efficiency

Figure 4.8 illustrates the fact that most operation centers show slightly faster response times for both incidents and disabled vehicles during holidays in 2014.

**Incidents**

<table>
<thead>
<tr>
<th>Operation Center</th>
<th>Non-holiday</th>
<th>Holiday</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOC</td>
<td>6.38 (342)</td>
<td>6.41 (3259)</td>
</tr>
<tr>
<td>SOC</td>
<td>7.95 (284)</td>
<td>10.25 (3153)</td>
</tr>
<tr>
<td>TOC3</td>
<td>11.04 (3042)</td>
<td>11.04 (3042)</td>
</tr>
<tr>
<td>TOC4</td>
<td>10.85 (2658)</td>
<td>10.85 (2658)</td>
</tr>
<tr>
<td>TOC7</td>
<td>11.65 (1648)</td>
<td>11.65 (1648)</td>
</tr>
</tbody>
</table>

**Disabled Vehicles**

<table>
<thead>
<tr>
<th>Operation Center</th>
<th>Non-holiday</th>
<th>Holiday</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOC</td>
<td>9.50 (2183)</td>
<td>9.00 (255)</td>
</tr>
<tr>
<td>SOC</td>
<td>15.58 (1652)</td>
<td>15.58 (1652)</td>
</tr>
<tr>
<td>TOC3</td>
<td>15.75 (1467)</td>
<td>15.75 (1467)</td>
</tr>
<tr>
<td>TOC4</td>
<td>16.33 (1667)</td>
<td>16.33 (1667)</td>
</tr>
<tr>
<td>TOC7</td>
<td>14.28 (479)</td>
<td>14.28 (479)</td>
</tr>
</tbody>
</table>

**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.

**Figure 4.8 Average Response Times for Operation Centers by Holiday in 2014**
Figures 4.9 to 4.13 present the average response times by time of day during weekdays for each operation center. The bar graph represents the average incident frequencies to which the operation center responded, where the line graph illustrates its average response times by the time of day. Overall, AOC shows quite consistent response times during the daytime, and its response times after midnight become shorter, likely due to the low incident frequency. On the other hand, the response times by SOC vary with the incidents responded to during the day. Since AOC and SOC operate as the backup of TOCs 3, 4 and 7 after their operational hours (5 a.m. - 9 p.m.), their incident response frequencies during non-operational hours are much higher than those by major TOCs (see Figures 4.11 to 4.13).

Figure 4.9 Average Response Times for AOC by Time of Day on Weekdays in 2014
CHAPTER 4
4.2 Analysis of Response Efficiency

Figure 4.10 Average Response Times for SOC by Time of Day on Weekdays in 2014
The response times by TOC 3 and TOC 4 are quite consistent during their operational periods (5 a.m. – 9 p.m.), and the responded incident frequencies also exhibit distinct patterns during peak periods. On the other hand, the response times by TOC 4 fluctuate during non-operational hours, but by TOC 3 are fairly consistent.

Figure 4.11 Average Response Times for TOC3 by Time of Day on Weekdays in 2014
CHAPTER 4

4.2 Analysis of Response Efficiency

Figure 4.12 Average Response Times for TOC4 by Time of Day on Weekdays in 2014
CHAPTER 4
4.2 Analysis of Response Efficiency

Figure 4.13 shows the average response time and the incident frequency by time of day on weekdays. As shown in the incident frequency chart, the highest incident frequency is around the PM peak period (4:00 p.m. - 6:30 p.m.), but their average response times are relatively shorter than those during other operational hours.

Figure 4.13 Average Response Time for TOC7 by Time of Day on Weekdays in 2014
CHAPTER 4
4.2 Analysis of Response Efficiency

Figure 4.14 shows a further analysis of response efficiency, where most operation centers demonstrated faster responses for incidents involving vehicle collision, injuries (CPI), and fatalities (CF). On the other hand, most operation centers 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 each parenthesis 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.

Figure 4.14 Average Response Times for Operation Centers by Incident Nature in 2014
CHAPTER 4
4.2 Analysis of Response Efficiency

With respect to the pavement conditions, each operation center shows a different pattern for response times under different pavement conditions. Overall, AOC shows a shorter average response time than any other operation centers (See Figure 4.15).

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

Figure 4.15 Average Response Times for Operation Centers by Pavement Conditions in 2014
CHAPTER 4
4.2 Analysis of Response Efficiency

Figures 4.16 through 4.20 present the response times for operation centers by detection source. The bar graph represents the available data to compute the average response times, while the line graph represents the computed average response times. The major detection source for AOC is MDTA, while the state police detects the most incidents to which SOC responded. For SOC, on average, the incidents detected by CHART units have relatively fast responses.

Figure 4.16 Average Response Times for AOC by Detection Source in 2014

Figure 4.17 Average Response Times for SOC by Detection Source in 2014
CHAPTER 4
4.2 Analysis of Response Efficiency

As shown in Figure 4-18, 19 and 20, for TOCs 3, 4, and 7, CHART and state police are the two major detection sources. However, the incidents detected by CHART response units have relatively shorter response time than those detected via other sources in TOCs 3, 4, and 7.

Figure 4.18 Average Response Times for TOC 3 by Detection Source in 2013
CHAPTER 4
4.2 Analysis of Response Efficiency

Figure 4.19 Average Response Times for TOC 4 by Detection Source in 2014

Figure 4.20 Average Response Times for TOC 7 by Detection Source in 2013
4.3 Analysis of Clearance Efficiency

As is well recognized, the efficiency of incident clearance could be varied by many factors. Figure 4.21 summarizes the performance of CHART incident clearance operations by operation center. The average clearance time by SOC is longer than any other for incidents. On the other hand, TOC 3 and TOC 7 show the smallest average clearance times for incidents and disabled vehicles, respectively. Further analyses of incident clearance times are presented in Chapter 6.

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

Figure 4.21 Average Clearance Times by Operation Center in 2014
4.4 Reduction in Incident Duration

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 comparing average incident clearance times in 2014 for non-responded incidents and those to which CHART responded. Since CHART’s incident management team responded to most incidents in 2014, 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 22.99 minutes and 33.45 minutes in 2014. Note that incidents with durations of less than one minute were excluded from the analysis. Also, incidents of Unknown Lane Blockage were redistributed to other blockage categories based on their resulting clearance times. Based on the results shown in Table 4.1, it seems clear that the assistance of CHART response units reduced the time it took to clear an incident. On average, CHART in 2014 contributed to a reduction in blockage duration of about 31.27 percent, which has certainly contributed significantly to savings in travel times, fuel consumption, and related socioeconomic costs. Note that the statistical results shown in Table 4.1 are likely to be biased, as only about 88 percent of incident reports contain all required information (i.e., received time and cleared time) for incident duration computation.
### CHAPTER 4
4.4 Reduction in Incident Duration

Table 4.1 Comparisons of Incident Durations for Various Types of Lane Blockages in 2014 (Duration= Cleared Time-Received Time)

<table>
<thead>
<tr>
<th>Blockage</th>
<th>With SHA Patrol</th>
<th></th>
<th>Without SHA Patrol</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Duration (min)</td>
<td>Sample Frequency</td>
<td>Duration (min)</td>
<td>Sample Frequency</td>
</tr>
<tr>
<td>Shoulder</td>
<td>20.23</td>
<td>4,644</td>
<td>30.29</td>
<td>1,053</td>
</tr>
<tr>
<td>1 lane</td>
<td>20.48</td>
<td>11,521</td>
<td>32.63</td>
<td>1,403</td>
</tr>
<tr>
<td>2 lanes</td>
<td>32.67</td>
<td>2,334</td>
<td>45.01</td>
<td>309</td>
</tr>
<tr>
<td>3 lanes</td>
<td>40.82</td>
<td>631</td>
<td>48.18</td>
<td>63</td>
</tr>
<tr>
<td>&gt;=4 lanes</td>
<td>46.25</td>
<td>338</td>
<td>31.71</td>
<td>18</td>
</tr>
<tr>
<td>Weighted Average</td>
<td>22.99 (21.64)</td>
<td>19,468 (9,149)</td>
<td>33.45 (31.54)</td>
<td>2,846 (1,454)</td>
</tr>
<tr>
<td>Unknown</td>
<td>17.80</td>
<td>6,536</td>
<td>31.52</td>
<td>1,143</td>
</tr>
</tbody>
</table>

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 2013.
Chapter 5

ANALYSIS OF RESPONSE TIMES
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.
Chapter 5
5.1 Distribution of Average Response Times by Time of Day

Figure 5.1 Distributions of Average Response Times by Time of Day in 2014 and 2013

Figure 5.1 compares response times by time of day in 2014 and 2013. In 2014, the average response time during a.m. peak hours was slightly longer than that during p.m. peak hours for both incidents and disabled vehicles. The response times to incidents during off-peak hours were shorter than those during peak hours in 2014.
Chapter 5
5.1 Distribution of Average Response Times by Time of Day

Figure 5.2 shows the average response times by different times of day on the major roads. The incidents on I-270 experienced the longest response times during off-peak periods, and peak periods, while I-95 experienced the shortest response times. For disabled vehicles, the average response time on I-270 was also the longest one among major roads.

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

Figure 5.2 Distributions of Average Response Times for Roads by Time of Day in 2014
Chapter 5
5.2 Distribution of Average Response Times by Incident Nature

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

**Figure 5.3 Average Response Time by Incident Nature in 2014**

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

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

**Figure 5.4 Average Response Time for Roads by Incident Nature in 2014**

*Note:* 1. Incident data only for response times between 1 minute and 60 minutes are used for this analysis.
2. Numbers in each parenthesis show frequencies.
Chapter 5

5.3 Distribution of Average Response Times by Various Factors

This section presents the results of analysis on how other factors would influence the response times.

Figure 5.5 illustrates that the response times may vary with the pavement conditions. The responses are likely to be slower on wet or snow/ice pavement, whereas they tend to be faster on a dry condition. The information on weather conditions is usually unavailable in most incident databases. When the pavement is chemically wet, the response time is likely to be faster than under any other conditions.

As shown in Figure 5.6, incidents causing lane closure are likely to be responded faster than other incidents of non-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.
Chapter 5
5.3 Distribution of Average Response Times by Various Factors

Figure 5.7 shows that the average response time in 2014 is quite consistent regardless of involving heavy vehicles or not in the incidents.

**Figure 5.7 Average Response Time (mins) by Heavy Vehicle Involvement in 2014**

*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.*

Note that the response time may differ among regions, due to the discrepancy in the available resources and incident frequency among operation centers, including coverage area, incident rates, traffic volumes, etc. Figure 5.8 demonstrates that the response times were faster in suburban areas, including Eastern and Southern Maryland, than for the metropolitan areas such as the Baltimore and Washington regions. Urban areas are more likely to have higher incident rates and heavier traffic volumes, which could impede the efficiency of response units. One can also notice that the responses for incidents were quicker than those for disabled vehicles in most regions.

**Figure 5.8 Average Response Time by Region in 2014**

*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.*
Chapter 6

ANALYSIS OF INCIDENT DURATIONS
Chapter 6

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

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.
Chapter 6
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 are defined as those disabled vehicles that interrupt the normal traffic flow on the main lanes. In the category of incidents without collision, most are Disabled Vehicles. In 2014, about 42 percent of incidents without collision were caused by Disabled Vehicles. A similar pattern was also observed in 2013, when also about 42 percent of non-collision incidents occurred due to Disabled Vehicles. In contrast, the other types of non-collision incidents occurred in relatively low frequencies; therefore, the study classifies all such incident types as one category, i.e., Others, as shown in Table 6.1.

**Table 6.1 Categories of Incident Nature**

<table>
<thead>
<tr>
<th>Incidents</th>
<th>With collisions</th>
<th>Without collisions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collisions-Fatalities (CF)</td>
<td>Others</td>
</tr>
<tr>
<td></td>
<td>Collisions-Property Damage (CPD)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Collisions-Personal Injuries (CPI)</td>
<td></td>
</tr>
<tr>
<td>Disabled Vehicles</td>
<td>Police Activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Off-Road Activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emergency Roadwork</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Debris in Roadway</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vehicles on Fire</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 6
6.1 Distribution of Average Incident Durations by Nature

Figure 6.1 summarizes the average incident duration for each type in year 2014. The statistical results indicate that the average incident duration for CFs is significantly higher than for the other incident natures. Statistically, an incident that has resulted in a fatality can last more than an hour on average. In contrast, incidents caused by Disabled Vehicles, on average, were much shorter in duration.

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

Figure 6.1 Distribution of Average Incident Duration by Nature in 2014 and 2013
Chapter 6
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 much shorter incident duration, as shown in Figure 6.2. Figures 6.3 to 6.5 illustrate that incident durations in the Baltimore region were likely to be shorter than those in other regions. However, Figure 6.3 shows that the incidents especially around Carroll and Harford Counties had longer durations than incidents occurring in any other counties in the Baltimore region.

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

Figure 6.2 Distribution of Average Incident Duration by County in Washington Region in 2014 and 2013

Incidents that occurred in counties of western and southern Maryland mostly resulted in relatively longer durations. Figure 6.4 shows that the average incident duration in these areas is usually close to one hour. Allegany County had the shortest average incident duration in western and southern Maryland in the year 2014.

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

Figure 6.3 Distribution of Average Incident Duration by County in Baltimore Region in 2014 and 2013
Chapter 6
6.2 Distribution of Average Incident Durations by County and Region

Similarly, the incidents occurring in Kent County on the Eastern Shore (Figure 6.5) are highly likely to result in longer durations than those in any other areas of Eastern Shore. On the other hand, incidents occurring in Queen Anne’s County on the Eastern Shore take only about 18.5 minutes on average to be cleared.

Figure 6.4 Distribution of Average Incident Duration by County in Western and Southern Regions in 2014 and 2013

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 2014 and 2013

Note: Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis
Chapter 6
6.2 Distribution of Average Incident Durations by County and Region

Table 6.2 summarizes the average response times, clearance times, and incident durations by region. One can easily notice that the average response time in the southern area was relatively short, although it took longer to clear the detected incident than in any other region. On the other hand, the Washington region takes longer to respond to an incident, even though the average clearance time was shorter than for any other area in Maryland in 2014.

Table 6.2 Summary of Incident Duration Components by Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Sample Frequency*</th>
<th>Avg. Response Time (mins)</th>
<th>Avg. Clearance Time (mins)</th>
<th>Avg. Incident Duration (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltimore</td>
<td>11,590</td>
<td>6.54</td>
<td>21.44</td>
<td>27.98</td>
</tr>
<tr>
<td>Washington</td>
<td>9,126</td>
<td>8.01</td>
<td>19.16</td>
<td>27.17</td>
</tr>
<tr>
<td>Eastern</td>
<td>1,097</td>
<td>5.74</td>
<td>22.87</td>
<td>28.61</td>
</tr>
<tr>
<td>Western</td>
<td>244</td>
<td>9.59</td>
<td>43.98</td>
<td>53.57</td>
</tr>
<tr>
<td>Southern</td>
<td>86</td>
<td>3.15</td>
<td>49.78</td>
<td>52.93</td>
</tr>
</tbody>
</table>

*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 Baltimore County was shorter than in any other area. On the other hand, CF-related incidents in Anne Arundel mostly resulted in relatively long durations. In most areas, the incident durations are highly likely to increase as the incident becomes more severe. For instance, the incidents with any fatality showed the longest durations, followed by incidents with personal injury, incidents with property damage, and so on.
Chapter 6

6.2 Distribution of Average Incident Durations by County and Region

Figure 6.6 Distribution of Average Incident Duration by County and Nature

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

Figure 6.6 Distribution of Average Incident Duration by County and Nature
Chapter 6
6.3 Distribution of Average Incident Durations by Weekdays/Ends and Peak/Off-Peak Hours

According to the statistics in Table 6.3, although the difference in average response times for weekdays and weekends in 2014 is only about less than 1 minute, the average clearance time for weekends was approximately 3 minutes 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 due to the fact that 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

<table>
<thead>
<tr>
<th></th>
<th>Year</th>
<th>Sample</th>
<th>Avg. Response</th>
<th>Avg. Clearance</th>
<th>Avg. Incident</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Frequency</td>
<td>Time</td>
<td>Time</td>
<td>Duration</td>
</tr>
<tr>
<td>Weekdays</td>
<td>2014</td>
<td>18,337</td>
<td>7.23</td>
<td>20.45</td>
<td>27.68</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>13,719</td>
<td>7.02</td>
<td>19.08</td>
<td>26.10</td>
</tr>
<tr>
<td>Weekends</td>
<td>2014</td>
<td>3,819</td>
<td>6.61</td>
<td>23.34</td>
<td>29.94</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>1,897</td>
<td>5.34</td>
<td>25.96</td>
<td>31.30</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Year</th>
<th>Sample</th>
<th>Avg. Response</th>
<th>Avg. Clearance</th>
<th>Avg. Incident</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Frequency</td>
<td>Time</td>
<td>Time</td>
<td>Duration</td>
</tr>
<tr>
<td>Off-Peak</td>
<td>2014</td>
<td>15,611</td>
<td>7.16</td>
<td>20.51</td>
<td>27.66</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>10,252</td>
<td>6.89</td>
<td>21.26</td>
<td>28.15</td>
</tr>
<tr>
<td>Peak2</td>
<td>2014</td>
<td>6,545</td>
<td>7.20</td>
<td>18.29</td>
<td>25.50</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>5,364</td>
<td>6.68</td>
<td>17.36</td>
<td>24.03</td>
</tr>
</tbody>
</table>

Note: 1. Incident records with the complete information for duration computation.
2. 7:00 AM to 9:30 AM and 4:00 PM to 6:30 PM
3. Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis.

Table 6.4 shows that the average clearance time during off-peak hours was longer than during peak hours. Consequently, the average duration for incidents occurring during off-peak hours was longer than for those during peak hours.
Whether or not CHART responded to an incident is another significant factor affecting the distribution of incident durations. When CHART was involved in the incident recovery task, the incident duration was likely to be reduced. This observation indicates that CHART played an efficient role in shortening incident durations, reducing the delay caused by non-recurrent congestion.

The response time and clearance time of incidents could vary with the pavement conditions. Figure 6.7 shows that the average response time for dry, wet, and snow/ice wet conditions are similar to one another, but the average clearance time is likely to be longer on snow/ice and chemical wet (e.g., oil spill) conditions.

**Table 6.5 Distribution of Average Incident Duration without and with CHART**

<table>
<thead>
<tr>
<th></th>
<th>Year</th>
<th>Sample* Frequency</th>
<th>Avg. Response Time</th>
<th>Avg. Clearance Time</th>
<th>Avg. Incident Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>w/o CHART</td>
<td>2014</td>
<td>2,380</td>
<td>7.40</td>
<td>27.50</td>
<td>34.90</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>2,115</td>
<td>5.52</td>
<td>26.76</td>
<td>32.28</td>
</tr>
<tr>
<td>w/ CHART</td>
<td>2014</td>
<td>19,704</td>
<td>7.10</td>
<td>20.08</td>
<td>27.18</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>13,501</td>
<td>7.02</td>
<td>18.85</td>
<td>25.87</td>
</tr>
</tbody>
</table>

* Incident records with the complete information for duration computation.

**Note:** Incident data only for incident duration between 1 minute and 120 minutes are used for this analysis.
Chapter 6
6.4 Distribution of Average Incident Durations by CHART Involvement, Pavement Condition, Heavy Vehicle Involvement, and Road

Figure 6.8 illustrates the influence of heavy vehicles on the average incident durations. In 2014, the response and clearance times for incidents involved with heavy vehicles were likely to take longer times due to their resulting severity.

![Graph showing average incident durations by heavy vehicle involvement.]

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 durations by road and nature. Notably, the average incident duration of CFs was much longer than those for other incident types. Also, note that CF incidents occurring on I-270 seemed to exhibit the longest average duration (i.e., 268.31 minutes).
Chapter 6

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

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
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.
Chapter 7
7.1 Assistance to Drivers

Since the inception of CHART, the public has expressed great appreciation for the timely assistance 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 flow, 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 2014 and Year 2013 are depicted in Figure 7.1. Those assists offered by TOC 3, TOC 4, and TOC 7 are illustrated in Figure 7.2, Figure 7.3, and Figure 7.4, respectively.
These types of driver assistance in 2014 include flat tires, shortages of gas, or mechanical problems. Out of the 50,611 assistance requests, 12,285 assists were related to “out of gas” or “tire changes,” less than the number in 2013 (8,350 cases).
Chapter 7
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 with the above definition, using the accident database of the MSP for the year 2014. Notably, 930 secondary incidents occurred in 2014. 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: 930
- Estimated number of secondary incidents without CHART, which reduced incident duration by 33.01 percent, calculated as: 930/(1-0.3301) = 1,388 incidents
- The number of incidents potentially reduced due to CHART/MSHA operations: 1,388-930 = 458 secondary incidents

Note that the 458 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.

Figure 7.5 Distributions of Reported Secondary Incidents
Chapter 7
7.3 Estimated Benefits due to Efficient Removal of Stationary Vehicles

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 changes 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>
<thead>
<tr>
<th>Road Name</th>
<th>I-495/95</th>
<th>I-95</th>
<th>I-270</th>
<th>I-695</th>
<th>I-70</th>
<th>I-83</th>
<th>I/MD-295</th>
<th>US-50</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mileage</td>
<td>41</td>
<td>63</td>
<td>32</td>
<td>44</td>
<td>13</td>
<td>34</td>
<td>30</td>
<td>42</td>
<td>848</td>
</tr>
<tr>
<td>No. Potential Incidents Reduced</td>
<td>2014</td>
<td>203</td>
<td>231</td>
<td>48</td>
<td>149</td>
<td>72</td>
<td>44</td>
<td>30</td>
<td>71</td>
</tr>
<tr>
<td>2013</td>
<td>126</td>
<td>183</td>
<td>36</td>
<td>87</td>
<td>43</td>
<td>29</td>
<td>11</td>
<td>67</td>
<td>582</td>
</tr>
<tr>
<td>2012</td>
<td>90</td>
<td>140</td>
<td>27</td>
<td>54</td>
<td>39</td>
<td>13</td>
<td>8</td>
<td>58</td>
<td>429</td>
</tr>
<tr>
<td>2011</td>
<td>86</td>
<td>174</td>
<td>33</td>
<td>68</td>
<td>38</td>
<td>22</td>
<td>7</td>
<td>54</td>
<td>482</td>
</tr>
<tr>
<td>2010</td>
<td>99</td>
<td>225</td>
<td>41</td>
<td>84</td>
<td>27</td>
<td>18</td>
<td>10</td>
<td>60</td>
<td>564</td>
</tr>
</tbody>
</table>

*Note: The analysis has excluded the outlier data (i.e. mean ± 2 standard deviation)*
Chapter 7
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 (2014) and the Energy Information Administration (2014). Figure 7.6 also shows the difference in benefits between 2013 and 2014.

The evaluation for 2014 has adopted delay reduction for cars and trucks to convert the delays to fuel consumption. Please refer to Note 3 under Table 7.2 for details.

The estimated reductions in vehicle emissions for HC, CO, and NO were based on the parameters provided by MDOT and the total delay reduction. Since CO₂ is recognized as a primary factor for global warming, this study also included the estimated CO₂ reduction, based on the information from the Energy Information Administration. Using the cost parameters shown in Table 7.2 (DeCorla-Souza, 1998), the above reduction in emissions resulted in a total savings of 41.43 million dollars. Thus, CHART operations in Year 2014 generated a total savings of 1,264.53 million dollars.
Chapter 7
7.4 Direct Benefits to Highway Users

Table 7.2 Total Direct Benefits to Highway Users in 2013

<table>
<thead>
<tr>
<th>Reduction due to CHART</th>
<th>Amount</th>
<th>Unit rate</th>
<th>In M Dollar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay (M veh-hr)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck</td>
<td>1.59 (2.31)</td>
<td>Driver $20.20/hour (19.29) 2</td>
<td>32.19 (44.58)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cargo $45.40/hour 2</td>
<td>72.37 (104.96)</td>
</tr>
<tr>
<td>Car</td>
<td>34.71 (30.34)</td>
<td>$31.54/hour (31.36) 2</td>
<td>1,094.71 (951.39)</td>
</tr>
<tr>
<td>Fuel Consumption (M gallon)</td>
<td>6.77 (6.77)</td>
<td>Gasoline $3.44/gal (3.58) 2</td>
<td>23.83 (24.63)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diesel $3.83/gal (3.92) 2</td>
<td></td>
</tr>
<tr>
<td>Emission</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HC</td>
<td>474.64</td>
<td>$6,700/ton</td>
<td>41.43 (37.41)</td>
</tr>
<tr>
<td>CO</td>
<td>5,330.96</td>
<td>$6,360/ton</td>
<td></td>
</tr>
<tr>
<td>NO</td>
<td>227.32</td>
<td>$12,875/ton</td>
<td></td>
</tr>
<tr>
<td>CO₂ 4</td>
<td>61,817.23</td>
<td>$23/metric ton</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>$1264.53 (1,162.97)</td>
</tr>
</tbody>
</table>

Note:
* The number in each parenthesis is the estimate in year 2013
* Italic unit rates indicate changes in 2014, and the number in the parenthesis is the unit rate for the 2013 analysis
* All values are rounded to the nearest hundredth in this table only for the presentation purpose, since actual values need more spaces to be presented. For example, the benefit from truck drivers = 2,311,857.08... veh-hr * $19.285/hr = $44,584,163.74...

1. The total delay reduction consists of the car delay reduction occurring over all roads covered by CHART, and the truck delay reduction occurring only along major roads. The extended analysis of the total benefit with respect to truck volume using both major highways and all roadways covered by CHART is presented in Appendix-B
2. The car driver’s cost and fuel price are updated based on the information from the U.S Census Bureau in Year 2014 and the Energy Information Administration in Year 2014, respectively.
3. 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).
4. This value is computed based on the unit rates of 19.56 lbs CO₂/gallon of gasoline and 22.38 lbs CO₂/gallon of diesel from the Energy Information Administration and $23/metric ton of CO₂ from CBO (Congressional Budget Office)’s cost estimate for S. 2191, America’s Climate Security Act of 2007.
   e.g. 4.73 (million gallon) * 19.56 (lbs CO₂/gallon) / 2204 (lbs/metric ton) * 23($/metric ton)
Chapter 7

7.4 Direct Benefits to Highway Users

The total benefits increased from 1,162.97 million dollars in 2013 to 1,264.53 million dollars in 2014, and the possible contributing factors are listed below:

• The AADT changes are shown in Table 7.3. There are slight increases on MD-295 and I-70 but decreases on other major roads.
• As shown in Table 7.4, the ratio, showing the efficiency in clearing incidents with and without CHART, increased from 31 percent to 33 percent. This indicates the improvement of CHART performance to respond and clear detected incidents.
• Table 7.5 shows that the truck percentage decreased on all major roads.
• The total number of eligible incidents for the benefit estimate increased by about 14 percent from 2013 to 2014 as shown in Table 7.6.

Since each key factor has a different degree of exponential impact on the resulting benefit change, Appendix-B has further illustrated the results in detail.
Chapter 7
7.4 Direct Benefits to Highway Users

Table 7.3 Changes in AADTs for Major Roads from 2013 to 2014

<table>
<thead>
<tr>
<th></th>
<th>Year</th>
<th>I-495</th>
<th>I-95</th>
<th>I-270</th>
<th>I-695</th>
<th>MD 295</th>
<th>US 50</th>
<th>US 1</th>
<th>I-83</th>
<th>I-70</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2014</td>
<td>11,677</td>
<td>7,979</td>
<td>7,164</td>
<td>10,680</td>
<td>4,343</td>
<td>1,891</td>
<td>4,203</td>
<td>2,936</td>
<td>3,181</td>
<td>54,054</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>12,107</td>
<td>8,278</td>
<td>7,229</td>
<td>11,290</td>
<td>4,301</td>
<td>2,227</td>
<td>4,249</td>
<td>3,478</td>
<td>3,100</td>
<td>56,259</td>
</tr>
<tr>
<td>∆('13 ~ '14) (%)</td>
<td></td>
<td>-3.55</td>
<td>-3.61</td>
<td>-0.90</td>
<td>-5.40</td>
<td>0.98</td>
<td>-15.09</td>
<td>-1.08</td>
<td>-15.58</td>
<td>2.61</td>
<td>-3.92</td>
</tr>
</tbody>
</table>

Table 7.4 Comparison of Incident Duration Reduction between 2013 and 2014

<table>
<thead>
<tr>
<th></th>
<th>With CHART (mins)</th>
<th>Without CHART (mins)</th>
<th>Difference (mins)</th>
<th>Ratio in Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2014</td>
<td>23.32</td>
<td>34.82</td>
<td>11.50</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>21.64</td>
<td>31.54</td>
<td>9.90</td>
</tr>
</tbody>
</table>

Table 7.5 Changes in Truck Percentage for Major Roads from 2013 to 2014

<table>
<thead>
<tr>
<th></th>
<th>Year</th>
<th>I-495</th>
<th>I-95</th>
<th>I-270</th>
<th>I-695</th>
<th>MD 295</th>
<th>US 50</th>
<th>US 1</th>
<th>I-83</th>
<th>I-70</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2013</td>
<td>11.89</td>
<td>17.77</td>
<td>10.11</td>
<td>13.22</td>
<td>3.92</td>
<td>11.22</td>
<td>5.72</td>
<td>13.50</td>
<td>17.79</td>
<td>11.68</td>
</tr>
</tbody>
</table>

Table 7.6 Total Number of Incidents Eligible for the Benefit Estimate

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2014</th>
<th>∆('13 ~ '14) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Incidents</td>
<td>23,706</td>
<td>27,014</td>
<td>13.95</td>
</tr>
</tbody>
</table>

* Note: Only incidents causing a blockage on one or more travel lanes are included in the benefit estimation.
In addition to the above benefit analyses, the reduction in emissions due to reduced travel time in the Baltimore and Washington regions has also been computed. The results are summarized in Tables 7.7(a) and 7.7(b), where the daily delay reductions for the Washington region in 2014 were 1,615 hours/day and 44,214 hours/day for trucks and cars, respectively, compared with the 2,218 hours/day for trucks and 37,022 hours/day for cars in 2013. The delay reduction for trucks in the Baltimore region decreased from 6,674 hours/day in 2013 to 4,516, hours/day in 2014, and increased from 79,664 hours/day in 2013 to 89,296 hours/day in 2014 for passenger cars. The overall reductions in emissions (i.e., by cars and trucks) for the entire region were $159,359/day and $143,873/day for the years of 2014 and 2013, respectively.

### Table 7.7(a) Delay and Emissions Reductions for Trucks Due to CHART/MSHA Operations for Washington and Baltimore Regions

<table>
<thead>
<tr>
<th>Truck</th>
<th>Total by CHART</th>
<th>Washington Region</th>
<th>Baltimore Region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 2014</td>
<td>Year 2013</td>
<td>Year 2014</td>
</tr>
<tr>
<td>Annual Delay Reduction</td>
<td>hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,594,083</td>
<td>2,311,857</td>
<td>419,899</td>
</tr>
<tr>
<td>Daily Delay Reduction</td>
<td>hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6,131</td>
<td>8,892</td>
<td>1,615</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emission Reduction</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>HC reduction</td>
<td>ton/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.080</td>
<td>0.116</td>
<td>0.034</td>
<td>0.051</td>
<td>0.046</td>
</tr>
<tr>
<td></td>
<td>$/day</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>537.02</td>
<td>778.82</td>
<td>228.67</td>
<td>342.33</td>
<td>308.35</td>
</tr>
<tr>
<td>CO reduction</td>
<td>ton/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.900</td>
<td>1.306</td>
<td>0.383</td>
<td>0.574</td>
<td>0.517</td>
</tr>
<tr>
<td></td>
<td>$/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5,725.49</td>
<td>8,303.53</td>
<td>2,438.00</td>
<td>3,649.83</td>
<td>3,287.49</td>
</tr>
<tr>
<td>NO reduction</td>
<td>ton/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.038</td>
<td>0.056</td>
<td>0.016</td>
<td>0.024</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>$/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>494.23</td>
<td>716.77</td>
<td>210.45</td>
<td>315.06</td>
<td>283.78</td>
</tr>
<tr>
<td>CO₂ reduction</td>
<td>metric ton/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>52.92</td>
<td>76.75</td>
<td>22.53</td>
<td>33.73</td>
<td>30.38</td>
</tr>
<tr>
<td></td>
<td>$/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,217.12</td>
<td>1,765.16</td>
<td>518.27</td>
<td>775.88</td>
<td>698.85</td>
</tr>
<tr>
<td>Total</td>
<td>$/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7,973.85</td>
<td>11,564.27</td>
<td>3,395.39</td>
<td>5,083.10</td>
<td>4,578.46</td>
</tr>
</tbody>
</table>
# Chapter 7

## 7.4 Direct Benefits to Highway Users

Table 7.7(b) Delay and Emissions Reductions for Cars Due to CHART/MSHA Operations for Washington and Baltimore Regions

<table>
<thead>
<tr>
<th>Car</th>
<th>Total by CHART</th>
<th>Washington Region</th>
<th>Baltimore Region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 2014</td>
<td>Year 2013</td>
<td>Year 2014</td>
</tr>
<tr>
<td><strong>Annual Delay Reduction</strong></td>
<td>hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>34,712,700</td>
<td>30,338,401</td>
<td>11,495,722</td>
</tr>
<tr>
<td><strong>Daily Delay Reduction</strong></td>
<td>hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>133,510</td>
<td>116,686</td>
<td>44,214</td>
</tr>
<tr>
<td><strong>Emission Reduction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HC reduction</strong></td>
<td>ton/day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.745</td>
<td>1.525</td>
<td>0.743</td>
</tr>
<tr>
<td></td>
<td>$/day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11,694.05</td>
<td>10,220.44</td>
<td>4,979.51</td>
</tr>
<tr>
<td><strong>CO reduction</strong></td>
<td>ton/day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$/day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>124,678.03</td>
<td>108,966.80</td>
<td>53,089.83</td>
</tr>
<tr>
<td><strong>NO reduction</strong></td>
<td>ton/day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.836</td>
<td>0.731</td>
<td>0.356</td>
</tr>
<tr>
<td></td>
<td>$/day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10,762.32</td>
<td>9,406.11</td>
<td>4,582.76</td>
</tr>
<tr>
<td><strong>CO2 reduction</strong></td>
<td>metric ton/day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>184.84</td>
<td>161.55</td>
<td>78.71</td>
</tr>
<tr>
<td></td>
<td>$/day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4251.33</td>
<td>3715.60</td>
<td>1810.28</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$/day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>151,385.73</td>
<td>132,308.95</td>
<td>64,462.39</td>
</tr>
</tbody>
</table>
Chapter 8

CONCLUSIONS AND RECOMMENDATIONS
Chapter 8

8.1 Conclusions

Building on the previous research experience, this study has conducted a rigorous evaluation of CHART’s performance in 2014 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.

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 2014 was 11.01 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 2014 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.
The main recommendations, based on the performance of CHART in 2014, are listed below:

- A strategy should be developed and updated 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.
- CHART’s quality evaluation report should be made available to the operators to facilitate their continuous improvement of response operations.
- CHART should coordinate with county traffic agencies to extend its operations to major local routes and to include the data collection, as well the performance benefit, in the annual CHART review.
- Training sessions should be implemented to educate/re-educate operators on the importance of high-quality data and discuss how to effectively record critical performance-related information.
- The data structure used in the CHART-II system for recording incident locations should be improved to eliminate the current laborious, complex procedures.
- The database structure should be documented and re-investigated on a regular basis to improve the efficiency and quality of collected data.
- Possible explanations for extremely short or long response and/or clearance times should be documented so that the results of performance analysis can be more reliable.
- Police accident data should be efficiently integrated into the CHART incident response database in order to have a complete representation of statewide incident records.
- The benefits of reduced potential secondary incidents on delay and fuel consumption should be incorporated into the CHART benefit evaluation.
REFERENCES


REFERENCES

20. Incident reports for 1997 from statewide operation center, Traffic Operation Center 3 and 4, State Highway Administration, Maryland.
26. Maryland Wages by Occupation, Department of Business and Economic Development, Maryland.
REFERENCES

APPENDIX A - Additional Analyses

Figure A.1 Distributions of Incidents by Time of Day on I-95 in Year 2014

Figure A.2 Distributions of Disabled Vehicles by Time of Day on I-95 in Year 2014
APPENDIX A - Additional Analyses

Figure A.3 Distributions of Incidents by Time of Day on I-495 in Year 2014

Figure A.4 Distributions of Disabled Vehicles by Time of Day on I-495 in Year 2014
APPENDIX A - Additional Analyses

Figure A.5 Distributions of Incidents by Time of Day on I-270 in Year 2014

Figure A.6 Distributions of Disabled Vehicles by Time of Day on I-270 in Year 2014
APPENDIX A - Additional Analyses

Figure A.7 Distributions of Incidents by Time of Day on I-695 in Year 2014

Figure A.8 Distributions of Disabled Vehicles by Time of Day on I-695 in Year 2014
APPENDIX A - Additional Analyses

Figure A.9 Distributions of Clearance Time by Time of Day in Year 2014

Figure A.10 Distributions of Incident Duration by Time of Day in Year 2014
APPENDIX A - Additional Analyses

Figure A.11 Distributions of Incident Duration by Time of Day on I-95 in Year 2014

Figure A.12 Distributions of Incident Duration by Time of Day on I-495 in Year 2014

Figure A.13 Distributions of Incident Duration by Time of Day on I-270 in Year 2014
APPENDIX A - Additional Analyses

Figure A.14 Distributions of Incident Duration by Time of Day on I-695 in Year 2014

Figure A.15 Distributions of Incident Duration by Time of Day on I/MD-295 in Year 2014

Figure A.16 Distributions of Incident Duration by Time of Day on I-83 in Year 2014
APPENDIX B - Benefit Estimation Procedure and Sensitivity Analysis

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

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

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

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

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

Step 5: Estimate the total delay reduction ($\Delta TD$) by the CHART performance based on the estimated CHART efficiency

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

Step 7: Convert the total delay reduction, fuel consumption reduction, emission reduction into monetary values
APPENDIX B - Benefit Estimation Procedure and Sensitivity Analysis

Sensitivity Analysis

Because the total benefits have been increased from $1,162.97 million in 2013 to $1,264.53 million in 2014, this section is devoted to the analysis of each critical factor’s impact on the total benefit variation. The procedures for such sensitivity analyses include the following steps:

- Identifying key factors contributing to computation of the total CHART benefit, which are: traffic volume, the number of incidents resulting in lane blockage, incident duration difference between with and without CHART involvements, truck percentage, gas price, and value of time;
- Computing the marginal impact of the selected factor using its 2014 value, but setting all other factors identical to those in 2013; and
- Following the same procedure to analyze the sensitivity of the total 2014 benefit with respect to each key factor.

The results of sensitivity analysis for each factor are shown in the following table:

<table>
<thead>
<tr>
<th>Key Factor</th>
<th>Δ ('13 - ’14)</th>
<th>Benefit difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Volume</td>
<td>⇩ 3.92 %</td>
<td>1,011.06 (⇩13.06%)</td>
</tr>
<tr>
<td>Number of incidents</td>
<td>↑ 13.95 %</td>
<td>1,303.96 (↑12.12%)</td>
</tr>
<tr>
<td>Incident duration difference between w/ and w/o CHART</td>
<td>↑ 16.11 %</td>
<td>1,223.66 (↑5.22%)</td>
</tr>
<tr>
<td>Truck percentage</td>
<td>⇩21.89 %</td>
<td>1,145.08 (⇩15.41%)</td>
</tr>
<tr>
<td>Monetary unit value of time</td>
<td>⇩ 2.64%</td>
<td>1,169.63 (⇩0.57%)</td>
</tr>
<tr>
<td>Monetary unit of gas price</td>
<td>⇩3.04 %</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benefit in 2013</th>
<th>1,162.97</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit of the Current Year (2014)</td>
<td>1,264.53 (⇧8.73%)</td>
</tr>
</tbody>
</table>

The number in each parenthesis shows the percentage of benefit change from 2013.

Notably, the compound impact of all key factors has caused CHART operations in 2014 to produce 8.73 percent more benefit than in 2013. The average decrease in traffic volume by 3.92 percent in 2014 resulted in 13.06 percent benefit increase. With respect to the benefit to truck traffic due to CHART operations, the computation of delay reduction only includes major highways (i.e., I-495, I-95, I-270, I-695, I-70, I-83, I/MD295, US50, and US1).
APPENDIX C - Sources of Images Used in This Report

P15: From Maryland State Highway Administration (SHA)

P17, P73:
http://itsmd.org/?attachment_id=12

P21:
http://md511.org/

P34, P90:

P52:
http://www.chart.state.md.us/