Performance Evaluation

Of

CHART

-An Incident Management Program-

in 1997

Final Report

Prepared by

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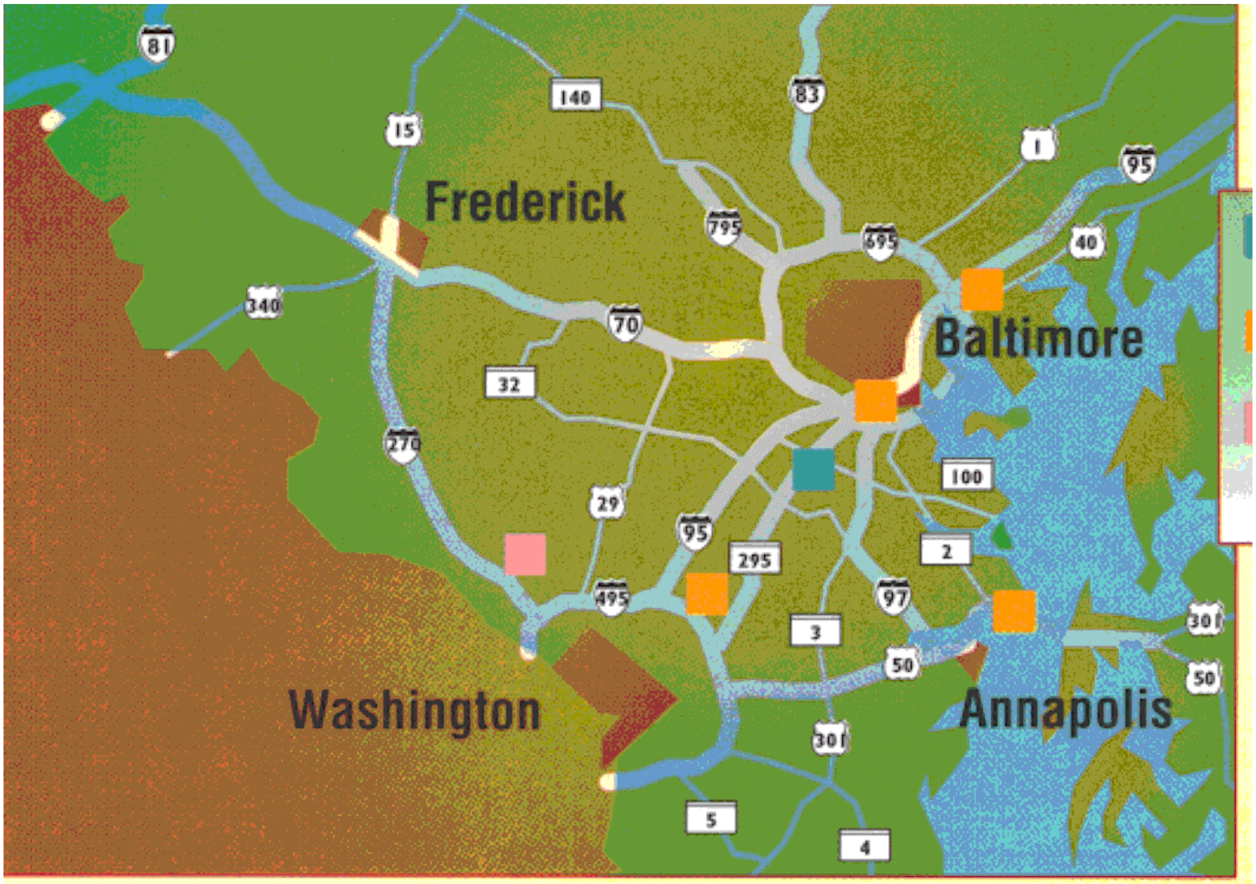
Area Road Network Map Covered by CHART



SOC TOC

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Executive Summary

- **Objectives**

This chapter presents the summary of the 1997 CHART Benefits Evaluation study conducted for Maryland State Highway Administration (MSHA) by the Civil Engineering Department of the University of Maryland at College Park and MSHA staff. The purpose of this study is to assess the effectiveness of the Maryland CHART program with an emphasis on its ability to detect and respond to incidents on major freeways and highways. The efficiency of the entire incident management operations along with its resulting benefits also constitutes the core of the study.

The evaluation study consists of two phases. Whereas the focus of Phase-1 was on defining the objectives, identifying the available data, and developing the methodology, the core of Phase-2 was to reliably assess the efficiency of the incident management program and to estimate its resulting benefits from data available in the 1997 CHART incident operations record. As some information essential for efficiency and benefit assessment was not collected in 1997, this study presents only those evaluation results that can be directly computed from incident management data or derived with reliable statistical methods.

- **Available data for analysis**

In 1996, an evaluation study with respect to the incident response system of CHART was conducted by COMSIS (COMSIS, 1996). In performing the evaluation, the 1994 incident management data from the Traffic Operations Center were considered, but not used due to various reasons. Thus, its conclusions were mostly grounded on either the data from other states or from a nationwide average published by the Federal Highway Administration.

To ensure the quality of evaluation and also to consider the opening of the Statewide Operations Center (SOC) in August 1995, all members involved in the evaluation study concluded that a reliable analysis should be based on the *actual performance data from the CHART program*. Thus, the 1996 incident management data were collected and used in the pilot evaluation analysis conducted jointly by the University of Maryland and MSHA staff (Chang and Point-Du-Jour, 1996). This pioneering study inevitably faced the difficulty of having a data set with sufficient information for analysis, as it was the first time for CHART to identify and organize all previous performance records for a rigorous evaluation.

Unlike all previous studies, the evaluation for the 1997 CHART performance has the advantage of receiving relatively rich information, including all 1997 incident management reports from the SOC, TOC-3 (located at the proximity of the Capital Beltway) and TOC-4 (located near to Baltimore Beltway). The SOC record contained a total of **905** incident reports for the entire 12 months in 1997, and TOC-3 had **1,450** incident reports over the same period. However, TOC-4 had only a partial record of **395** incident reports available for analysis. Also provided were the 1997 accident reports from Maryland State Police.

- **Distribution of incidents**

The methodology for the evaluation was developed to take the full advantage of available data. It started from an analysis of incident characteristics by the blockage frequency, duration and blocked lanes. The analysis indicates that there were a total of **1,161** incidents resulting in one-lane blockage, and **842** incidents causing two-lane closures. The incidents on freeways were mostly distributed along four major commuting corridors, where I-495 (Beltway around Washington, D.C.) experienced a total of **1,051** incidents, I-695(Beltway around Baltimore city), I-270 and I-95 had **266, 247** and **169** incidents, respectively, in 1997. Thus, CHART had responded to, on average, **3** incidents per day for I-495 alone, and **0.7, 0.6** and **0.5** incidents for the other three main commuting freeways.

With respect to the blockage duration, most incidents on major commuting freeways did not block the traffic for more than one hour. For instance, the total number of incidents, having blockage duration shorter than one hour, was about **89** percent on I-495 in 1997. A similar incident pattern also exists on I-270. There were about **82** percent of incidents on I-270 having lane blockages for less than one hour. The statistic is relatively low for I-695 and I-95, about **75** percent and **73** percent respectively.

It, however, should be noted that in comparison with other highways, drivers on I-495 clearly had been caught in a long incident blockage much more often than others. For instance, there were a total of 71 incidents in 1997 on I-495 lasting over one hour, and about 29 of those blocking the traffic for more than 2 hours. Thus, by defining those over one hour as severe incidents, drivers on I-495 had experienced on average of *one severe incident per five days* in 1997, in contrasting to *one severe incident per three days in 1996*. Certainly, a variety of factors may contribute to the reduction of severe incidents on I-495 from 1996 to 1997, the improved operations for incident management by CHART could be one of the primary contributors.

In brief, it is clear that the highway network covered by CHART has been plagued by the high frequency of incidents, ranging from about 20 minutes to more than 2 hours. Those incidents were apparently one of the primary contributors to the traffic congestion in the entire region, especially on those major commuting highway corridors such as I-495, I-695, I-270 and I-95.

- **Efficiency of Operations**

In evaluating the efficiency of an incident management program, it is essential to cover the following three vital aspects: detection, response, and recovery of traffic conditions. Unfortunately, data needed for performing the detection and complete response time analysis are not yet available under the current CHART operations.

One of the indicators related to the detection is the response rate. It was found to be about **99** percent for the TOC-3, **94.7** percent for TOC-4 and **92.3** percent for SOC. The Maryland State Police (MSP) and the local/county Police were the main sources for detecting and reporting incidents for CHART.

To understand the contribution of the incident management program, this study has computed and compared the average incident clearance time between responded and non-responded incidents. For instance, for those two-lane blockage incidents CHART did not respond to, the average operation time was about **99** minutes, significantly longer than the average of **78** minutes for the same type of two-lane blockage incidents managed by CHART. Taking into account all types of incidents, the average incident duration with and without the management by **CHART** was found to be **44.7 minutes** and **68.2 minutes, respectively.** Thus, based on the available record in 1997, the operations of CHART resulted in about 35 percent reduction on the average incident duration.

- **Resulting Benefits**

The benefits attributed to the CHART program that were estimable directly from the available data include: assistance to drivers, reduction in driver delay time, vehicle operational hours, reduction in fuel consumption, emission and secondary incidents.

The 1997 incident record from CHART indicates that its incident management team responded to a total of **2645** incidents, including providing assistance to drivers that may prevent some potential severe secondary incidents. The average duration for driver assistance from a sample size of **183** cases was found to be around **25.6 minutes**. The direct benefits of reduction in delay time and fuel consumption were estimated with CORSIM, a traffic simulation program produced by FHWA. The procedures were to first replicate all incident scenarios in 1997 with CORSIM, and then to compare their resulting measures of effectiveness (MOEs) based on the 35 percent reduction on the average incident duration.

Using the same MOEs generated from simulation replications, the analysis results have indicated that due to the operation of CHART in 1997, the total reduction in delay time was about **15.6 million vehicle-hours,** and the total reduction in fuel consumption was approximately **5.85 million gallons**.

Another major benefit of CHART, reduction in secondary incidents was computed from Maryland State Police accident reports. The potential reduction in secondary incidents, due to the incident management of CHART in 1997, was found to be **337**. Any other cost savings associated with the reduction in secondary incidents, such as medical expenses, was not included in the analysis as those were not directly measurable from the existing data.

- **Recommendations**

The primary recommendations based on the results of analysis and evaluation are summarized below:

. *Developing an incident information management system* that can automate the incident data recording and archiving process, and generate the up-to-date CHART performance report as needed.

. *Training operators to effectively record all essential operations related data*
many of those incident reports in 1997 were found to have a large number of either missing or incomplete items.

. *Modifying the current report form to contain all vital information*
for improving the operations efficiency and justifying the resulting benefits.

. *Continuing the performance and benefit analysis*
so as to best allocate the available resources and sustain the support from both the general public and state legislators.

. *Evaluating the efficiency as well as cost/benefit of other components*
of CHART such as the Traveler Information System and Traffic Management Program.

. *Improving the utilization of freeway service patrols*
and optimizing their spatial distribution on freeway segments of high incident frequency so as to reduce the incident response time.

. *Installing additional surveillance sensors*
to share the incident detection load that is undertaken mostly through drivers' phone reports to the state and county police departments.

. *Investigating the interrelations between the traffic demand patterns*
and the distribution of incidents so as to effectively contending with non-recurrent congestion.

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Chapter 1: Introduction

1.1: Background

CHART is the highway incident management program of the Maryland State Highway Administration (MSHA). Initiated in the mid 80' as "Reach the Beach", it has extended into a statewide program headquartered in Hanover, Maryland where the newly built and integrated statewide operations center (SOC) is located. The SOC is also supported by three satellite traffic operations centers (TOC), one being seasonal. CHART's field operations are also supported by the maintenance shop personnel. The current network covered by CHART consists of statewide freeways and highway arterials.

CHART is comprised of four major components: traffic monitoring, incident response, traveler information, and traffic management. Among those four components, the incident response and traveler information systems have received an increasing attention from general public, media, and transportation professionals.

The objective of this study was thus to assess the effectiveness of CHART's current operations, including its incident detection, response, and traffic management on the interstate freeways as well as major arterials. The assessment work also covers the benefit estimate of CHART, as such benefits are essential for MSHA to receive the sustained support for all their on-going programs from both general public and state policy makers.

1.2: Available data for performance evaluation

The first attempt to evaluate the performance of CHART was made by COMSIS in 1996, which, however, was derived from either other states or the nationwide statistics by FHWA. A subsequent study of CHART's performance in 1996 was conducted by The University of Maryland based on the 1996 incident record from CHART, and accident reports from the state policy office (Chang and Point-du-Jour, 1996). However, since it was the first time for CHART to use its historical incident management record for performance evaluation, some valuable information was not available for analysis.

The performance evaluation of CHART in 1997, detailed in this report, has employed relatively rich data, including a complete set of incident reports (i.e., 12 months) from all these three active traffic operations centers (SOC, TOC-3 and TOC-4), and the accident report data from state police for estimating secondary incidents. It, however, should be mentioned that the information contained in the incident report form was designed originally for operational record, rather than for the evaluation need. Thus, many critical data for a thorough performance evaluation remain unavailable at this stage. For instance, both incident detection time and preparation time are not available for assessing the detection and complete response efficiency.

Figure 1.1 illustrates the definition and interrelations between technical terms used typically in an incident performance evaluation. Also presented are those data associated with operational efficiency and available for use in this 1997 CHART evaluation study.

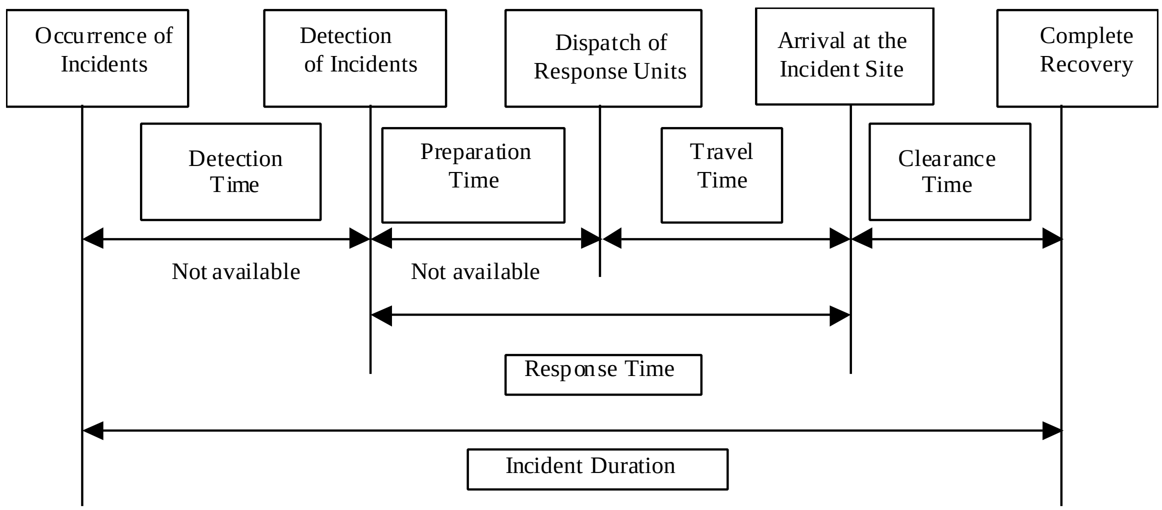

Figure 1.1: A graphical illustration of technical terms associated with an incident operation

1.3: Evaluation methodology

To take full advantage of available data and also to ensure the reliability of results, the research team has divided this evaluation study into the following principal tasks:

- Defining the principal objectives of this study,
- Identifying available data sources and their quality,
- Selecting the target areas for analysis based on data availability and quality such as:
  - incident characteristics;
  - incident detection efficiency;
  - distribution of incident detection sources;
  - incident response efficiency; and
  - effectiveness of incident traffic management.
- Computing the primary benefits from the incident management program, including:
  - modeling of sample incident scenarios with traffic simulation programs so as to generate benefit related data.
  - constructing statistical relations between principal benefits (i.e., delay,

fuel consumption and emission) and key incident related variables such as volume, number of available and blocked lanes, and incident duration.
- estimating the resulting benefits for each incident managed by CHART in 1997 with those constructed statistical relations.

- Assessing some measurable indirect benefits, including:
  - assistance to various requests by drivers, and
  - potential reduction in secondary incidents due to efficient incident management.

- Identifying critical missing information from the current incident report form.

- Developing a new incident report form.

- Recommending critical areas for potential improvements.

Note that the above tasks do not include the estimation of some indirect impacts such as the reduction on travel time and fuel savings from potentially reduced secondary incidents, the associated medical and legal costs, and improvement of the commuting environment. This is due understandably to the fact that most of such data are not available at the evaluation stage. Thus, the results of this study can be used not only to picture the approximate benefits and performance of CHART, but also to assist SHA in identifying and collecting critical related data for future analysis.

1.4: Literature Review

Despite the increasing investment on incident management by most state highway agencies, comprehensive evaluations for assessing effectiveness of such programs, however, are not available in the literatures. Some related studies reported in the literature are briefly reviewed below.

Carson et al. (1999) used quantified information, such as duration of detection/reporting, response and clearance, to investigate the effectiveness of incident management systems in Washington State. They calculated the monetary savings per incident by considering the reduction in average duration per incident from 1994 to 1995, and the value of time per vehicle-hour of delay from the traffic simulation results presented by Garrison and Mannering (1990). They did not compute the reduction in delays precisely neither compare the incident duration with and without the response of an incident management system. The public opinions and personnel input from relevant agencies were collected to estimate the perceived benefits.

Cuciti et al. (1993) performed an evaluation of Patrol Pilot Program designed to detect and remove disabled vehicles from the roadway quickly so as to minimize the resulting congestion backups for the I-25 corridor in Denver. In the entire evaluation, the authors focused on some critical issues such as: the incident response implementation procedures, incident types and services provided by the patrols, levels of motorist satisfaction with the program, comparison of alternative service delivery modes and their impacts on traffic conditions. However, it did not include the estimation of the direct and indirect benefits such as fuel consumption and reduction in secondary incidents.

Amos et al. (1995), in their study for installation of an incident management system on M4 in Sydney, Australia, proposed that evaluation of an incident management system should consist of project objectives, the evaluation approach, a clear and realistic measurement system and definition of the data requirements to measure the before and after condition. But the study was mainly at the conceptual level rather than actually performing the evaluation.

Along the same line, Karimi et al. (1993) pointed out four important elements of incident management system for Santa Monica Smart Corridor, which are detection, verification, response and monitoring. They proposed that response plans must be dynamic to reflect the evolving characteristics of the incident. To do so, incident management subsystem should monitor both the response plan and the incident, and may modify the response based on any changes that are detected. However, they neither did actual evaluation of the system nor discussed the necessary data for evaluating such a system.

Skabardonis et al. (1996) indicated that some factors such as: incident frequency and characteristics, freeway operational characteristics, the number of tow trucks involved, hours of operations and dispatching strategy, are critical to the effectiveness of freeway service patrol systems. They collected information on incidents, such as types of incident, number of lanes affected, vehicles involved (type, color), location (direction, lane, upstream or downstream to the nearest exit), time first witnessed an incident and arrival and departure times of tow trucks or patrols. Additional data were gathered from a computer-aided dispatch system, tow truck companies and patrol records. They developed a methodology to estimate incident delays based on the travel time difference under normal and incident conditions using data from loop detectors. The savings in delays and fuel consumptions were converted to monetary benefits. They also measured average time saving for vehicles assisted by freeway service patrol.

Chapter 2: Analysis of Incident Characteristics

To provide a clear picture for both incident management and traffic safety improvement, the evaluation work starts with a comprehensive analysis of the spatial distribution of incidents and their key characteristics, including:

- Distribution of incidents by roads;
- Distribution of incidents by blockage duration;
- Distribution of incidents by peak and off-peak hours;
- Distribution of incidents by weekday and weekend;
- Distribution of incidents by lane blockage;
- Distribution of incidents by location.

. With such information one can certainly better design the incident management strategy, such as: the distribution of patrol vehicles around freeway segments of a high incident frequency; assessing the impact areas under the average and the worst incident scenarios; and identifying hazardous highway segments from both the safety and operations perspectives.

2.1: Distribution of incidents by roads

Figure 2.1 presents the distribution of incident frequency by road. It is clear that the four major commuting freeways, I-495, I-695, I-95 and I-270, had a very large number of incidents in 1997, significantly higher than all other highways. I-495 experienced a total of **1,051** incidents; I-695 and I-270 had **266** and **247** incidents, respectively, in 1997. The frequency of incidents indicates that CHART had responded to about ***3** incidents per day for I-495 alone, about 0.7 incident per day for I-695, and 0.6 incident per day for I-270*.

It should be noted that both I-95 and I-270 are connected to I-495, and are the main contributors of traffic demand to I-495 during daily commuting periods. Due to the high traffic demand on I-495, any of its severe incidents is very likely to have vehicles queued back to both I-95 and I-270, thus causing serious congestion patterns on those two freeways. Such interdependent nature of incidents should be taken into account in prioritization and implementation of incident management strategies.

Conceivably, having such a high frequency of incidents on all those major commuting freeways is unacceptable from either the traffic safety or congestion mitigation perspective. Some effective remedies to improve both the driving conditions and driving behavior shall be taken as priority tasks. Since all those incidents also resulted in lane blockage on congested freeways, all responsible agencies for highway operations and safety ought to take the implementation of an efficient incident management program as one of their most vital tasks.

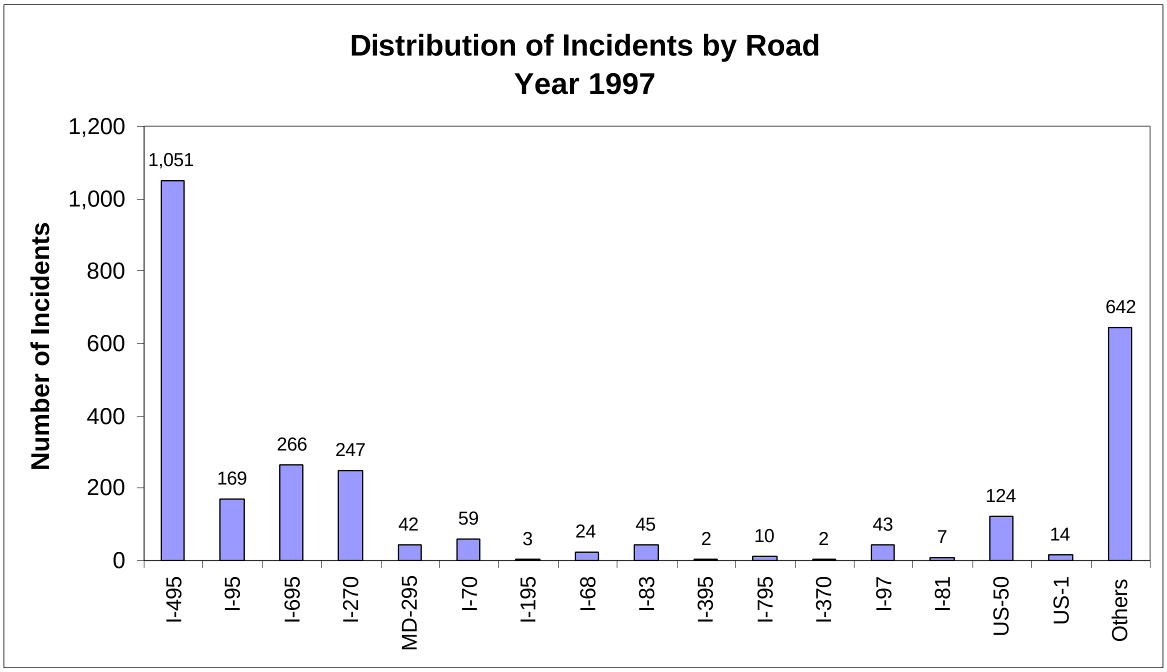

Figure 2.1: Distribution of incidents by roads

2.2: Distribution of incidents by blockage duration

This section presents the distribution of incidents by lane-blockage duration on the network covered by CHART. As shown in Figure 2.2 most incidents did not block the traffic for more than one hour.. For instance, the number of incidents shorter than one hour was about 89% on I-495, 75% on I-695, 82% on I-270, and 73% on I-95. Although those were generally minor incidents, their impacts were quite significant as to cause traffic blockage and congestion during peak hours. The clearance of such blockages generally did not require special equipments and hence the resulting incident duration mainly depended upon arrival of the incident response unit. Note that there was a high frequency of short duration incidents (less than 30 minutes), such as flat tires, on I-495 and I-270. On average, it had about 1.25 such incidents per day on I-495 and 0.28 per day on I-270 in year 1997.

Overall, drivers on I-495 and I-95 are more likely to be caught into a long incident blockage as reflected in the analysis. There was one severe incident, which blocked the road at least one hour, per 5 days on these freeways. On average, I-495 experienced 2 incidents per three days with delay duration longer than half an hour. Similarly, I-95 was impacted by 2 such incidents per 3.5 days whereas I-695 had 1 such incident every 3 days and I-270 had 1 such incident every 5 days.

The 1997 data has also indicated that I-270 had quite frequent short duration incidents, with blockage duration less than half an hour. This may be due to the rapid development in I-270 corridor that has resulted in high traffic demand and severe congestion. However, among those four major freeway corridors, I-495 had the highest numbers of both short- and long-duration incidents. Thus, MSHA should give a high priority to continuously improve its incident management efficiency.

Considering the commuting flow rate on I-495 and its incident frequency, one shall recognize the urgent need to implement an efficient incident management program. The high frequency of incidents on I-495 also confirms the general perception that incident-related traffic blockage is the primary contributor to highway congestion.

In brief, it is clear that the highway network covered by CHART has been plagued by a high frequency of incidents, ranging from about 30-40 minutes to more than 3 hours. Those incidents were apparently one of the primary contributors to the traffic congestion in the entire region, especially on those major commuting highway corridors such as I-495, I-695, I-270 and I-95. Thus, there is an urgent need to continuously improve and upgrade the traffic management as well as incident response systems. Considering the ever-increasing traffic demand and resulting incidents, it is likely that any investment on contending with such non-recurrent congestion should yield tremendous benefits to both the highway users and the quality of transportation for the entire region.

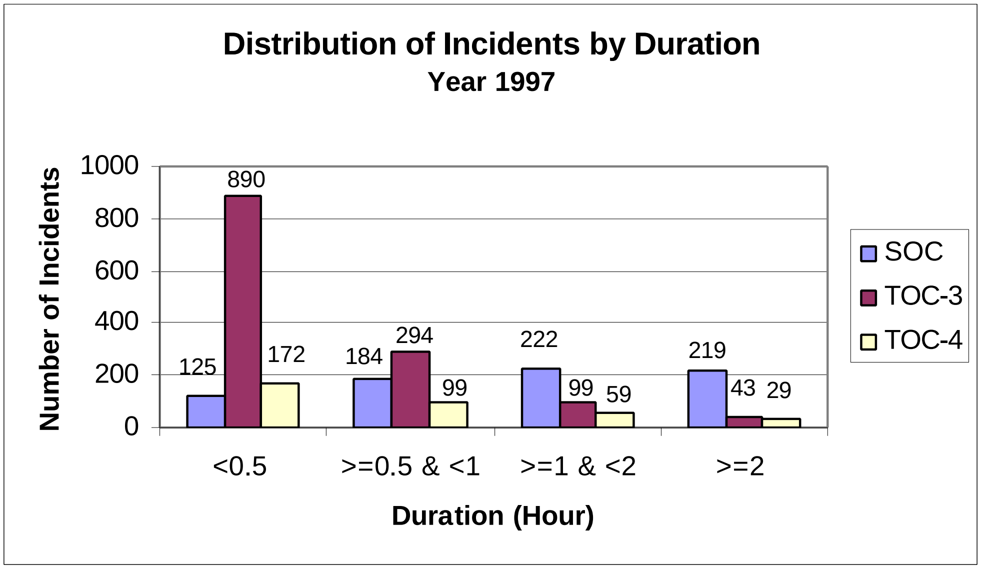

Figure 2.2: Distribution of incidents by duration

2.3: Distribution of incidents by peak and off-peak hours

As is notable from Figure 2.3, all major highways were plagued by not only the day-to-day congestion, but also frequent incidents during peak hours. By defining the peak hours as from 7:00 AM to 9:30 AM and 4:00 PM to 6:30 PM in this analysis, the record in 1997 indicates that about one third of overall incidents occurred during such a congested period, on average about 2.5 incidents per day. Conceivably, any minor incident during congested rush hours will quickly block the traffic and spread the queue to a long distance. Thus, how to optimally allocate available resources and response units to balance the needs between peak and off-peak has emerged as an increasingly vital operational issue in contending with non-recurrent congestion.

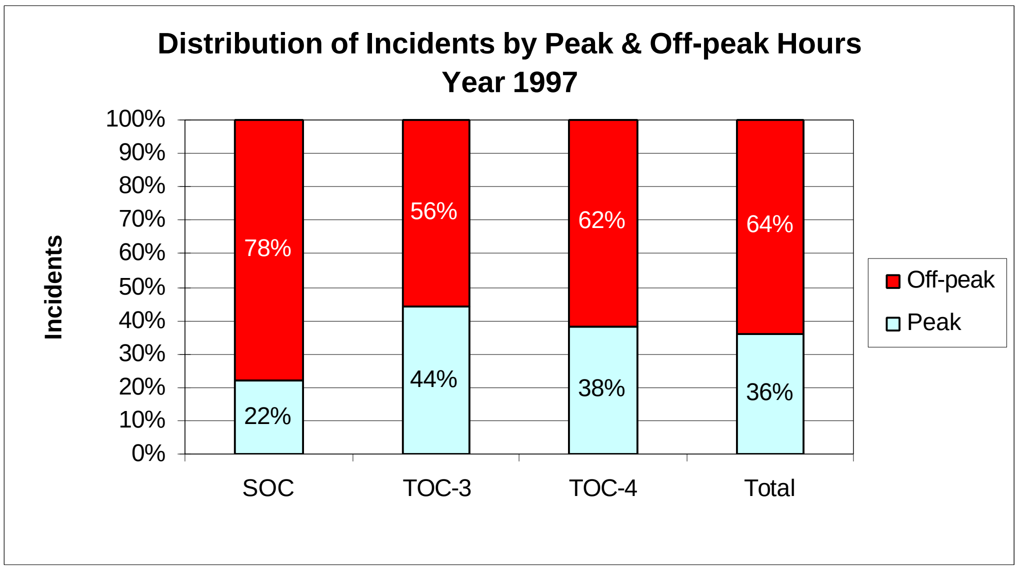

Figure 2.3: Distribution of incidents by peak and off-peak hours

2.4: Distribution of incidents by weekdays and weekends

This study has also analyzed the distribution of incidents between weekdays and weekends. As shown in Figure 2.4, it is expected that most incidents, about 88%, occurred on weekdays. Thus, more resources and manpower are required to manage those incidents effectively on weekdays than on weekends. The patrol cars on roads, response units and operators in the control center can, however, be reduced on weekends to minimize the operating costs of the system.

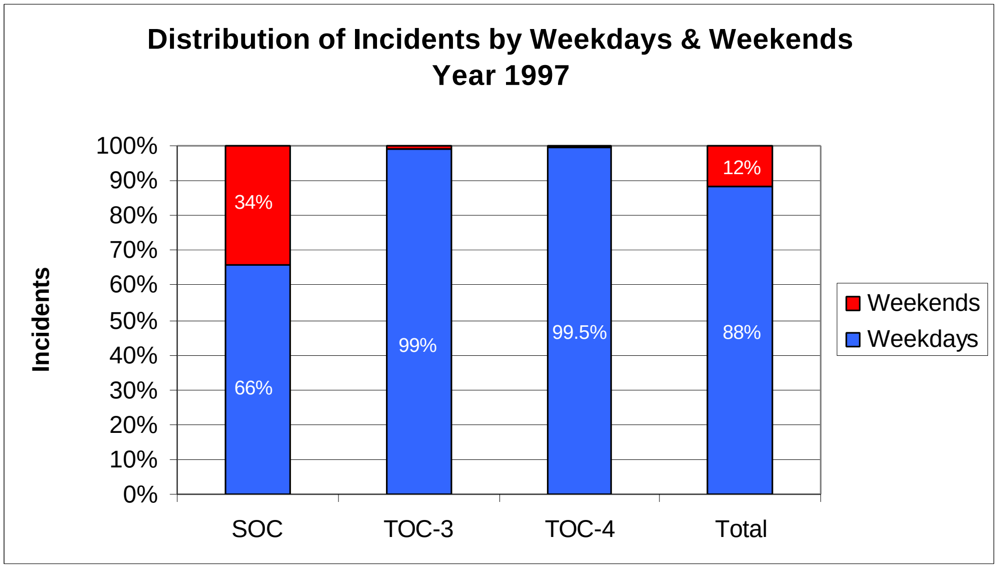

Figure 2.4: Distribution of incidents by weekdays and weekends

2.5: Distribution of incidents by lane blockage

Figure 2.5 illustrates the distribution of incidents by lane blockage. As is notable from the statistics, most incidents in 1997 resulted in either one- or two-lane blockages. About 48% of the incidents were one-lane blockage about 35% were having 2-lane closures. Table 2.1 further shows that among all one-lane blockage incidents, 15.6% of those also blocked the shoulder. Similarly, among all 2-lane closure incidents, 13.4% of those also incapacitated the shoulder lane.

Overall, about 4.4% of the total incidents did not result in any lane closure but only shoulder blockage.

Table 2.1: Distribution of incidents by lane blockage

Lane blocked	Shoulder blocked	Total
0	1	107
1	1	181
1	0	980
2	1	113
2	0	729
3		173
>=4		148
Total		2431

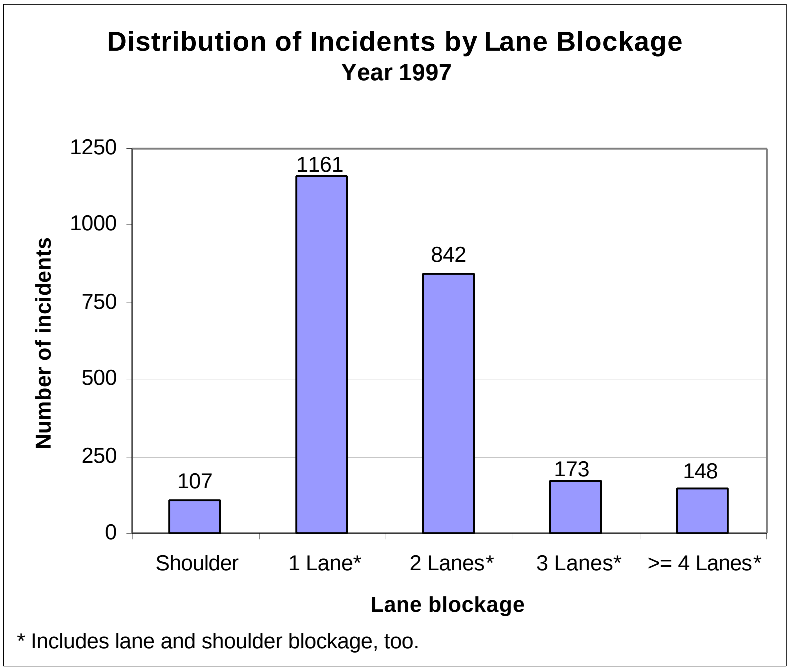

Figure 2.5: Distribution of incidents by lane blockage

2.6: Distribution of incidents by location

To best allocate patrol vehicles and response units to hazardous highway segments, this study has also analyzed the distribution of incidents by location along major freeways. By grouping the total number of incidents between two consecutive exits as an indicator, Figure 2.6 shows their distribution by location on I-495. Notably, the highest number of incidents occurred between Exits 2 and 3, representing the I-495 segment between the Woodrow Wilson Memorial Bridge and those ramps connected to I-295. This particularly hazardous segment experienced a total of **168** incidents in 1997, nearly one incident on every other day. It was more than 4 times of the average incident frequency on the entire I495/95 segment.

Figures 2.7, 2.8, 2.9, 2.10 and 2.11 show the distribution of incidents by locations on I-695, I-270, I-95 and MD-295, respectively. The highest number of incidents on I-695 occurred between Exits 22 and 23. The total frequency of 23 incidents was almost 4 times that of the average on the entire I-695. In contrast, the highest number of incidents on I-95 was 21, about 2 times the average, and occurred between Exits 41 and 43. Similarly, the most hazardous segment on I-270 was between Exits 1 and 2, where I-270 intersects with I-495. It had about 25 incidents in 1997, about twice the average. The highest number of incidents on MD-295 occurred between US-100 and Ridge Road, also about double the average number on the entire highway.

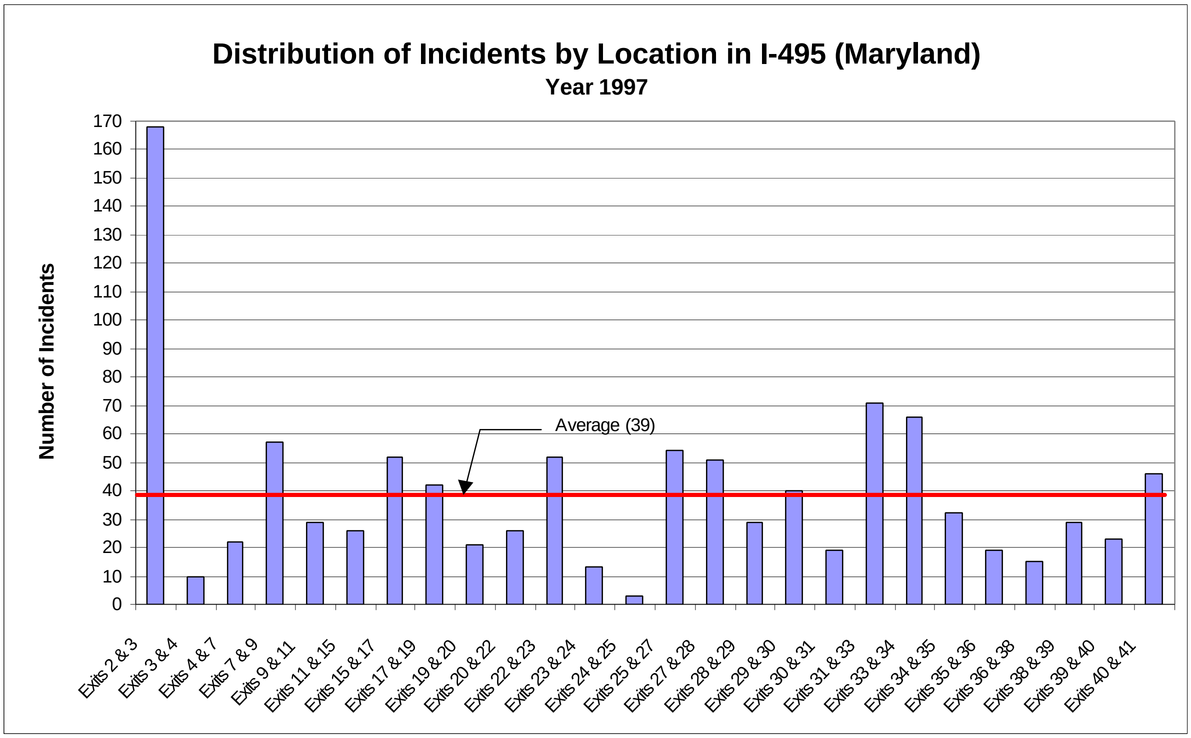

Figure 2.6: Distribution of incidents by location on I-495

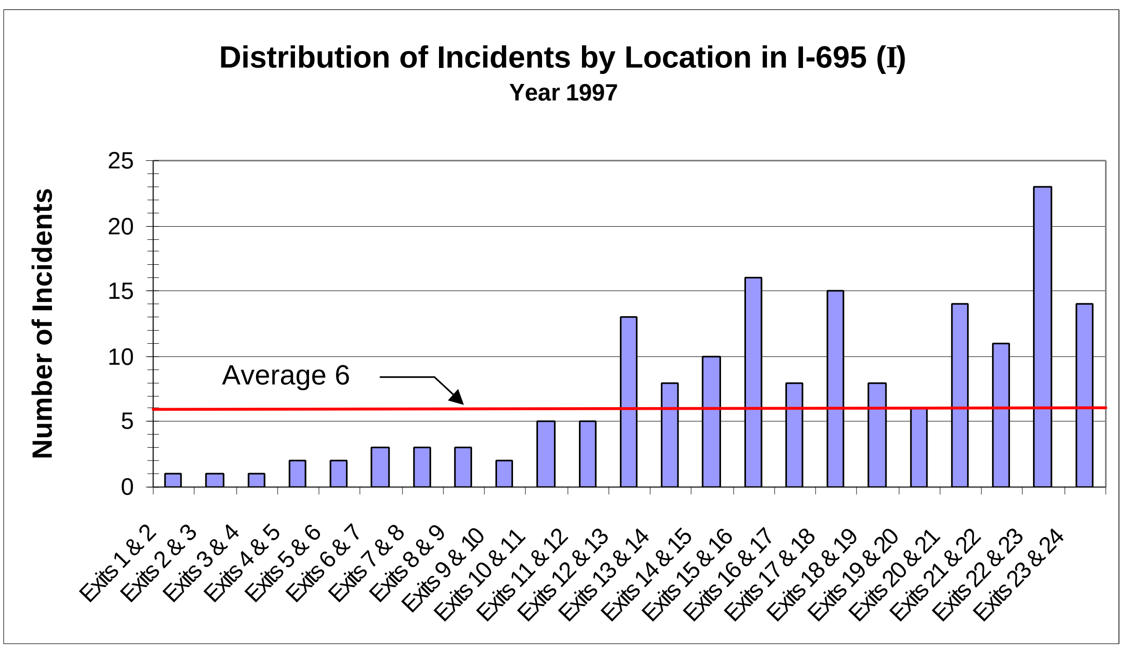

Figure 2.7: Distribution of incidents by location on I-695 (I)

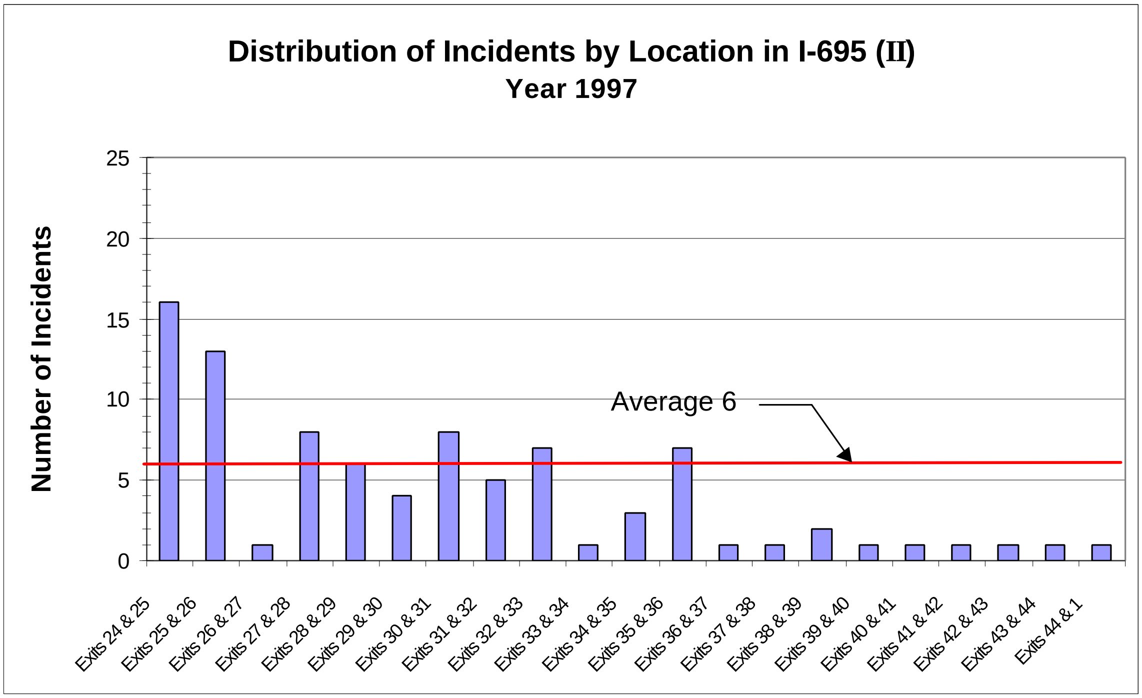

Figure 2.8: Distribution of incidents by location on I-695 (II)

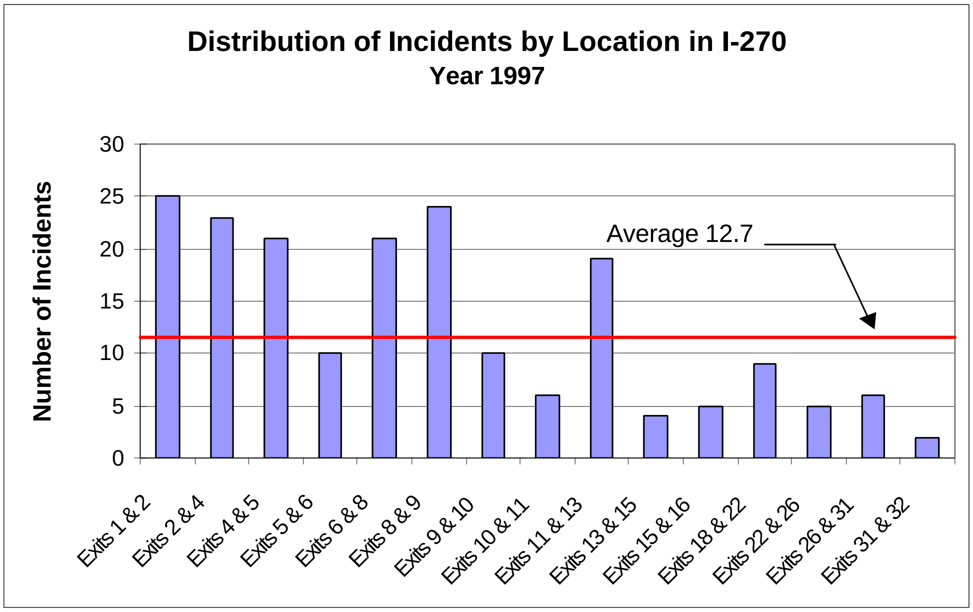

Figure 2.9: Distribution of incidents by location on I-270

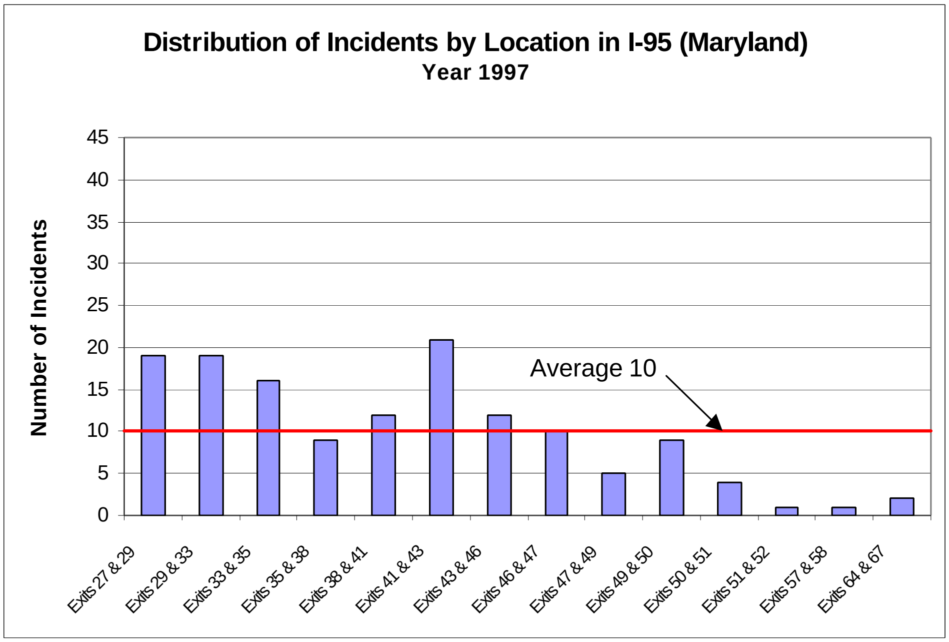

Figure 2.10: Distribution of incidents by location on I-95

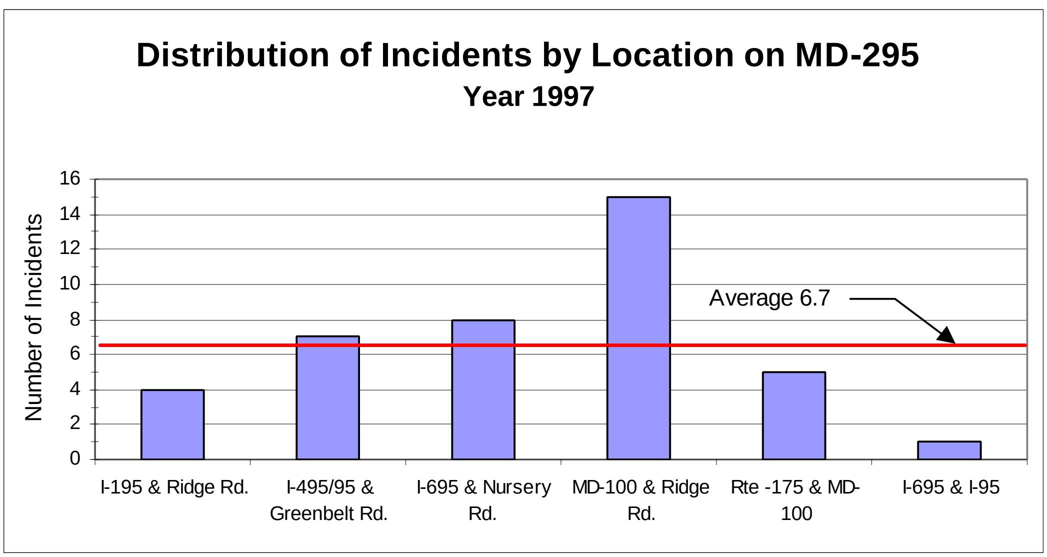

Figure 2.11: Distribution of incidents by location on MD-295

Chapter 3: Detection Efficiency and Effectiveness

3.1: Evaluation of detection efficiency and effectiveness

The evaluation of incident detection efficiency and effectiveness shall, in general, cover the following three critical aspects:

- the overall incident detection rate and false alarm rate;
- the average duration from the starting time of an incident until the traffic control center has actually been informed;
- the ratio between the total number of detected incidents and those being responded immediately by the incident response team; and
- the distribution of incident detection sources.

Since CHART has not implemented any automatic incident detection system, it naturally offers no information for evaluating the detection and false alarm rates. The second aspect, concerning how long it takes the traffic control center to receive an incident report from various sources after it has occurred, cannot be assessed in this study either, as the current incident management report, completed by operators in the traffic control center, does not contain such items. *As such, the evaluation of detection efficiency and effectiveness can only be focused on the latter two aspects: incident response rate and distribution of detection sources.*

3.2: Response rate for detected incidents

Note that the response rate discussed in this chapter is defined as *the ratio between the total number of traffic incidents reported to the CHART control center and those managed by the CHART incident response teams.* According to the 1997 incident management record, CHART had provided traffic management to most reported incidents. The response rates byTOC-3, TOC-4 and SOC were found to be 99%, 94.7% and 92.3%, respectively.

Although the existing incident management reports available in CHART do not indicate the reasons for not responding to some incidents, it appears that most of such incidents either were incurred during very light traffic periods, or were not so severe as to block the traffic. Nevertheless, to prepare for possible inquiries from either general public or legislators, CHART operators in the on-going operations should clearly document such incident scenarios, and detail the reasons for those incidents to be handled by police alone. For instance, in compiling the incident reports in 1997 we have discussed with responsible SHA staff and found that CHART incident response teams were not able to respond to some lane-blockage incidents due to either equipment limitations or manpower shortage.

3.3: Distribution of incident detection sources

Despite the lack of automated incident detection systems, it is notable that CHART has maintained quite effective coordination with all state and city agencies responsible for contending with traffic incidents and congestion. Serving as a focal point, all CHART operation centers were able to take full advantage of various available sources for identifying incidents and taking necessary actions in a timely manner.

With respect to the distribution of all detection sources, it is clear that about 50 percent of incidents were detected by either the state or city police troops and forward to CHART traffic control centers (see Figure 3.1). Although this fact may have reflected an effective interaction between state traffic and police departments, it may also raise some concerns about the detection efficiency due to potential human-factors issues. For instance, some significant delay may occur in the series of action chains, including the elapsed time for motorists to notice an incident and place the call, the processing time for the police department to confirm and forward the message, and for the traffic control center to take necessary actions.

Assuming that every incident can be detected immediately and reported to the traffic control center, it is still not uncommon to see that the time duration from beginning of an incident to the arrival of incident management units could be excessively long due to some potential human-factors related delay in the entire response process. Thus, it would be desirable for CHART to have some reliable means such as having an automated incident detection and dispatching system that can minimize any potential operational delay in response to a reported incident. All other information, including police reports, can certainly be used as supplemental sources to further confirm or better understand the incident condition.

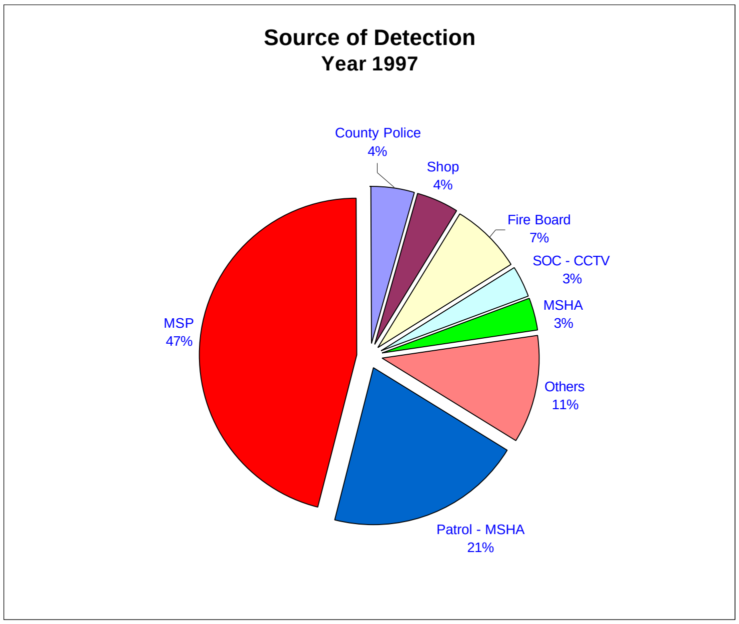

Figure 3.1: Detection sources of incidents

Chapter 4: Efficiency of Incident Response and Management

4.1: Analysis of incident response efficiency

To analyze the efficiency of incident management operated by CHART, it is essential to focus on the following vital aspects:

- How long it takes an incident response unit to reach the reported incident site after the control center being informed via various detection sources?
- What is the average travel distance for incident response units to reach the identified incident site?
- How long it takes the incident response team to clear various types of incidents?
- What is the approximate reduction in the incident blockage time due to the operations of CHART's incident response program?

Having information on all above vital aspects will enable SHA to have a clear picture of the efficiency in every link of the incident management process, from receiving the incident report to the complete removal of any resulting blockage.

For instance, the information regarding the first aspect shall shed light on any necessary improvement with respect to the interactions between the traffic control center and the responsible offices to dispatch incident response units. If the duration between the arrival time of response units and the incident report time was found to be unexpectedly long, it should be an indication of having inadequate response units, or an operating process that may easily cause operators to make "human-factors" errors, such as delay in calling for the dispatching operations.

The information on the first aspect, along with the data on the distribution of travel distance to incident sites, shall also enable SHA to evaluate its routing strategies for emergency response units and assess if the current equipment is sufficient to respond to the increasing incidents during peak periods. One may consider to place some available incident response units along highway segments, identified to have a high incident frequency, at different times of a day, so as to minimize the travel time to reach potential incident sites.

Since the incident record for 1997 contains only the arrival time of response units to the incident site but not travel distance, the evaluation of management efficiency has focused mainly on the distribution of response times and incident clearance times.

As presented in Chapter 1, the response time is *defined as the elapsed duration from the moment, the control center has received a reported incident to the physical presence of the incident management team at the target incident site.* Since notification time is not available in the current data, the time interval from dispatch of response teams till its arrival at the scene is taken as the response time in this analysis. The average response time for CHART, as shown in Figure 4.1, was found to be 11.4 minutes.

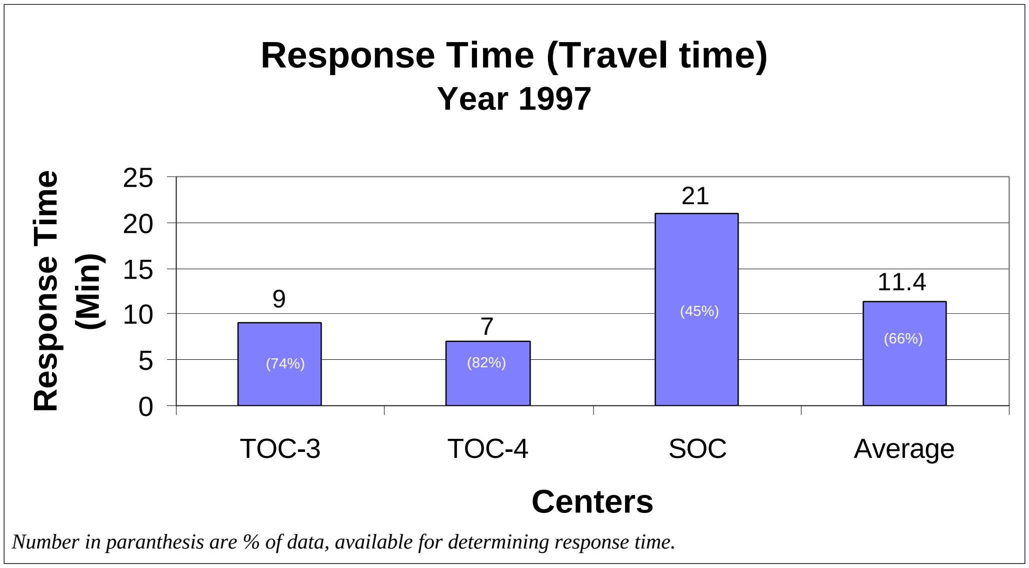

Figure 4.1: Response time of CHART

4.2: Reduction in incident duration

Aside from evaluation of the entire incident management process, one of the obvious performance indicators is the average reduction in incident duration due to the operations of CHART. Theoretically, to have a reliable estimate for such an indicator one should perform a typical before-and-after comparison. However, most incident management related data prior to the actual operations of CHART are practically unavailable for any meaningful analysis. Thus, the alternative is to compute the average incident clearance time in 1997 with and without the assistance from CHART.

Since the incident management team by CHART has responded to most incidents in 1997 covered in its network, the data associated with non-responded incidents for performance comparison are quite limited.

As shown in Table 4.1, the average duration to clear an incident with and without the involvement of CHART operations was about **44.65** minutes versus **68.17** minutes. Figure 4.2 further compares the operations efficiency of each operation center. It is notable that, the average incident duration with and without the response of CHART was found 76.5 minutes against 97.9 minutes for SOC, 26.4 minutes against 57.3 minutes for TOC-3, and 35.1 minutes versus 44.1 minutes for TOC-4.

Undoubtedly, with the assistance of CHART, the clearance duration has been substantially reduced under all types of incidents, ranging from one-lane to multiple-lane closures. On average, CHART has contributed to about **35** percent reduction on the incident blockage duration. Such a substantial reduction in operational time has certainly resulted in significant savings on travel time, fuel consumption, as well as other related social impact costs due to non-recurrent congestion. Table 4.2 shows the incidents by types, to which CHART did not respond.

Table 4.1: Incident clearance duration with and without CHART

Lane Blockage	With CHART		Without CHART	
	Duration (min.)	Frequency	Duration (min.)	Frequency
1 lane	32.71	569	49.67	58
2 lanes	78.00	198	99.00	22
3 lanes	43.00	50	148.00	4
1 lane & shoulder	29.00	23	132.00	1
2 lanes & shoulder	54.12	67	72.00	3
Weighted Average	44.65		68.17	
Total		907		88

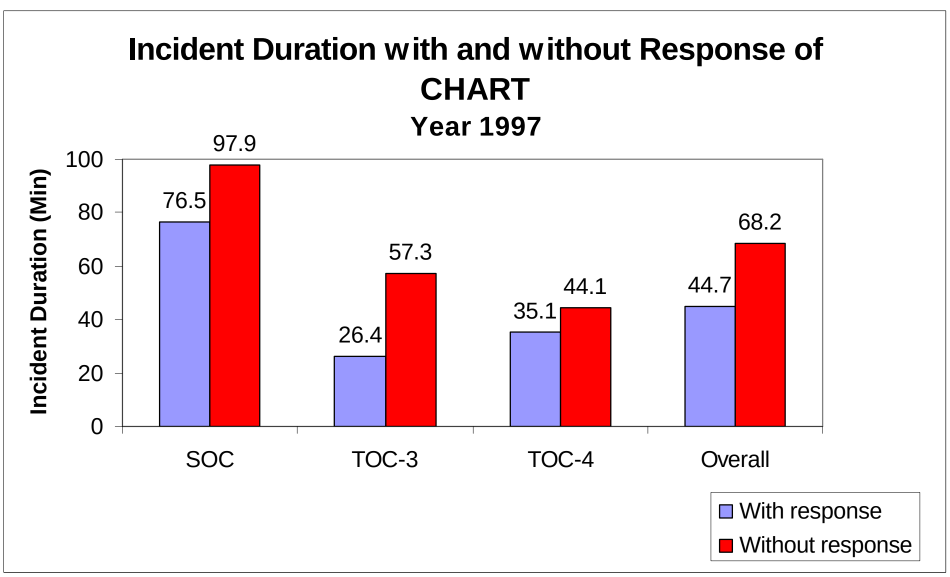

Figure 4.2: Incident duration with and without response of CHART

Table 4.2: Incidents, to which CHART did not respond

Incident Type	Frequency	%
Accident with minor personal injury	21	23.9%
Accident with serious personal injury	6	6.8%
Accident with pedestrian	9	10.2%
Car fire	4	4.5%
Water main break	5	5.7%
Pole fire	1	1.1%
Vehicle hit pole	1	1.1%
Assist motorists	9	10.2%
Wooden pallet	1	1.1%
Unknown	31	35.2%
Total	88	100.0%

Chapter 5: Benefits from the Incident Management by CHART

5.1: Estimation of Benefits

Despite well perceived benefits from an efficient incident management, most state highway agencies, including MSHA, are facing the pressing need to justify their system investment and operating costs, especially in view of the diminishing resources and the increasing demand for infrastructure renovation. Thus, reliably quantifying the benefits from the implemented incident management system is one of the essential tasks for assessing the contribution of CHART.

To ensure the quality of analysis under the data limitations as well as resource constraints, the benefit assessment of CHART was focused only on those either directly measurable or quantifiable from the given data. Such direct benefits include:

- Assistance to drivers;
- Reduction in secondary incidents;
- Reduction in driver delay time;
- Reduction in vehicle operating hours; and
- Reduction in fuel consumption.
- Reduction in emissions

Some other indirect impacts, such as improving the air quality, vitalizing local economy, and increasing network mobility, are not include in the following report.

5.2: Assistance to drivers

Among all 2,750 incident reports available in the CHART database, it has been found that there were a total of **183** incidents associated with requests from drivers for assistance such as flat tire, shortage of gas, or some mechanical problems. The number of assists could be significantly higher since records of all those assists were not available for this analysis. Table 5.1 shows the distribution of driver assistance by center, the average incident duration and resulting blockage. The average duration for providing assistance to drivers was about **25.6 minutes**.

Note that according to CHART staff, its response teams actually responded to many more assistance requests from drivers than those well documented 183 incidents. However, most of those unreported drivers assistance did not need major efforts or equipment from the response unit, and thus were not recorded.

Conceivably, the prompt response of CHART incident management units to such requests not only has been greatly appreciated by general public, but also has contributed directly to minimizing the potential rubbernecking effects from drivers, especially during peak hours, that could result in excessive delay. Thus, despite the difficulty in precisely quantifying the impacts of such assistance, it shall undoubtedly be counted as one of the major direct benefits.

Table 5.1: Assistance to Drivers

Center	Average incident duration (minute)	Number of incidents			
		Shoulder blocked	Shoulder & 1 lane blocked	1 lane blocked	Total
TOC-3	23	7	14	137	158
TOC-4	42	3	0	11	14
SOC	42	1	0	10	11
Total	25.6	11	14	158	183

5.3: Reduction in secondary incidents

It has been well recognized that the probability of having traffic accidents or incidents is quite often mutually dependent. In general, a major accident may incur a number of relatively minor secondary incidents due to a sudden change in the traffic condition such as the rapid spreading of queue length and a dramatic drop in the traffic flow speed. The likelihood of having such incidents increases consistently with the incident duration and the congestion level. Thus, an efficient recovery of incident blockage not only may directly benefit drivers in the traffic queue, but also may reduce potential incidents incurred by incoming vehicles that may further deteriorate the traffic condition.

Note that there is no universal definition for "secondary incidents" in the transportation literature, unless the nature of incidents can be known directly from the field data. This study has adopted the definition of secondary incidents as *"the number of incidents occurred within two hours after a major incident and within the range of two miles."* For convenience of comparison, Figure 5.1, however, presents the distribution of secondary incidents under different definitions.

Notably, under the selected definition, there were 625 secondary incidents reported in 1997. As the frequency of secondary incidents reveals a clear positive correlation with the primary incident duration, it is conceivable that without implementing the incident management program, the resulting number of secondary incidents would be much higher.

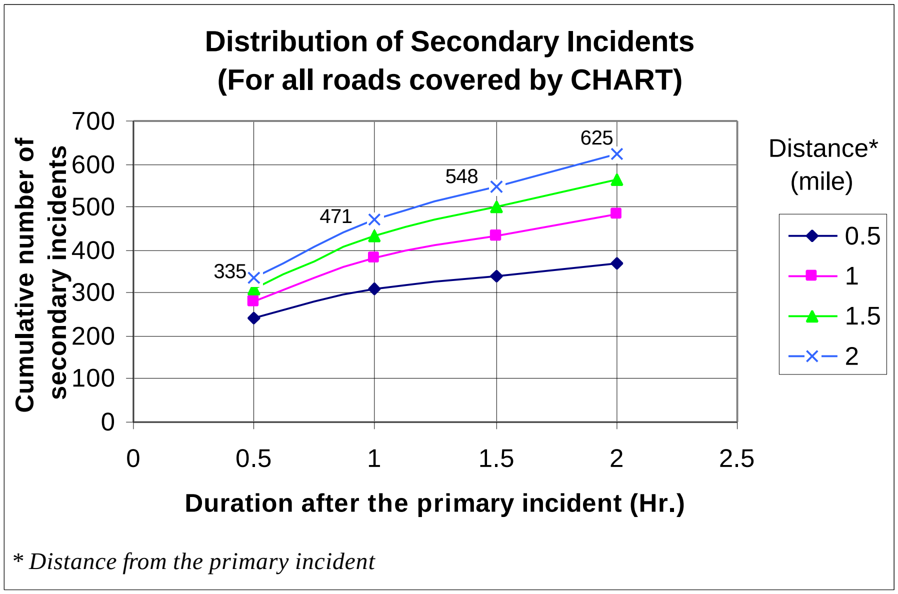

Figure 5.1: Distribution of secondary incidents

For convenience but without loss of the generality, one may assume such a correlation as linear in nature, and estimate the potential reduction in the total secondary incidents due to CHART as follows:

- Reported number of secondary incidents: 625

- The estimated number of secondary incidents without CHART (that has resulted in a 35% reduction on the average incident duration):

  625/(1-0.35) = 962

- The number of potentially reduced secondary incidents due to the operations of CHART: ***962 - 625 = 337***

Note that each of those 337 secondary incidents, if actually occurs, may further prolong its primary incident duration and result in additional loss of travel time, fuel consumption, and congestion on surface streets. Such impacts and accompanying benefits are not computed in this report due to data limitations, but should not be understated.

5.4: Direct benefits to highway users

The section presents the direct benefits of CHART to highway users, including the reduction on trip time, fuel consumption, and emissions. Procedures employed for performing such estimation are summarized below:

- Select a sample size of 120 incidents from the 1997 record;

- Collect all incident associated information, including volume, geometry, lane-blockage, and incident duration;

- Calibrate the simulation program, CORSIM, with collected data;

- Replicate those sample incidents with CORSIM, and collect the resulting delay, fuel consumption, and emissions;

- Simulate the same set of traffic scenarios but without incidents, and collect all resulting delay, fuel consumption, and emissions;

- Compute the excessive delay, fuel consumption, and emissions due to incidents, based on the results of the above two steps;

- Compile the results from the sample set of 120 cases, and develop the statistical relation between each target benefit measure and associated factors (e.g., volume, incident duration), and

- Apply the estimated statistical relations to all incidents reported in the 1997 record, and compute the total benefits.

For instance, the excessive delay due to an incident, not the recurrent congestion, has been calibrated as follows:

$$\Delta Delay = e^{-10.19} * (V)^{2.8} * (NLB / TNL)^{1.4} * (ID)^{1.78}$$

Similarly, the functional relation between additional fuel consumption and other variables was given as follows.

$$\Delta Fuel = e^{-10.77} * (V)^{2.27} * (NLB / TNL)^{0.9} * (ID)^{1.69}$$

where,

Δ *Delay = excessive delay due to incidents*

$\Delta Fuel =$ *Additional fuel consumption due to incidents*

TNL = Total number of lanes

NLB = Number of lanes blocked

V = Traffic volume

ID = Incident duration

e_1 *and* e_2 *are random terms for modeling errors*

To further estimate potential emission reduction, a linear relation was developed between emission and fuel consumption generated from the output of each simulated scenario.

Using the above statistical relations, it has been found that additional delays incurred in all reported incidents with the assistance of CHART was about **29.04 million** vehicle-hours, which would be **44.68 million** vehicle-hours if without CHART. Thus, reduction in delays due to the incident management of CHART was found to be **15.64 million** vehicle-hours. Using the time value of $14.34/hour, the average hourly income in Maryland in 1997, the total trip cost savings due to delay reduction by CHART was estimated to be **$224.23 millions**.

The cost savings associated with reduction in fuel consumption due to the operations of CHART was about **5.85 million gallons,** and amounted to **$5.85 million,** assuming the price of gasoline as $1 per gallon in 1997.

Similarly, reductions in vehicle emission were estimated to be as follows:

HC : 19,326 gm,
CO : 828, 691 gm and
NO : 152, 822 gm.

Note that the above emission data generated from CORSIM should be referenced for comparison only, as its embedded method for computing emissions has not been well calibrated. Unfortunately, a rigorous model or method for emission estimation under various traffic conditions remains to be developed by the transportation community.

Using the cost data in the literature (Patrick, 1998), the total cost savings resulted from emission reduction was approximately $7,368, assuming the rate of $6,700/ton for HC, $6,360/ton for CO and $12,875/ton for NO. Thus, the total direct benefits of CHART amounted to about **$230.091 millions** in 1997. A summary of all above delay and fuel consumption is presented in Table 5.2.

Table 5.2: Summary of delay and fuel consumption due to incidents with CHART

Road Name	Total Number of Incidents	Additional deay (veh-hr)	Reduction in Delay (Veh-hr)	Additioal Fuel Consumption (gal)	Reduction in Fuel Consumption (gal)
I-495	1,051	18,348,296	9,880,557	6,107,546	3,288,914
I-95	169	2,095,769	1,128,572	817,453	440,198
I-695	266	3,444,434	1,854,828	1,282,386	690,565
I-270	247	2,826,174	1,521,895	1,378,260	742,193
I-295	42	120,624	64,956	61,194	32,953
I-70	59	303,260	163,306	173,991	93,694
I-195	3	171	92	222	120
I-68	24	31,632	17,034	25,752	13,867
I-83	45	635,670	342,308	290,430	156,397
I-395*	2	15,022	8,089	7,324	3,944
I-795*	10	141,110	75,988	52,370	28,201
I-370*	2	662	356	484	261
I-97*	43	548,379	295,302	257,269	138,539
I-81*	7	12,628	6,800	5,117	2,756
US-50	124	208,196	112,114	185,008	99,627
US-1	14	2,744	1,478	2,506	1,349
Others	642	303,666	163,524	209,934	113,049
Total	**2,750**	**29,038,437**	**15,637,198**	**10,857,246**	**5,846,627**

Chapter 6: Conclusions and Recommendations

6.1: Conclusions

Despite the lack of some critical data for a comprehensive performance and benefit evaluation, the results of all above analyses clearly indicate that CHART's operations have indeed substantially reduced the incident clearance duration that has in turn yielded significant direct and indirect benefits to highway users. The reduction of incident duration by 35% attributed to the operations of CHART in 1997 is well comparable to that of 36.2% in 1996 shown by the previous study. The travel time for response units to reach the incident site was 11.4 minutes, reasonably efficient when compared to other similar studies. Those quantifiable direct benefits include:

- Assistance to drivers' service requests;
- Reduction in the trip delay time;
- Reduction in the fuel consumption cost;
- Reduction in emission; and
- Reduction in the vehicle operating costs.

Most indirect benefits could all be estimated provided that all essential data regarding traffic conditions before-and-after incidents were collected during each operation. Such benefits include:

– Potential reduction in secondary incidents;
– All impacts associated with an incurred secondary incident;
– Reduction in various emission levels;
– Potential impacts on neighboring surface streets during incidents; and
– Reduction in the overall stress to drivers in major commuting corridors.

The aforementioned benefits, along with the ever-increasing congestion and incidents, certainly justify the need to best manage and continuously upgrade the current incident response program. However, it should be noted that "an efficient incident response" alone cannot effectively reduce the frequency of primary highway incidents. Considering the current volume level in major commuting highways, it is certainly true that commuters, even under an efficient incident response system, remain likely to face a long delay for any encountered incident. Thus, *taking "preventive measures" to minimize the likelihood of having incidents should at least, be viewed as vital as implementing an incident management program*. An in-depth analysis of the incident nature and their spatial distribution should offer some insightful information for developing safety-improvement related measures.

6.2 Recommendations

The primary recommendations based on the results of analysis and evaluation are summarized below:

. *Developing an incident information management system*
that can automate the incident data recording and archiving process, and generate the up-to-date CHART performance report as needed.

. *Training operators to effectively record all essential operations related data*
many of those incident reports in 1997 were found to have a large number of either missing or incomplete items.

. *Modifying the current report form to contain all vital information*
for improving the operations efficiency and justifying the resulting benefits.

. *Continuing the performance and benefit analysis*
so as to best allocate the available resources and sustain the support from both the general public and state legislators.

. *Evaluating the efficiency as well as cost/benefit of other components*
of CHART such as the Traveler Information System and Traffic Management Program.

. *Improving the utilization of freeway service patrols*
and optimizing their spatial distribution on freeway segments of high incident frequency so as to reduce the incident response time.

. *Installing additional surveillance sensors*
to share the incident detection load that is undertaken mostly through drivers' phone reports to the state and county police departments.

. *Investigating the interrelations between the traffic demand patterns*
and the distribution of incidents so as to effectively contending with non-recurrent congestion.

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