Performance Evaluation of CHART

– Coordinated Highways Action Response Team –

Year 2004

(Final Report)

Prepared by

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PERFORMANCE EVALUATION OF CHART
- THE REAL-TIME INCIDENT MANAGEMENT SYSTEM (YEAR 2004) -

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EXECUTIVE SUMMARY

- **Objectives**

This report presents the performance evaluation results of CHART in year 2004, including both operations efficiency and the resulting benefits. This is part of the annual CHART performance review conducted by Department of Civil Engineering at University of Maryland, College Park for Maryland State Highway Administration (MSHA).

Similar to all previous studies, the focus of this evaluation work is to assess the effectiveness of the Maryland CHART program with an emphasis on its ability to detect and manage 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 consisted 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 the data available in the year 2004 CHART incident operation records. 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 reliable statistical methods.

- **Available Data for Analysis**

Performance evaluation for CHART operations was first started in 1996 by COMSIS, based on the request of MSHA. In performing the evaluation, the year 1994 incident management data from the Traffic Operations Center were reviewed, but not used due to various reasons. Thus, its conclusions were mostly grounded on either the information from other states or from nationwide average data published by the Federal Highway Administration.

To ensure the quality of evaluation and also in view of 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 year 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, 1998). 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.

The evaluation for the year 1997 CHART performance had the advantage of receiving relatively rich information, including incident management reports from the SOC, TOC-3 (located in the proximity of the Capital Beltway), and TOC-4 (located near the Baltimore Beltway) over the entire year. Also provided were the year 1997 accident reports from Maryland State Police for secondary incident analyses.

Unlike all previous studies, the data set available for performance evaluation has increased substantially since year 1999 as CHART have recognized the need to keep an extensive operational record so as to justify the costs as well as the benefits of their emergency response operations. For example, the data available for analysis of lane-closure related incidents increases from a total of 2,567 reports in the year of 1997 to 19,127 reports in year 2004. A summary of total emergency response operations that have been documented reliably from the year of 1999 to 2004 is presented below:

	1999	**2000**	**2001**	**2002**	**2003**	**2004**
- Incidents only	5,000	8,687	9,313	13,752	18,068	19,127
- Total	27,987	34,891	26,008	32,814	38,523	40,539

Note that CHART may have responded to more emergency service requests than those reported in the incident database, as control center operators may not properly record all incident response operations for a variety of reasons. The difference between the actual and recorded number of incident responses has been diminished since the operation of the CHART-II online information system.

- **Evolution of Evaluation Work**

Over the past five years, CHART has consistently worked on improving its data recording for both major and minor incidents. Hence, the quantity and quality of incident reports available for performance analysis have been increased substantially since year 1999.

In response to the improvement in data availability, the evaluation work has also been evolved from its infancy of using all available data to a new stage of demanding data quality, and employing only reliable information in the performance as well as benefit analysis. Thus, from year 1999 the performance evaluation report for CHART has included the data quality analysis. This is aimed to ensure a sustained improvement in the quality of incident-related data so that all potential benefits due to efficient CHART operations can be reliably estimated.

Note that starting from February 2001, all incidents and requests of emergency assistance, regardless of responding by CHART or not, have all been recorded in the CHART-II information system. Overall, the quality of available data for evaluation has been improved significantly since the operation of the CHART-II system. The efforts needed for performing the evaluation, however, have not been reduced significantly, because the current CHART-II is only partially completed and the information associated with each incident is distributed in different categories of sub-databases. Besides, some 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 developed to take full advantage of all available data sets that have the acceptable quality. It started with an analysis of incident characteristics by the blockage frequency, duration, and blocked lanes.

With respect to severe incidents, the analysis results indicate that in year 2004 there were a total of **3,110** incidents resulting in one-lane blockage, **2,891** incidents causing two-lane closures, and about **1,925** incidents blocking more than two lanes. In addition, there were a total of 24,518 shoulder incidents during the same period due either to disabled vehicles or minor incidents. A comparison of lane-blockage incident data over the past six years is summarized below:

	1999	2000	2001	2002	2003	2004
- Shoulder	6,164	27,370	17,593	21,107	23,399	24,518
- 1 lane	2,376	3,195	2,357	2,268	3,015	3,110
- 2 lanes*	1,106	2,169	1,407	1,684	2,443	2,891
- 3 lanes*	186	478	403	571	801	870
- ≥ 4 lanes*	137	347	432	636	849	1,055

* Count the Shoulder lane as one lane

Overall, the incidents, including shoulder-lane blockages, on freeways were mostly distributed along six major commuting corridors, where I-495/95 experienced a total of **9,936** incidents; and I-695, I-95, US-50, MD-295 and I-270 had **9,277, 5,852**, **2,505, 1,462** and **1,375** incidents, respectively. Thus, CHART had managed, on average, **27** emergency response requests per day on I-495/95 alone, and **25**, **16**, **7, 4** and **4** responses along the other five main commuting freeways. The distribution of incidents on those major commuting corridors between 1999 and 2004 is presented below:

	1999	2000	2001	2002	2003	2004
- I-495/95	11,182	11,404	9,524	9,652	9,936	10,288
- I-695	3,946	7,704	5,165	7,916	8,938	9,277
- I-270	1,967	1,767	1,277	1,474	1,582	1,375
- I-95	1,948	2,779	2,296	3,211	4,568	5,852
- US-50	110	829	1,730	1,795	1,984	2,505
- MD-295	43	1,484	1,103	1,381	1,591	1,462

However, it should be mentioned that most incidents on major commuting freeways did not block traffic for more than one hour. For instance, the number of disabled vehicles and incidents with duration shorter than 30 minutes was about 87% and 60%, respectively. This could be attributed to both the nature of the incidents and, more likely the efficient response of CHART emergency operations units. The distribution of incident/disabled vehicle duration between 1999 and 2004 is summarized below:

Duration (Hr)	1999	2000	2001	2002	2003	2004
< 0.5	8,307	7,057	8,581	8,693	11,480	19,418
>=0.5 & <1	816	2,138	969	1,002	1,656	2,569
>=1 & < 2	418	743	356	446	784	1,095
>= 2	376	518	227	347	672	1,173

In brief, it is clear that the highway networks covered by CHART remain plagued by a high frequency of incidents, ranging from about 10 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-495/95, I-695, I-270, and I-95.

- **Efficiency of Operations**

In evaluating the efficiency of an incident management program, it is essential to cover 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 data system, and the MSHA patrols and Maryland State Police (MSP) remain the main sources for detecting and reporting incidents for CHART.

One of the indicators related to the detection is the average response time that refers to the elapsed time from receiving the incident calls to having emergency response units arriving at the incident site. The year 2004 data indicated that on average it took **11.45 minutes** for the TOC-3, **13.57 minutes** for TOC-4, and **8.55 minutes** for SOC to respond to a reported incident. Overall, CHART, as shown in the following statistics, has demonstrated a steady improvement on its response time over the past six years:

Response Time (min)	1999	2000	2001	2002	2003	2004
TOC-3	16.95	14.96	13.90	12.85	11.67	11.45
TOC-4	N/A	15.43	14.53	13.65	13.09	13.57
SOC	17.00	19.14	13.70	13.51	7.24	8.55
Weighted Average	**16.95**	**15.22**	**13.84**	**13.10**	**11.50**	**11.38**

To understand the contribution of the incident management program, this study has computed and compared the average incident duration of responded and non-responded incidents. For instance, for those shoulder-lane-blockage incidents SHA patrol did not respond to, the average operation time was about **24.64 minutes**, longer than the average of **14.93 minutes** for the same type of shoulder-lane-blockage incidents managed by CHART/SHA *(i.e., with SHA patrols*).

Taking into account all types of incidents, the average incident duration with and without the management by SHA response units was found to be **38.46 minutes** and **44.65 minutes**, respectively. Thus, based on the available record in year 2004, the operations of CHART/SHA resulted in about a **14** percent reduction in the average incident duration. The performance improvement of CHART/SHA from year 1999 to year 2004 is summarized below:

	with CHART (min)	without CHART (min)
1999	42	93
2000	33	77
2001	29	51
2002	28	39
2003	40	49
2004	38	45

- **Resulting Benefits**

The benefits attributed to the CHART/SHA operations that were estimable directly from the available data include assistance to drivers, and reduction in driver delay time, fuel consumption, emissions, and secondary incidents. The CHART/SHA operations in year 2004 responded to a total of **19,127** lane blockage incidents, and provided **assistance to 21,412 highway drivers** who may otherwise cause incidents or rubbernecking delays to the highway traffic. CHART's contribution to reduction in incident duration has also resulted in a potential reduction of **84** secondary incidents. In addition, efficient removals of stationary vehicles or large debris on travel lanes by CHART patrol units may have prevented **384** potential lane-changing-related collisions in year 2004, as approaching vehicles under those conditions are forced to perform unsafe mandatory lane changes that are likely to result in some crashes.

The direct benefits of reduction in delay time and fuel consumption were estimated with CORSIM, a traffic simulation program produced by FHWA. It has been found that the operations of CHART/SHA in year 2004 resulted in a total delay time reduction of **32.05 million vehicle-hours,** and a total fuel consumption reduction of approximately **5.41 million gallons**. A comparison of direct benefits from 1999 to 2004 is summarized below:

	Total Direct Benefits (dollar)	No. of Incidents/disabled vehicles
1999	345.08	27,987
2000	378.41	34,891
2001	402.75	26,008
2002	467.97	32,814
2003	498.70	38,523
2004	526.02	40,539

- **Recommendations**

The primary recommendations based on the performance of CHART in year 2004 are summarized below:

- Feeding back the quality evaluation report to CHART operators so that they can improve their performance on response operations.
- Training operators to effectively record all essential operations-related data such as cleared time, arrival time and lane-blockage type.
- Improving the data structure used in the CHART-II system for recording the incident location as the information item with the current narrative text format requires a laborious manual search and input of associated highway segments.
- Improving the use of freeway service patrols and dynamically assigning their locations based on both the spatial distribution of incidents along freeway segments and the probability of having incidents at different times of a day so that the average response time can be reduced.
- Efficiently integrating CHART incident response database with police accident data so as to have a complete picture of the statewide incident record.
- Including the benefits of delay and fuel consumption due to a potential reduction in secondary incidents in CHART benefit evaluation.

Note that a database converted from CHART-II system and comprehensive evaluation results performed by the research team are available in the Web site (http://chartinput.umd.edu/).

CHAPTER 1. INTRODUCTION

CHART (Coordinated Highways Action Response Team) is the highway-incident management system of the Maryland State Highway Administration. It was initiated in the mid-80's as the "Reach the Beach," Program and was subsequently expanded to a statewide program. Its Statewide Operations Center (SOC), an integrated traffic control center for the state of Maryland, is headquartered in Hanover, Maryland. The SOC is supported by three satellite Traffic Operations Centers (TOC), one of which is seasonal. CHART's current network coverage consists of both statewide freeways and major arterials.

CHART has four major functions: traffic monitoring, incident response, traveler information, and traffic management. Among these four components, the incident response and traveler information systems have received increasing attention by the general public, media, and transportation professionals.

In 1996, the incident management data was collected and used in the pilot evaluation analysis conducted jointly by the University of Maryland and MSHA staff (Chang and Point-Du-Jour, 1998). The researchers inevitably faced the difficulty of having a data set with insufficient information for analysis, but it was the first time researchers were able to identify and organize all previous performance records for a rigorous evaluation under the CHART program.

The evaluation of CHART's performance for 1997 was much more extensive than the previous year's analysis. The researchers were able to obtain a relatively rich set of data, including all 12 months of incident management reports from the SOC, TOC-3 (located in proximity of the Capital Beltway), and TOC-4 (located near the Baltimore Beltway). Accident reports provided by Maryland State Police were also available for secondary incident analyses.

The data set for performance evaluation has increased substantially since 1999, as CHART recognized the need to keep an extensive operational record in order to justify the costs as well as the benefits of their emergency response operations. For example, the data available for analysis of lane-closure incidents increases from a total of 5,000 reports in the year 1999 to 19,127 reports in year 2004. A summary of total emergency response operations documented from the years 1999 to 2004 is presented in Table 1.1.

Table 1.1 Number of Total Emergency Response Operations

Records	1999	2000	2001	2002	2003	2004
Incidents	5,000	8,687	9,313	13,752	18,068	19,127
Disabled Vehicles	22,154	20,428	16,274	19,062	20,455	21,412
Total	**27,987**	**34,891**	**26,008**	**32,814**	**38,523**	**40,539**

The objective of this study is to assess the effectiveness of CHART's operations, including its incident detection, response, and traffic management functions on interstate freeways and major arterials. This assessment also includes CHART benefits estimation, which is an integral part of the study since MSHA's support from both the general public and state policymakers is largely dependent on the benefits its ongoing programs bring to the state. The research team has divided this evaluation study into three principal tasks in order to conduct a comprehensive analysis using all available data to ensure the reliability of the evaluation results:

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

Task 2: Statistical Analysis and Comparison – consist of performing a comparison based on data available in years 2004 and 2003 with an emphasis on the following target areas: incident characteristics, incident detection efficiency, distribution of detection sources, incident response efficiency, and effectiveness of incident traffic management.

Task 3: Benefit Analysis – covers the reduction of total delay time, 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.

Based on the above principal tasks, the remaining chapters of this evaluation report are organized as follows:

Chapter 2 focuses on assessing the quality of data available in the year 2004 CHART performance evaluation, including total available incident reports, percentage of missing data for each critical performance parameter, and a comparison of the data quality in years 2003 and 2004.

Chapter 3 outlines the statistical analyses of incident data characteristics, including distributions of incidents and disabled vehicles by weekday and weekend, by road, by location, by lane-blockage type and by lane-blockage duration. A comparison of the average incident duration incurred by different types of incidents is also included in the analysis.

Chapter 4 provides a detailed report on the efficiency and effectiveness of incident detection, including the detection rate, distribution of detection sources for various types of incidents and driver requests for assistance. The chapter also includes an evaluation of incident response efficiency. The efficiency rate is based on the difference between incident report time and the emergency response unit's arrival time. In addition, the assessment of incident clearance efficiency is based on the difference between the emergency response unit's arrival time and the incident clearance time.

Chapter 5 estimates the direct benefits associated with CHART operations, including the total reduction in delays, fuel consumption, emissions, secondary incidents, and potential accidents. CHART patrol unit also respond to a significant number of driver assistance requests since these services result in direct benefits to drivers and minimize the potential rubbernecking impact on highway traffic.

Chapter 6 summarizes all key performance statistics to facilitate in the review and comparison of CHART's performance over the past several years, including data quality, response time, incident duration, and resulting benefits. The chapter also includes concluding comments and recommendations for future evaluation.

CHAPTER 2. DATA QUALITY ASSESSMENT

This chapter assesses the quality of data available in the CHART 2004 performance evaluation, including a comparison with data from CHART 2003. The analysis is focused on the following two aspects: data availability (Section 2.1) and data quality analyses (Section 2.2).

2.1 Analysis of Data Availability

In year 2004, CHART recorded a total of 40,539 emergency response cases, categorized into two groups: number of incidents and number of disabled vehicles. A summary of the total available incident reports for the years 2004, 2003 and 2002 is shown in Table 2.1.

Table 2.1 Comparison of Available Data for Years 2004, 2003 and 2002

Available Records		Year 2004		Year 2003		Year 2002	
		Records	Total (%)	Records	Total (%)	Records	Total (%)
CHART II Database	Disabled Vehicle	21,412	52.8	18,068	46.9	13,752	41.9
	Incident	19,127	47.2	20,455	53.1	19,062	58.1
Total		**40,539**	100	**38,523**	100	**32,814**	100

2.2 Analysis of Data Quality

The research team has filtered through more than 10 million records in 24 tables from the CHART II database to obtain some key statistics for a detailed evaluation of data quality. Figures 2.1 and 2.2 illustrate the data quality of all records in the years 2003 and 2004, respectively, in terms of several critical indicators for the CHART's performance evaluation. All other related information will be presented in the subsequent sections.

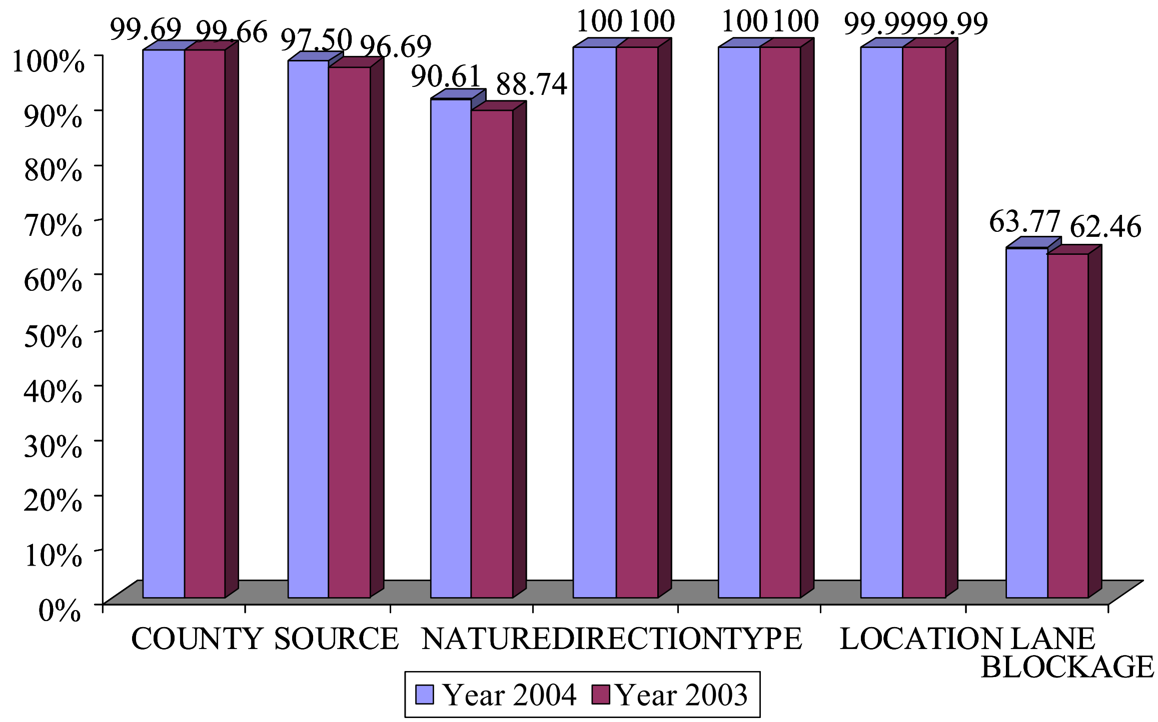


Figure 2.1 Summary of Data Quality for Several Critical Indicators

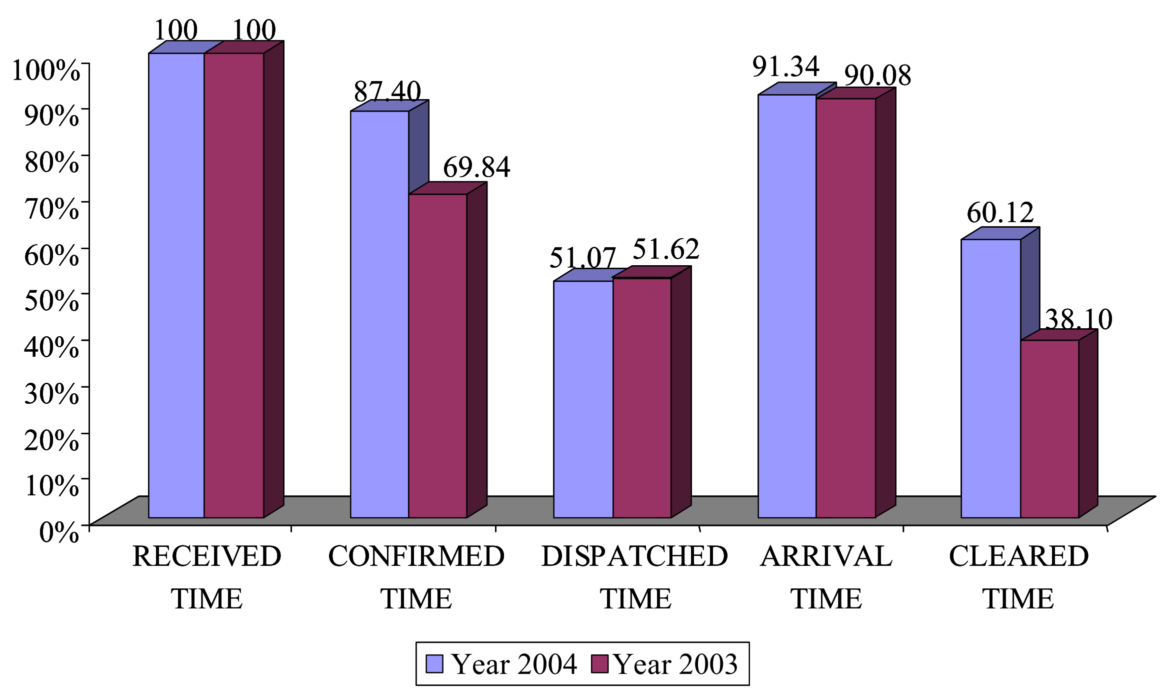


Figure 2.2 Summary of Data Quality for Time Indicators

Detection Source

As shown in Figure 2.1, about 97.5% of all emergency response reports in year 2004 contain the source of detection, which is 2,278 records more than the previous year's data. In year 2004, about 95.26% of the incident reports and 99.5% of the disabled vehicle reports have a definitive detection source.

Type of Reports

The total number of incidents/disabled vehicles managed by each operation center during the year 2004 is summarized in Table 2.2. Overall, CHART operations in year 2004 responded to a total of 19,127 incidents, including both major and minor incidents. Over the same period, the response team also provided assistance to 21,412 requests associated with disabled vehicles.

Table 2.2 Emergency Responses Reported by Each Operations Center in Year 2004

Operations Center	TOC3	TOC4	SOC	TOC5	Other	Total
Disabled Vehicles	8,551	9,750	932	904	1,275	21,412 (20,455)
Incidents	6,464	6,066	2,996	157	3,444	19,127 (18,068)
Total	15,015	15,816	3,928	1,061	4,719	40,539 (38,523)

Note: The numbers in parentheses show the corresponding data from year 2003

Nature of Incidents/Disabled Vehicles

This data item is used to classify the nature of incidents, such as vehicle on fire, collision-personal injury, and collision-fatality. The reports for disabled vehicles also cover the emergency response operations, such as abandoned vehicles, tire changes, and gas shortage. As shown in Figure 2.1, it has been found that about 90.61 percent of emergency response reports in year 2004 recorded the nature of incidents. In year 2003, only 88.74 percent recorded the nature of incidents. Therefore, CHART has slightly improved its quality in this regard.

Location and Road Name Associated with Each Response Operation

The location and road name information associated with each emergency response operation is used to analyze the spatial distribution of incidents/disabled vehicles, and to identify freeway segments that incur excessively frequent incidents. As shown in Figure 2.1, all incident response reports have valid location information, having the same quality as in year 2003 (i.e., 99.99%). 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, the research team has to manually search and input road names and highway segments.

Table 2.3 shows the percentage of data with valid location information or road name for incidents and disabled vehicles in the CHART II Database. Note that only 91.13 percent of highway segments that contain incident locations (reported in the CHART II Database for the year 2004) can be identified. The remaining 8.87 percent of incident locations are either unclear or not specific, and therefore, cannot be used for a reliable performance analysis.

Table 2.3 Data Quality Analysis with Respect to Road and Location in Year 2004

Data Quality	Incident	Disabled Vehicle	Total
Location	100.0%	100.0%	100.0%
Road	86.10%	95.61%	91.13%

Lane/Shoulder Blockage Information

Knowing the number of lanes (including shoulder lanes) being blocked is essential for the computation of additional delays and fuel consumption costs incurred by each incident. Analysis on all available data in year 2004 shows that up to 63.77 percent of available emergency response reports provided the lane/shoulder blockage information, which is slightly higher than 62.46 percent in year 2003.

Operational Time-Related Information

To evaluate the efficiency and effectiveness of emergency response operations, CHART 2004 used five specific time parameters for performance measurement: “Received Time”, “Dispatched Time”, “Arrival Time”, “Cleared Time”, and “Confirmed Time”. The data quality analysis with respect to these performance parameters is illustrated in Figure 2.2, which indicates that the quality of data for Received Time is sufficient for a reliable analysis. The quality of data with respect to Confirmed Time, Dispatched Time, Arrival Time and Cleared Time also shows some improvement over those reported in year 2003.

In summary, CHART staff has made significant progress in documenting CHART’s performance and recorded incident-operations-related information in year 2004. The use of the CHART II Database for the year 2004 has had an obvious positive impact on data quality improvement, but there is room for improvement, as evidenced in the above statistics of data quality evaluation. CHART operators should be aware that their contribution to mitigating traffic congestion, assisting driving populations, and improving the overall driving environment would not be underestimated if more quality data was available for analysis and used for further justifying the resulting benefits.

CHAPTER 3. ANALYSIS OF DATA CHARACTERISTICS

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

3.1 Distribution of Incidents and Disabled Vehicles by Day and Time

The research team analyzed the distribution of incidents/disabled vehicles between weekdays and weekends. As shown in Table 3.1, most (about 91%) incidents/disabled vehicles in year 2004 occurred on weekdays. Thus, it is obvious that more resources and manpower are needed on weekdays than on weekends to manage the incidents/disabled vehicles more effectively.

Table 3.1 Distribution of Incidents/Disabled Vehicles by Weekdays and Weekends

Center	TOC3		TOC4		TOC5		SOC		Other*		Total	
Year	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003
Weekdays	99%	98%	99%	98%	29%	30%	66%	70%	74%	70%	**91%**	92%
Weekends	1%	2%	1%	2%	71%	70%	34%	30%	26%	30%	9%	8%

* Includes AOC, DIST6, RAVENS TOC, and REDSKINS TOC

As defined by the 1999 CHART performance evaluation, peak hours in this study are set to be from 7:00 AM to 9:30 AM and from 4:00 PM to 6:30 PM. As shown in Table 3.2, about 39% of overall incidents/disabled vehicles reported in the year 2004 data set occurred during peak hour, slightly lower than that of 40% in year 2003.

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

Center	TOC3		TOC4		TOC5		SOC		Other*		Total	
Year	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003
Peak	44%	43%	46%	45%	16%	15%	20%	22%	26%	24%	**39%**	40%
Off-peak	56%	57%	54%	55%	84%	85%	80%	78%	74%	76%	61%	60%

* Includes AOC, DIST6, RAVENS TOC, and REDSKINS TOC

3.2 Distribution of Incidents and Disabled Vehicles by Road and Location

Both Figures 3.1 and 3.2 present the frequency distribution of incident/disabled vehicles by road. Specially, Figure 3.1 presents the distribution of incidents and disabled vehicles for the year 2004, while Figure 3.2 presents a comparison of the distribution of all incidents/disabled vehicles between the years of 2004 and 2003.

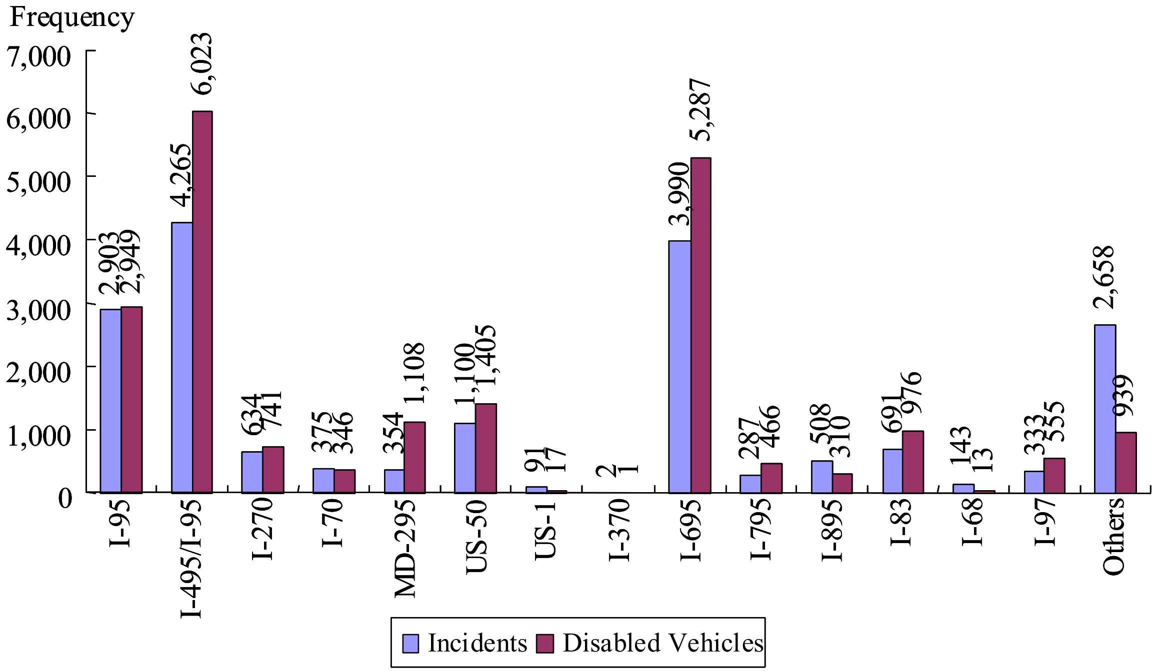


Figure 3.1 Distributions of Incidents/Disabled Vehicles by Road in Year 2004

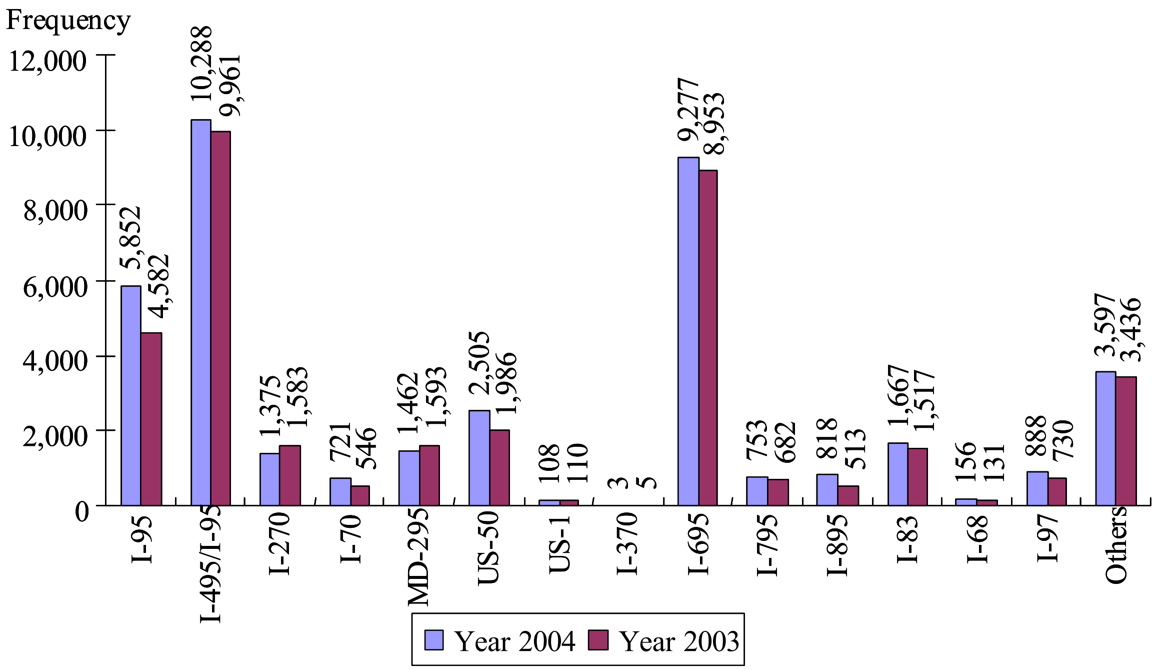


Figure 3.2 Comparisons for the Distribution of Incidents/Disabled Vehicles by Road

Based on the statistics shown in the two figures, it is clear that the six major commuting freeways, I-495/95 (Capital Beltway), I-695 (Baltimore Beltway), I-95 (from the Delaware border to the Capital Beltway), US-50, MD-295, and I-270, had a very large number of incidents/disabled vehicles in the year 2004. For example, I-495/95 experienced a total of 10,288 incidents/disabled vehicles in the year 2004, and I-695 showed a total of 9,277 incidents/ disabled vehicles during the same period. I-95, US-50, MD-295 and I-270 were plagued by 5,852, 2,505, 1,462 and 1,375 incidents/disabled vehicles, respectively, in year 2004.

It should be noted that I-95, US50 and I-270 are connected to I-495/95, and are the main contributors of traffic congestion on I-495 during the daily commuting periods. Because of the high traffic on I-495, any incident is likely to have vehicles queued back to I-95, US50 and I-270, thus causing serious congestion on those three freeways as well. The interdependent nature of incidents between the primary commuting freeways should be taken into account in prioritizing and implementing incident management strategies. To better allocate patrol vehicles and response units to hazardous highway segments, the researchers also analyzed the distribution of incidents/disabled vehicles by grouping the total number of incidents and disabled vehicles between two consecutive exits as an indicator.

Figures 3.3 and 3.4 present the geographical distribution of incidents and disabled vehicles on I-495/95, and the comparison results between years 2004 and 2003, including incidents and disabled vehicles. In Figure 3.3, the highest frequency of incidents (406 cases) occurred between Exit 31 and Exit 33 of I-495, representing the I-495 segment between MD-97 (Georgia Ave.) and MD-185 (Connecticut Ave.). The location having the highest frequency of disabled vehicles (413 cases) also occurred at the same location, which is one of the most congested segments of I-495 in Maryland.

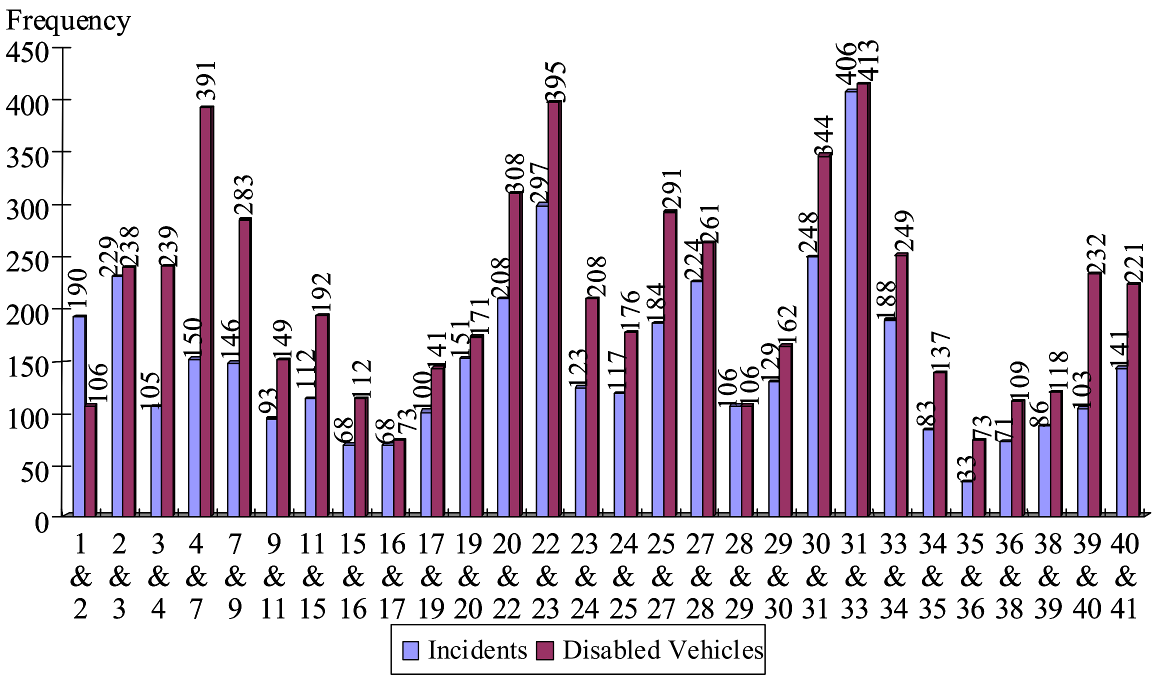


Figure 3.3 Distribution of Incidents/Disabled Vehicles by Location on I-495/I-95

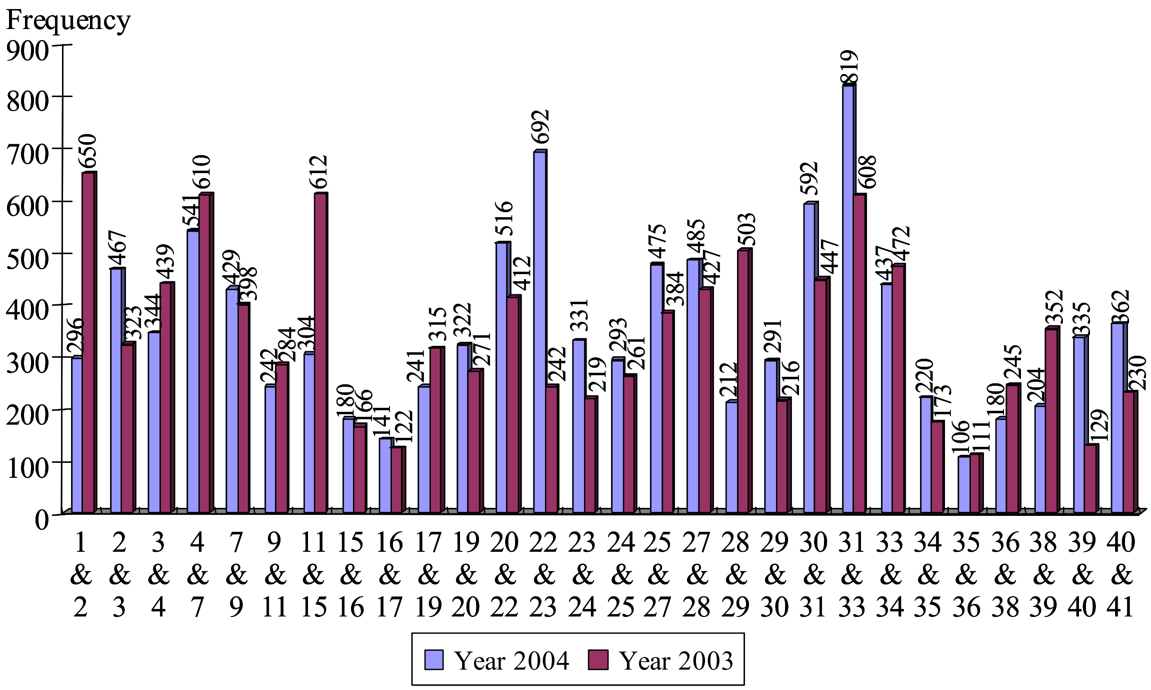


Figure 3.4 Comparison of Incidents/Disabled Vehicles Distribution by Location on I-495/I-95

Figure 3.5 presents the distribution of incidents and disabled vehicles by location on I-95, and Figure 3.6 compares this distribution between years 2004 and 2003. As shown in Figure 3.5, the highest number of incidents occurred between Exit 55 and Exit 56 (397 cases), which is close to the interchange between I-95 and I-895. Both the segment between Exits 27 and 29 and the segment between Exits 47 and 49 experienced a high number of disabled vehicles (i.e., 283 and 301 cases, respectively). The former location is near the interchange between I-95 and I-495, and the latter precedes the interchange between I-95 and I-695.

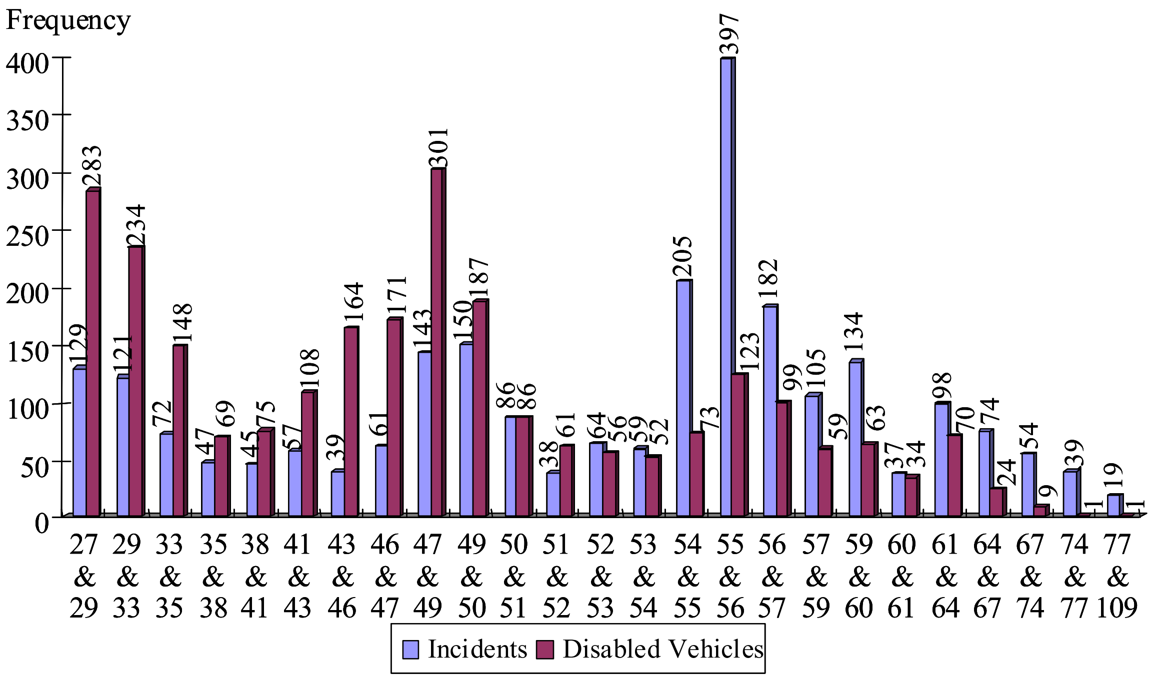


Figure 3.5 Distribution of Incidents/Disabled Vehicles by Location on I-95

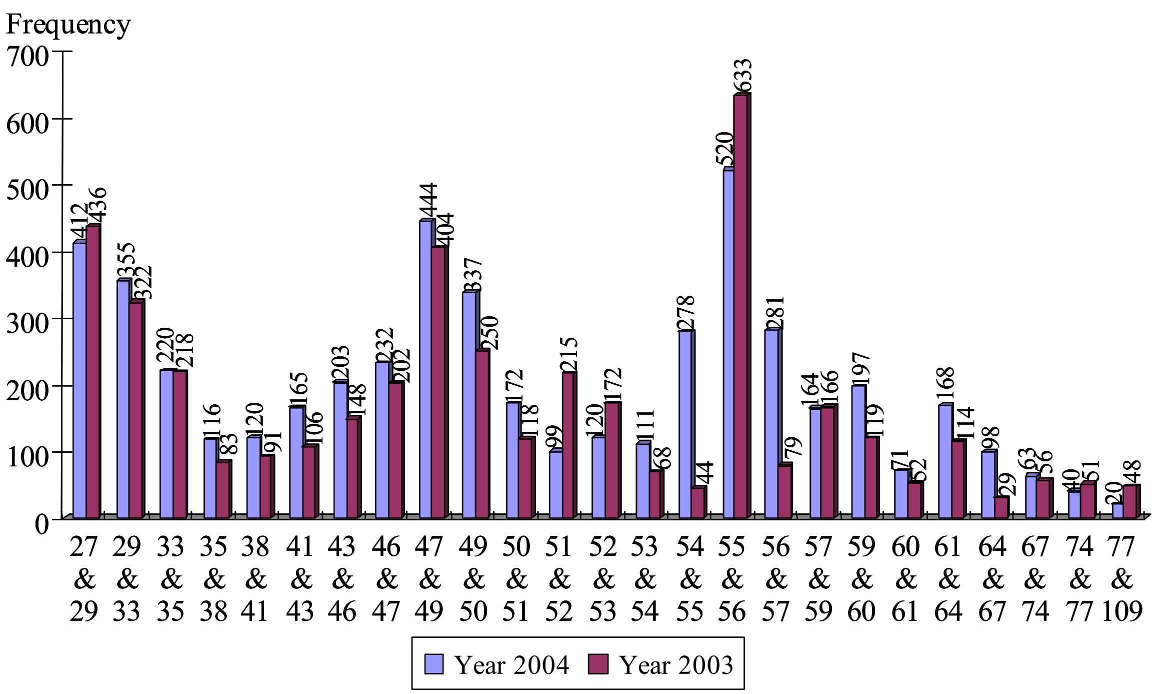


Figure 3.6 Comparison of Incidents/Disabled Vehicles Distribution by Location on I-95

Overall, the incidents and disabled vehicles in the year 2004 for the segment of I-95 between Exits 55 and 56 recorded the highest number of incident responses, with a total frequency of 520. The segment of I-95 between Exits 47 and 49 (between I-195 and I-695) suffered the second largest number of incidents/disabled vehicles, approximately 444 emergency requests in year 2004 compared with 404 requests in year 2003. The segment near the interchange between I-495 and I-95 had the third largest number of overall incident responses (i.e., 412 compared with 436 in year 2003).

Figure 3.7 represents the same spatial distribution of incidents/disabled vehicles data on I-270 for the year 2004. A comparison of emergency operations data between years 2004 and 2003 is shown in Figure 3.8.

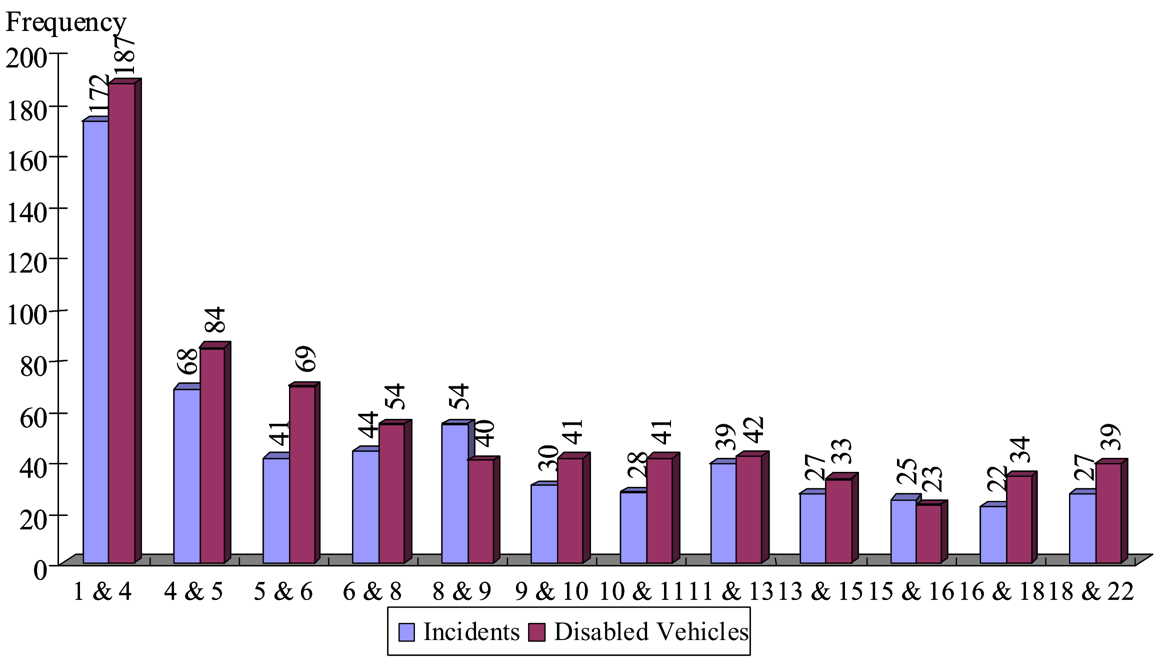


Figure 3.7 Distribution of Incidents/Disabled Vehicles by Location on I-270

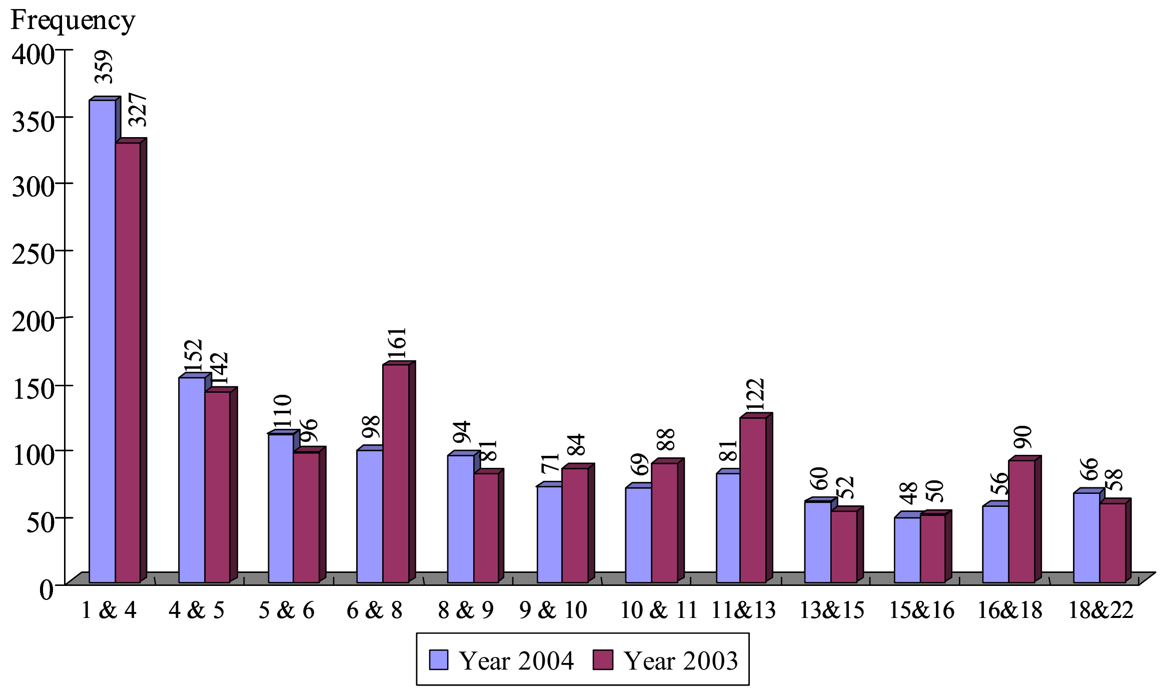


Figure 3.8 Comparison of Incidents/Disabled Vehicles Distribution by Location on I-270

In Figure 3.7, the segment between Exits 1 and 4 on I-270 had the highest numbers of incidents and disabled vehicles (i.e., 172 and 187, respectively). In Figure 3.8, 359 incidents/disabled vehicles occurred between Exits 1 and 4 compared to only 327 in the year 2003.

Figure 3.9 shows the distribution of incidents and disabled vehicles by location on I-695 in the year 2004, and Figure 3.10 shows the distribution of the total incidents/disabled vehicles in the year 2004 compared with year 2003. The high-incident segments, as shown in Figure 3.9, are from Exits 12 to 13 and Exits 13 to 14 (i.e., 214 and 210, respectively). Both are quite close to I-95. In Figure 3.10, the two highest frequencies (about 500 cases) are reported on the segments between Exits 22 and 23 and Exits 23 and 24, which are near the interchange to I-83.

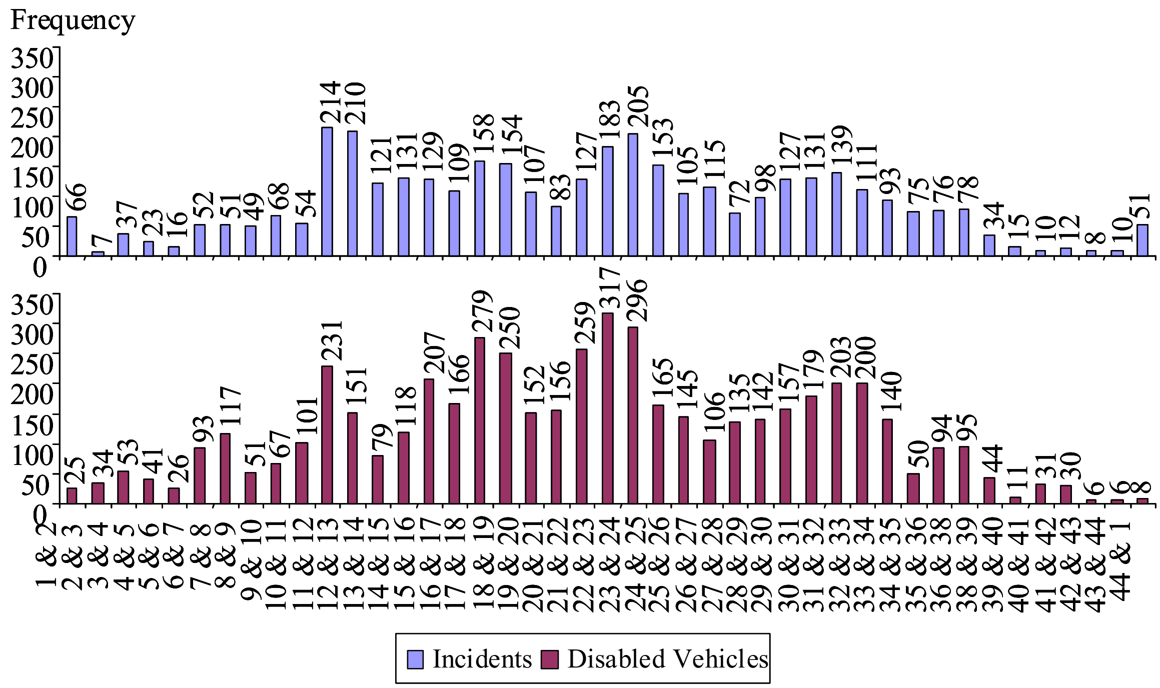


Figure 3.9 Distributions of Incidents/Disabled Vehicles by Location on I-695

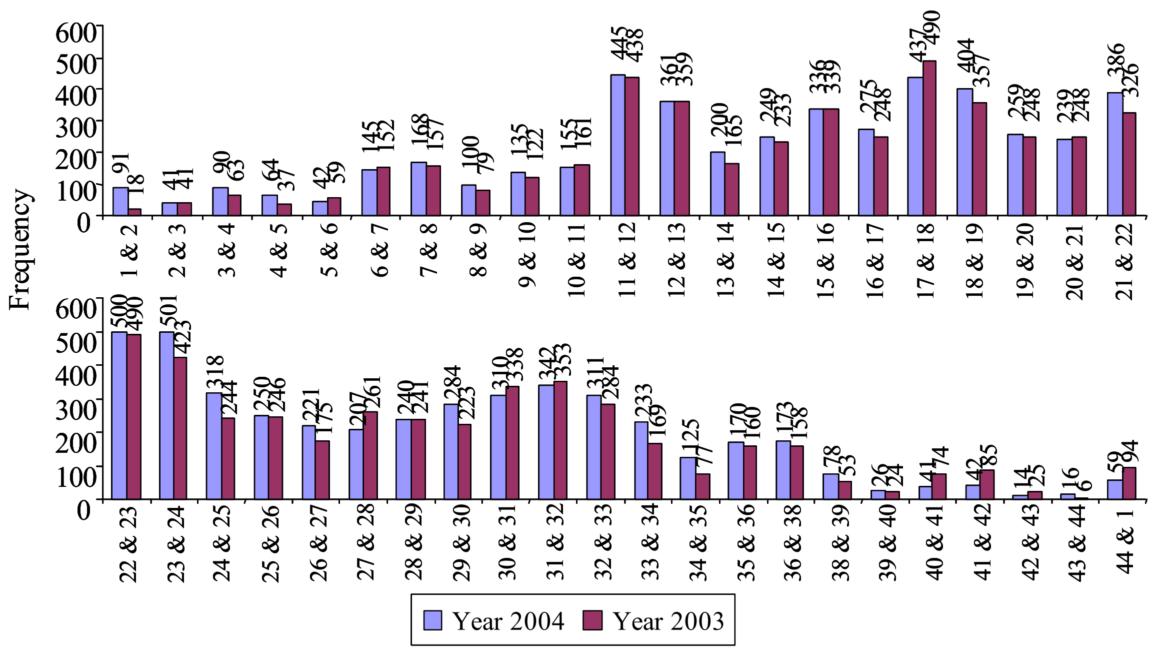


Figure 3.10 Comparison of Incidents/Disabled Vehicles Distribution by Location on I-695

3.3 Distribution of Incidents and Disabled Vehicles by Lane Blockage Type

Figure 3.11 illustrates the distribution of incidents by lane blockage in year 2004, where most incidents (3,110 cases) were one-lane blockages. The comparison of year 2004 incidents/disabled vehicles distribution by lane blockage with year 2003 results is illustrated in Figure 3.12. Note that all reported disabled vehicles are classified as shoulder lane blockages.

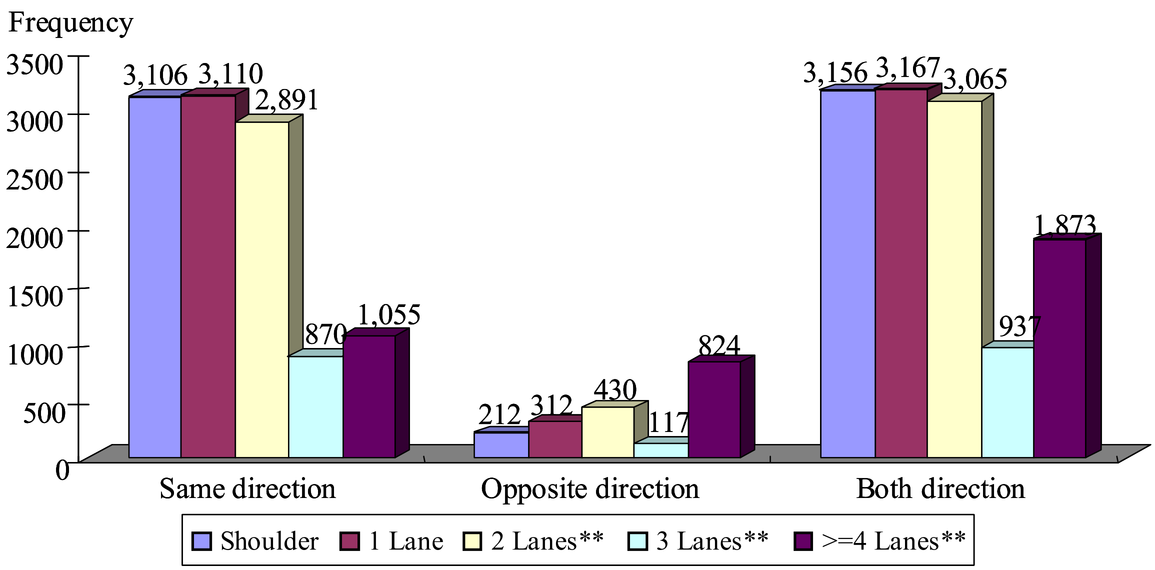


Figure 3.11 Distribution of Incidents by Lane Blockage

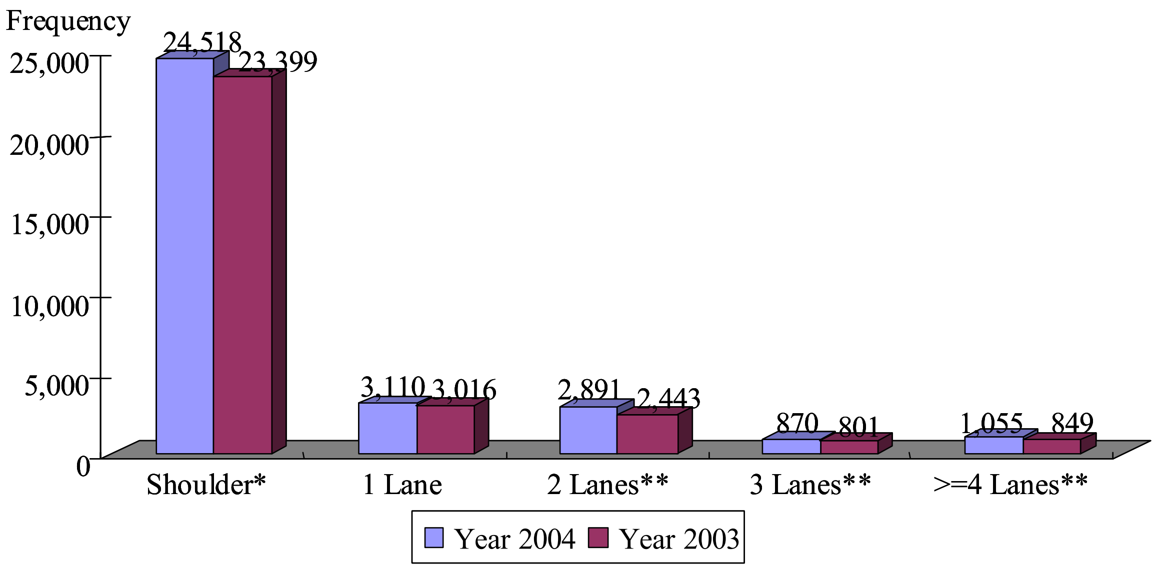


Figure 3.12 Comparison of Incidents/Disabled Vehicles Distribution by Lane Blockage

Figures 3.13 and 3.14 present a comparison of lane-blockage incidents between year 2004 and year 2003 for major roads in the Baltimore and Washington metropolitan areas.

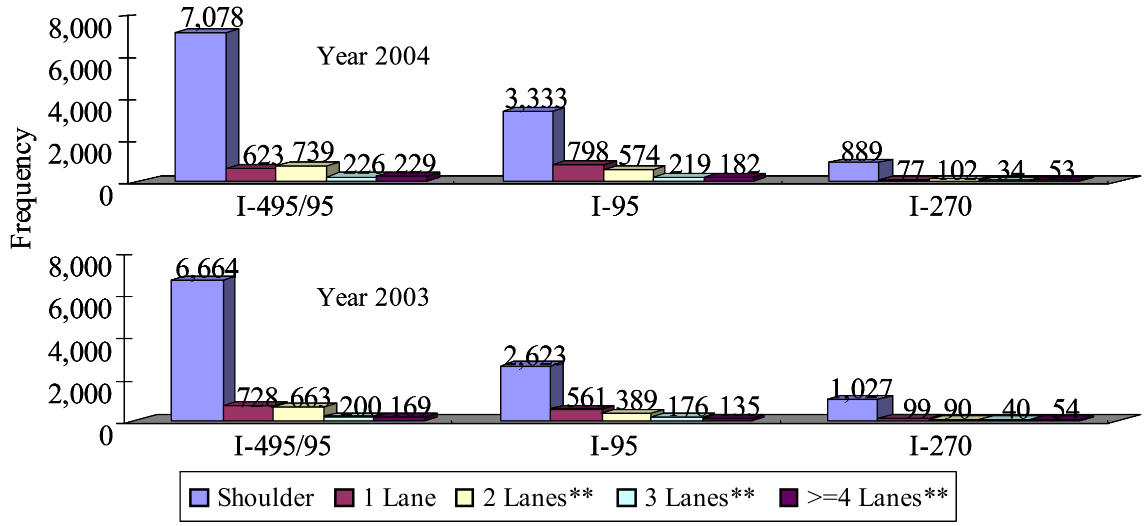


Figure 3.13 Distribution of Lane Blockages due to Incidents and Disabled Vehicles by Major Freeways in the Washington Region

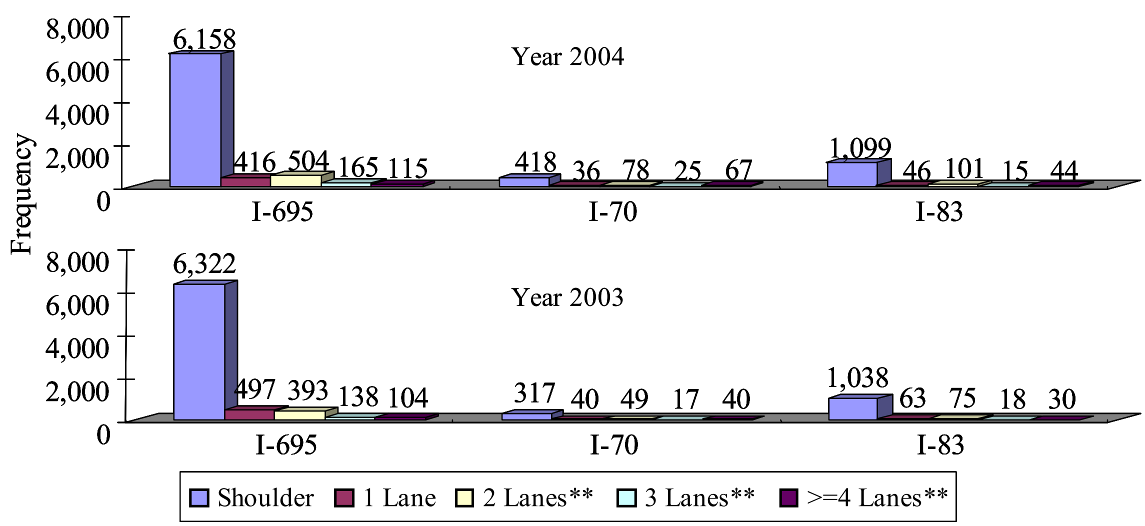


Figure 3.14 Distribution of Lane Blockages due to Incidents and Disabled Vehicles by Major Highways in the Baltimore Region

Note that a very large number of shoulder-lane blockages were due to disabled vehicles. Most of the disabled vehicles were related to some type of driver assistance requests due to flat tire, minor mechanical problems, or running out of gas.

3.4 Distribution of Incidents and Disabled Vehicles by Blockage Duration

The analysis of lane blockages naturally leads to the comparison of incident duration distribution. Figure 3.15 illustrates the distribution of lane blockages and their average duration on each major freeway. The distribution is based on available data only, including incidents and disabled vehicles.

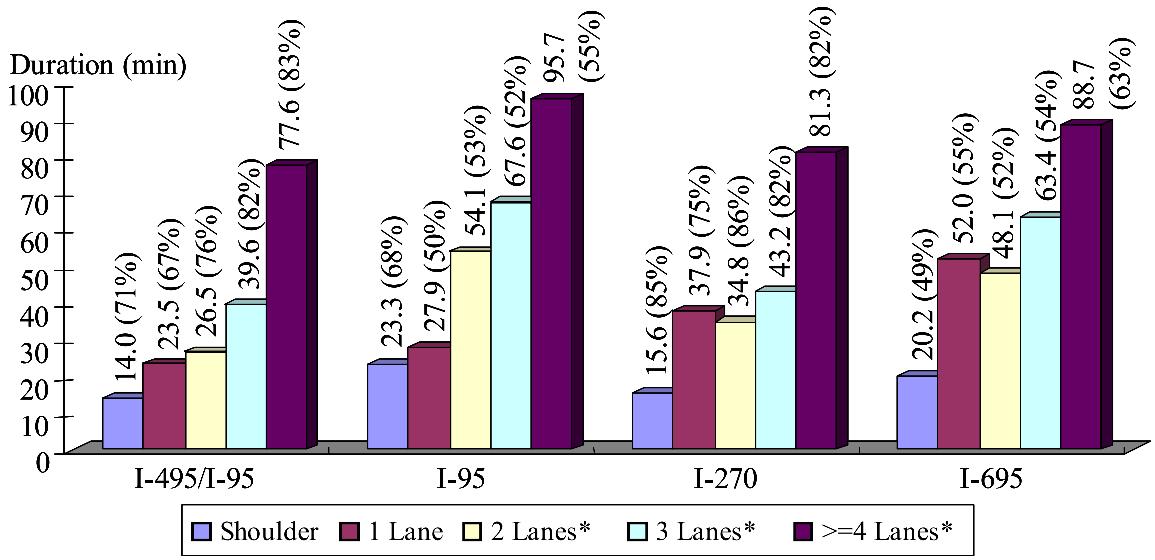


Figure 3.15 Distribution of Lane Blockages and Duration by Road

Based on the above statistics, it is clear that CHART's highway network coverage has been plagued by a high frequency of incidents, with durations ranging from approximately 10 minutes to more than 2 hours. The incidents are clearly one of the 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. Thus, it is imperative to continuously improve both the traffic management and incident response systems.

As shown in Figure 3.16, most disabled vehicles did not block traffic for more than a half hour. For instance, the number of disabled vehicles and incidents with duration less than 30 minutes was about 87% and 60%, respectively.

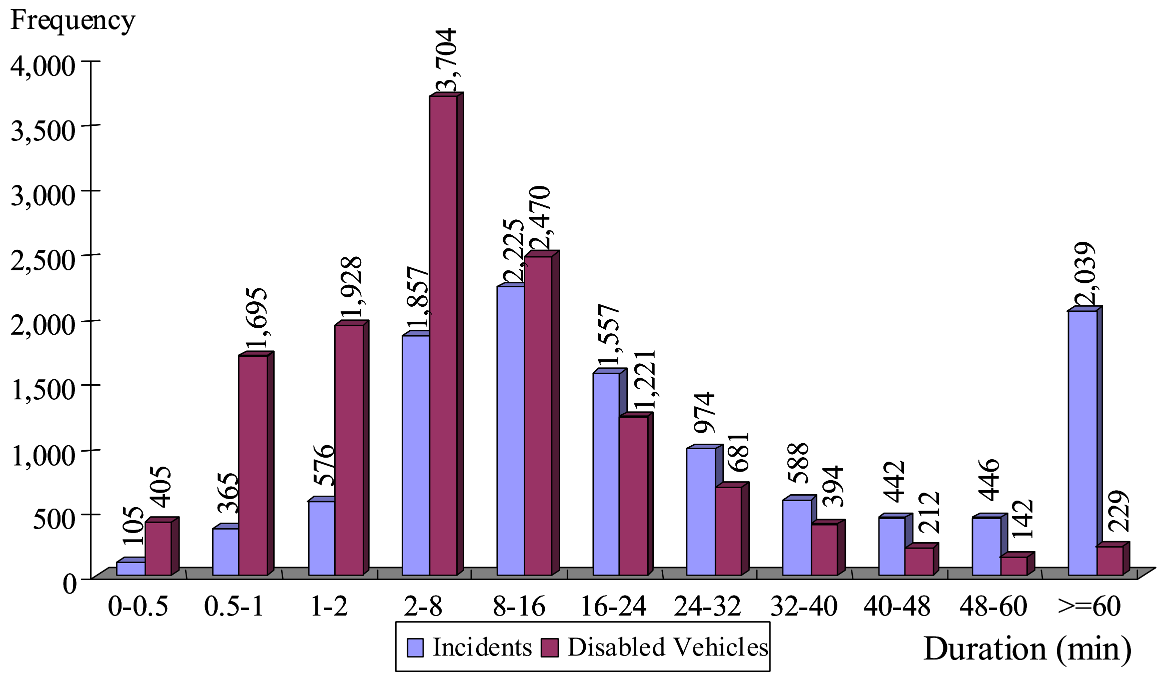


Figure 3.16 Distribution of Incidents/Disabled Vehicles by Duration

Although most incidents in the year 2004 were not severe, their impact was quite significant and caused traffic blockage and congestion during peak hours. The clearing of such blockages generally did not require special equipment, and the incident duration was dependent mainly upon the travel time of the incident response units.

Figure 3.17 presents the distribution of total records in year 2004 and its comparison with the year 2003 data. About 14% of reported incidents/disabled vehicles managed by TOC-3 had blocked traffic for more than 30 minutes, and about 16% and 8% for TOC-4 and TOC-5, respectively, for the same type of emergency requests in year 2004. For SOC, about 63% of reported incidents lasted more 30 minutes. Overall, about 20% of those responded to by CHART lasted more than 30 minutes in year 2004.

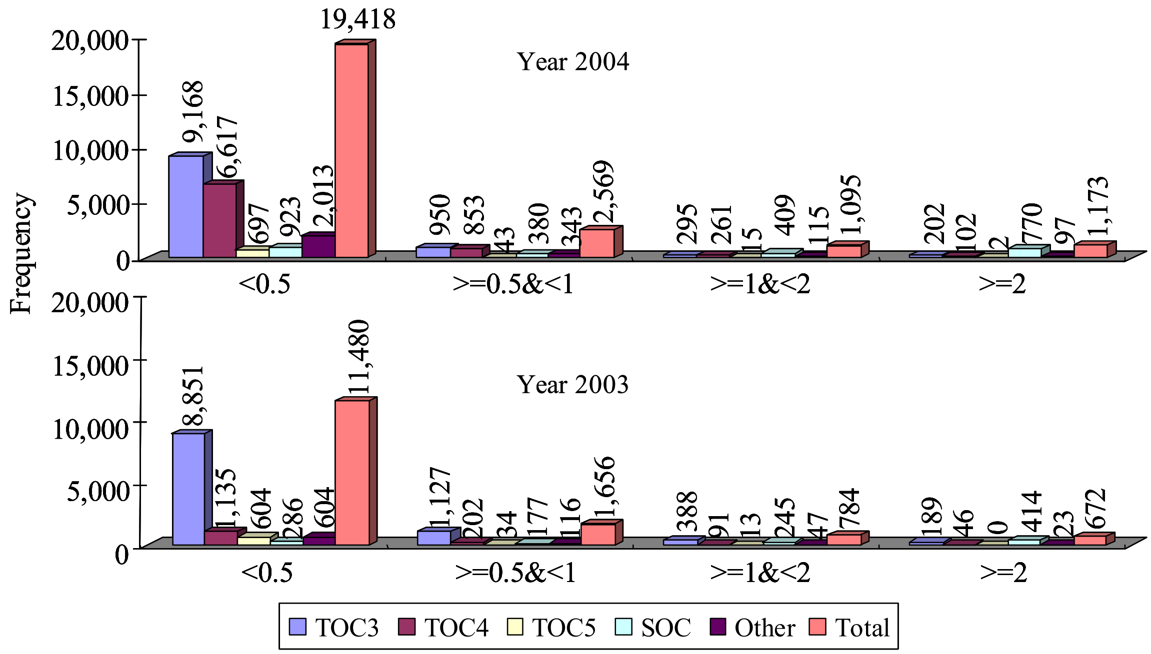


Figure 3.17 Comparison of Incidents/Disabled Vehicles Distribution by Duration

CHAPTER 4. EVALUATION OF EFFICIENCY AND EFFECTIVENESS

4.1 Evaluation of Detection Efficiency and Effectiveness

Since CHART has not implemented an automatic incident detection system, it naturally offers no information for evaluating the detection and false-alarm rates. Furthermore, at this point, there is also no way to determine how long it takes the traffic control center to detect an incident from various sources after its onset. As such, the evaluation of detection efficiency and effectiveness can focus only on the incident response rate and distribution of detection sources.

The response rate presented in this section is defined as the ratio between the total number of traffic incidents reported to the CHART control center to those managed by the CHART/MSHA emergency response teams. Based on year 2004 incident management records, the overall response rate was about 78%, slightly lower than the rate of 81% in year 2003. As in the previous year, existing incident reports that are available in CHART do not indicate the reasons for non-response. It appears that most of such incidents were either incurred during very light traffic periods or were not severe enough to cause any significant traffic blockage or delay. Despite the lack of an automated incident detection system, CHART has maintained a highly effective coordination system with all other state and municipal agencies responding to traffic incidents and congestion.

With respect to the distribution of all detection sources, the statistics in Figure 4.1 clearly show that in the year 2004 about 52.5 percent of incidents were detected by MSHA/CHART patrols, and about 19.2 percent were reported by the Maryland State Police (MSP). The results are similar to year 2003 figures, where it's 50.9 percent and 21.6 percent, respectively. Note that the numbers in parentheses indicate the year 2003 statistics.

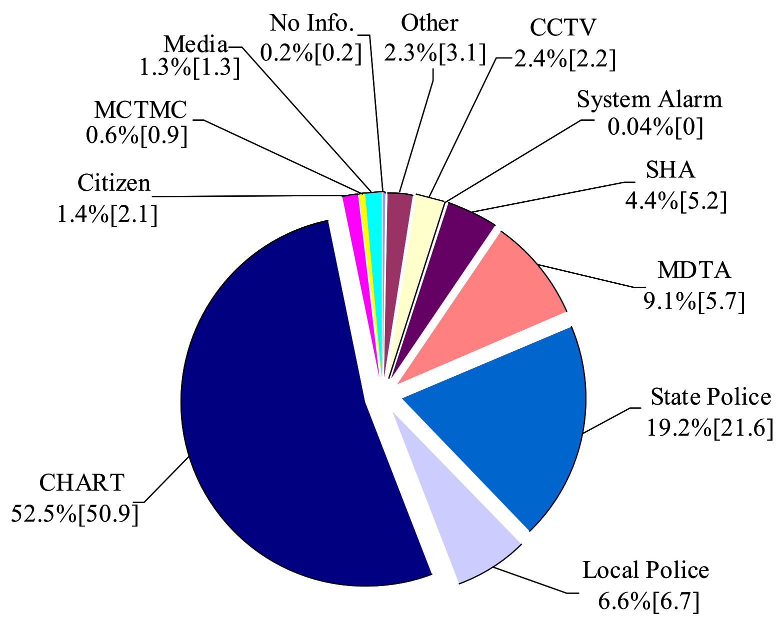


Figure 4.1 Distribution of Incident/Disabled Vehicles by Detection Sources

Figures 4.2 and 4.3 illustrate the distribution of detection sources for TOC 3 and TOC 4. It is evident from the figures that MSHA patrols (CHART Unit) took the primary role for detecting and responding to reported highway incidents/disabled vehicles in the year 2004.

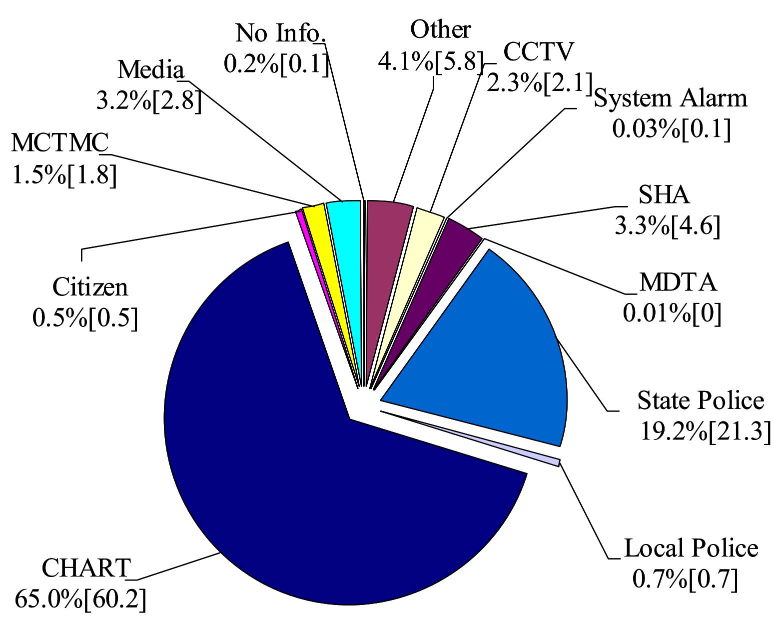


Figure 4.2 Distribution of Incident/Disabled Vehicles by Detection Source for TOC 3

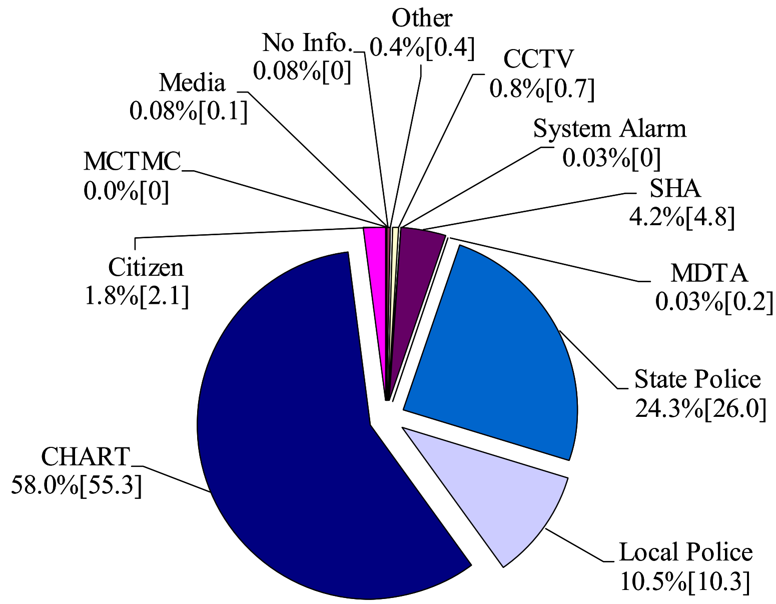


Figure 4.3 Distribution of Incident/Disabled Vehicles by Detection Source for TOC 4

4.2 Analysis of Response Efficiency

To analyze the efficiency of incident response by CHART/MSHA, the researchers focused mainly on the distribution of response times and incident duration. The response time is defined as the difference between the onset of an incident and the response unit's arrival time. Since it is difficult to determine an incident's actual starting time, the response time used in this analysis is based on the difference between the time the Response Center received the call and the time the response unit arrived at the incident site.

The average response time for all types of incidents in year 2004 is given in Figure 4.4. The average response time for all emergency response operations by CHART in year 2004 was 11.38 minutes, slightly lower than that of 11.50 minutes in year 2003.

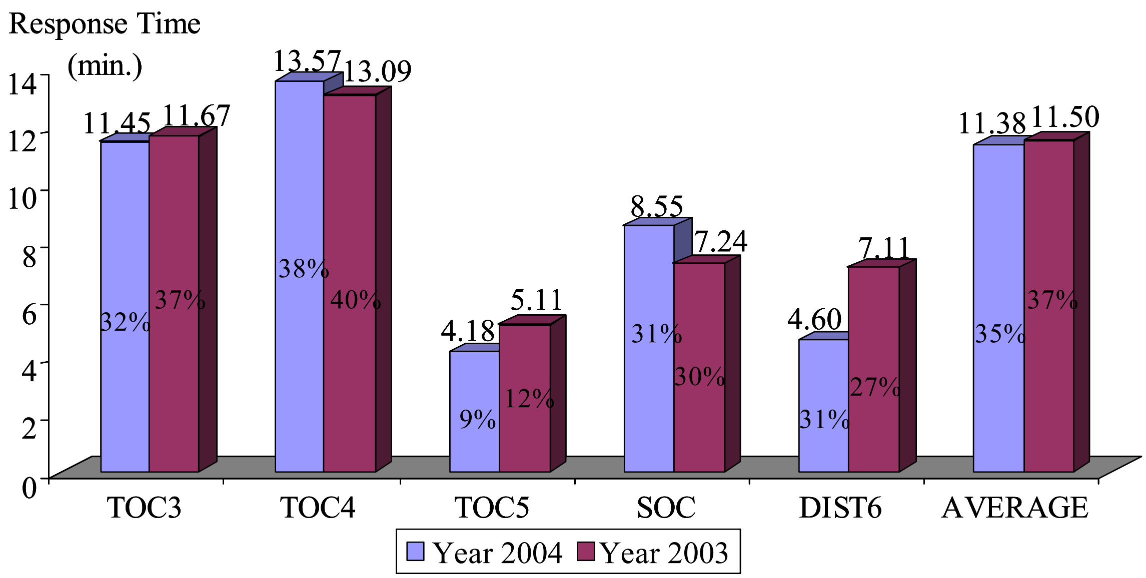


Figure 4.4 Overall Average Response Time

4.3 Reduction in Incident Duration

Aside from evaluating the entire incident management process, one of the major performance indicators is the reduction in average incident duration due to the operations of the CHART/MSHA response units. Theoretically, to reliably estimate such an indicator one should perform a typical before-and-after analysis. However, most incident-management-related data prior to CHART are practically unavailable for any meaningful analysis. Thus, the alternative is to compute the average incident clearance time in year 2004 with and without the assistance from CHART/ MSHA response units. Since CHART's incident management team responded to most incidents in the year 2004, the data associated with non-CHART response incidents for performance comparison is quite limited.

As shown in Table 4.1, the average duration for clearing an incident with and without the assistance of CHART was about **22.82** minutes versus **24.65** minutes. Note that this analysis excluded the outlier data with duration outside of the range of (mean ± two standard deviations) and 2 hours. Based on the results shown in Table 4.1, it appears that with the assistance of CHART/MSHA response units, the time it took to clear an incident was reduced. On average, CHART contributed to about a **7.4** percent reduction in its incident blockage duration in the year 2004, a slight decrease compared with the year 2003 record, which was about 9.9 percent. Overall, the reduction in incident duration has certainly contributed to significant savings on travel time, fuel consumption, and other related social-impact costs. Note that the statistics shown in Table 4.1 are likely to be biased as only about 30 percent of incident reports contain a complete set of data required to compute the incident duration (i.e., reported received time and cleared time). Data quality remains a critical issue to be addressed by CHART.

Table 4.1 Comparison of Incident Durations for Various Types of Lane Blockages

Blockage	With SHA Patrol		Without SHA Patrol	
	Duration (min)	Frequency	Duration (min)	Frequency
Shoulder	14.93	2,798	24.64	307
1 lane	43.99	1,648	22.86	1,462
2 lanes	49.86	2,159	54.41	732
3 lanes	52.47	653	76.69	217
>=4 lanes	106.61	847	77.04	208
Unknown	41.84	6,777	62.77	1,319
Weighted Average	**42.34**	14,882	**46.24**	4,245
Weighted Average	**38.46** **(39.5)**	14.035 (14,591)	**44.65** (49.1)	4,037 (3,477)

* The frequency of 4-lane blockage incidents seems to be biased by operator input errors.

Note: 1) "Duration" is computed by using qualified samples with durations within **mean±2*deviation** and **less than 2 hours**; 2) The number in each parenthesis shows the result in year 2003.

CHAPTER 5. BENEFITS FROM CHART’S INCIDENT MANAGEMENT

Due to concerns relating to data quality, the benefit assessment of CHART has always focused only on benefits that are directly measurable or quantifiable based on the incident reports. Such direct benefits, both to roadway users and to the entire community, are classified as:

- 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 vitalizing the local economy and increasing network mobility, are not included in this benefit analysis.

5.1 Assistance to Drivers

The general public has greatly appreciated a prompt response to various driver assistance requests, such as a flat tire or running out of gas, by CHART’s incident management units. The quick response on CHART’s part has directly contributed to minimizing the potential rubbernecking effects on traffic, especially during peak hours, where incidents can cause excessive delays. Therefore, despite the difficulty in precisely quantifying the impacts of such help, assists to drivers should undoubtedly be counted as one of the major direct benefits.

The overall distribution of assists to drivers (called Disabled Vehicle in the CHART II Database) by type of request in years 2004 and 2003 is available in Figure 5.1. Among those, the distribution for assists to drivers managed by TOC-3 and TOC-4 is illustrated in Figures 5.2 and 5.3, respectively.

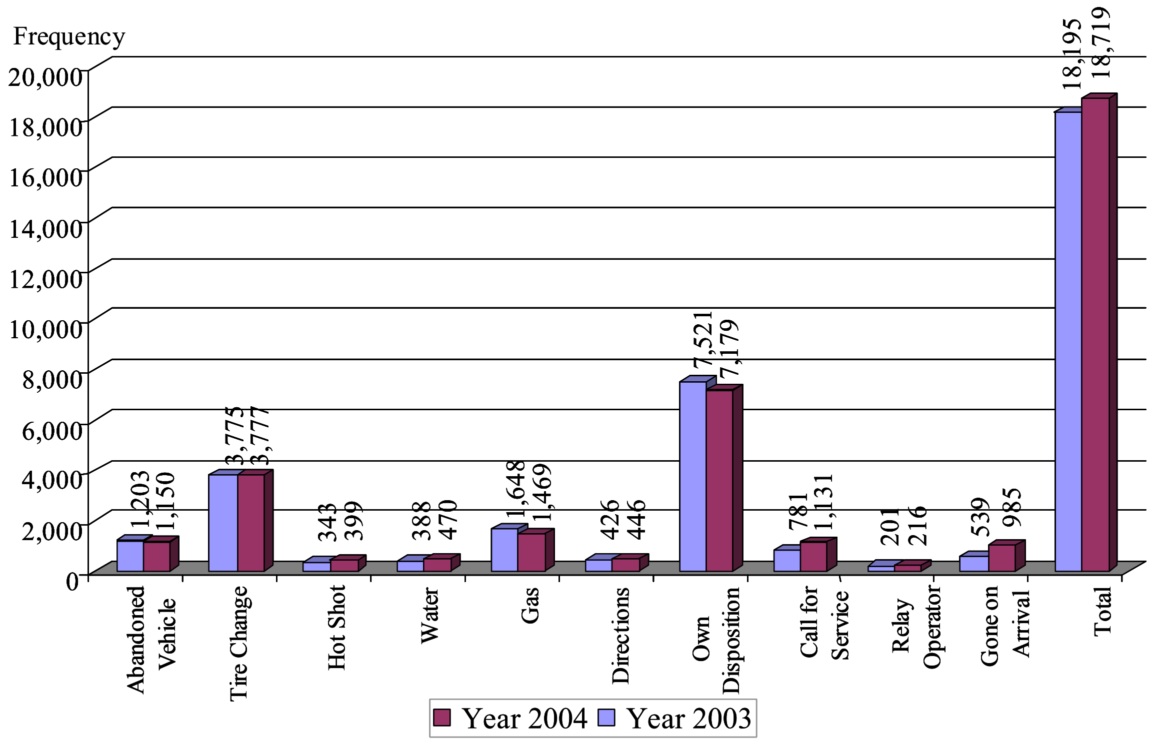


Figure 5.1 Nature of Driver Assistance Requests in Year 2004 and Year 2003

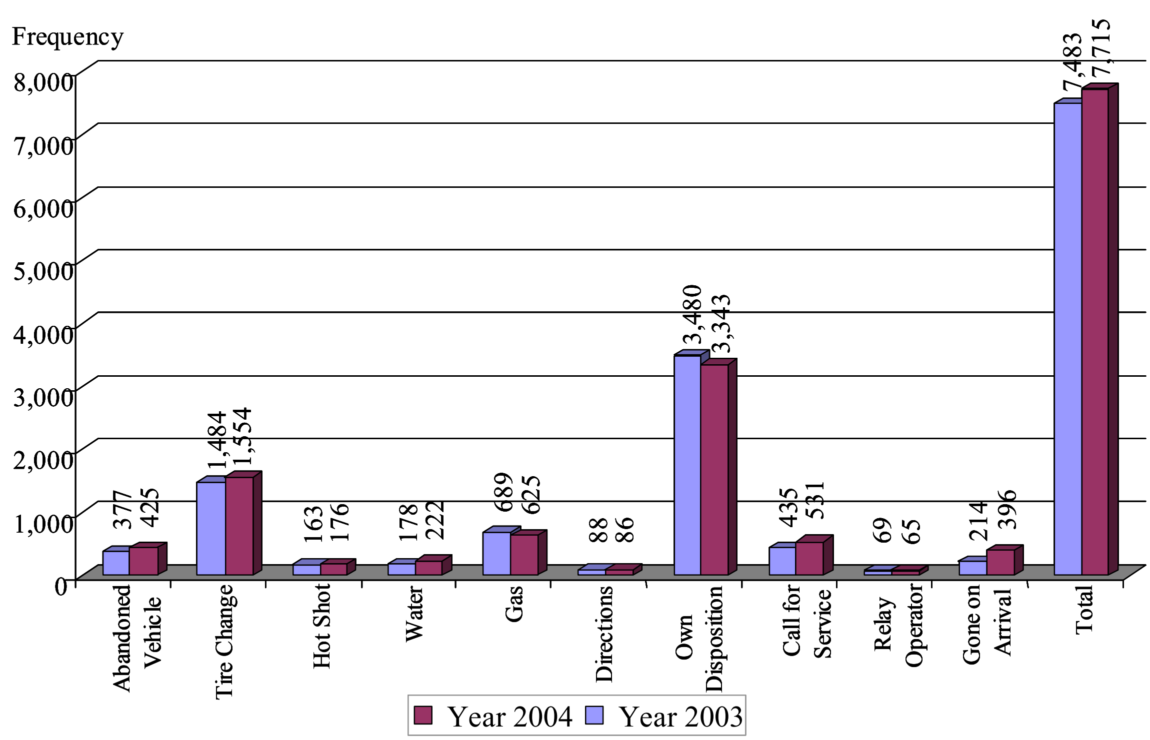


Figure 5.2 Nature of Driver Assistance Requests for TOC-3

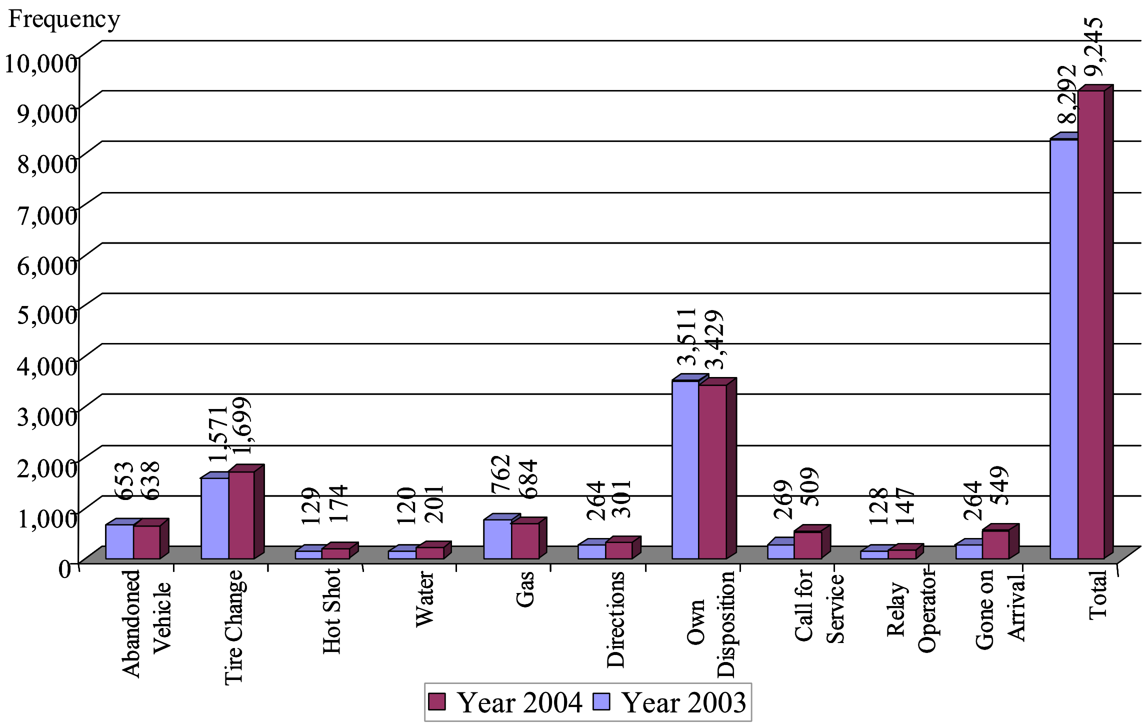


Figure 5.3 Nature of Driver Assistance Requests for TOC-4

As shown in Figure 5.1, there were a total of 21,412 records among all 40,539 available reports associated with requests from drivers for some type of assistance, such as a flat tire, shortage of gas, or mechanical problems in the year 2004. This number is higher than the 20,455 assistance requests from drivers in the year 2003. Out of the 21,412 assistance requests, a total of 5,423 were related to “out of gas” and “tire changes” requests, about the same level as in the year 2003 (i.e., 5,246 cases).

5.2 Potential Reduction in Secondary Incidents

It has been widely recognized that one major accident may incur a number of relatively minor secondary incidents due to a dramatic change in traffic conditions, such as the rapid spreading of queue length and a substantial drop in traffic flow speed. Thus, an efficient clearing of incident blockage may not only directly benefit drivers in the traffic queue, but also reduce potential incidents for approaching vehicles that may further deteriorate traffic conditions.

Grounded on the experience from our previous work, this study has adopted the following definition for secondary incidents that accounts for those incidents caused by rubbernecking effects in both traffic directions:

- Incidents that occur within two hours from the onset of a primary incident and also within two miles downstream of the primary incident location; or
- Incidents that occur in the opposite direction that are within a half-hour from the onset of a primary incident and lie within a half-mile either downstream or upstream from the primary incident location.

For the convenience of comparison, Figure 5.4 presents the distribution of secondary incidents under definitions based on the accident database provided by the Maryland State Police Department for the year 2004. Notably, under our definition, there were 917 secondary incidents that occurred in the year 2004. Generally, one may assume a linear correlation between the number of secondary incidents and incident duration, and estimate the potential reduction in the total secondary incidents due to CHART/MSHA operations as follows:

- Reported number of secondary incidents: 917
- Estimated number of secondary incidents without CHART/MSHA response units (that has resulted in a 8.43% reduction on the average incident duration): 917/(1-0.0843) = 1,001
- The number of potentially reduced secondary incidents due to CHART/MSHA operations: 1,001– 917 = 84

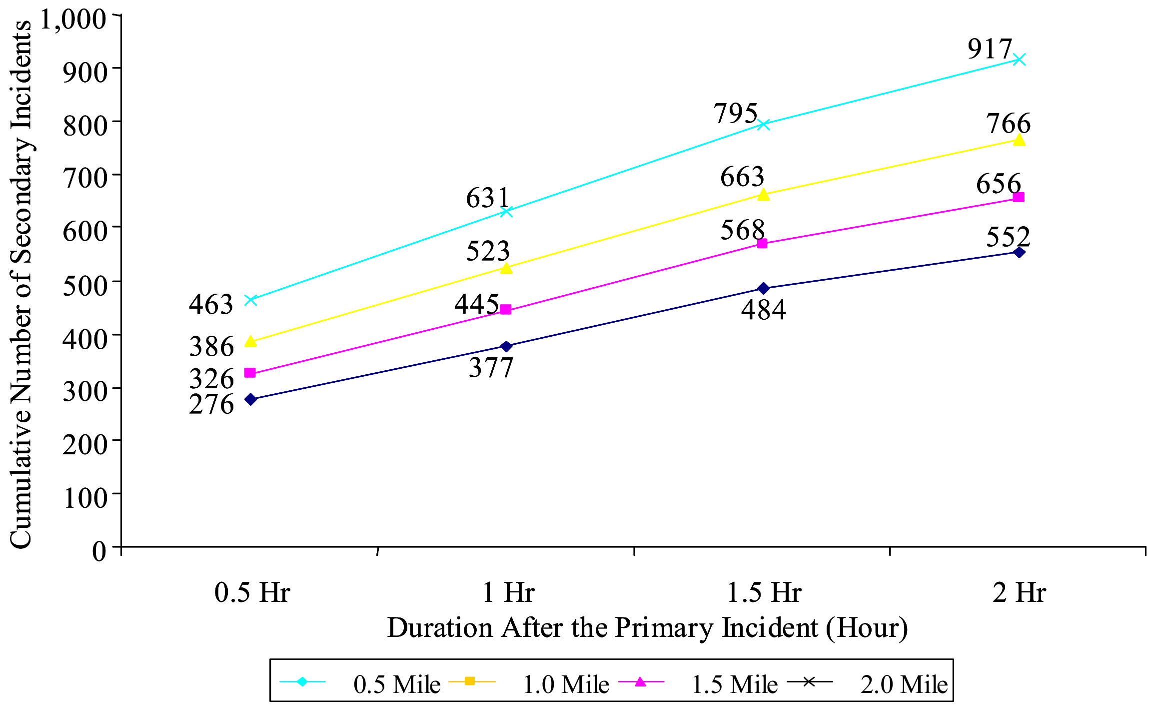


Figure 5.4 Distribution of Reported Secondary Incidents

Note that each of the 84 secondary incidents, if it actually occurs, may further prolong the primary incident duration and result in additional travel time, fuel consumption, and more congestion on surface streets. Such impacts and accompanying benefits are not computed in this report due to data limitations, but will be investigated in a future study.

5.3 Estimated Benefits due to Efficient Removal of Stationary Vehicles

As has been commonly observed around incident sites, many drivers are forced to perform undesirable lane-changing maneuvers because of lane-blockages. Considering the fact that a large number of traffic accidents are due to improper lane changes, it is likely that a prolonged incident removal operation may result in more accidents. Thus, CHART/MSHA's operations that are directly aimed at the efficient removal of stationary vehicles in travel lanes may directly prevent some potential lane-changing-related accidents around incident sites. This study attempts to explore such a benefit with the limited data available.

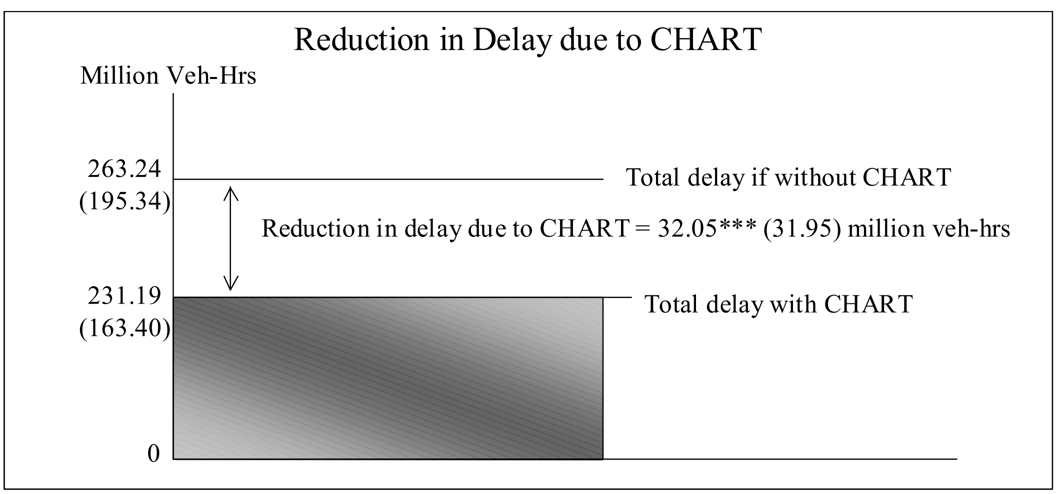
The estimated results for potential incident reduction for selected target freeways are reported in Table 5.1. Note that this estimation is only focused on the peak periods, as the relationship between lane-changing maneuvers and accidents during off-peak hours is determined to be statistically uncorrelated in our limited data set.

Table 5.1 Reduction of Potential Incidents due to CHART Operations

Road Name		I-495/ I-95	I-95	I-270	I-695	I-70	I-83	MD295	US50	Total
Number of Potential Incident Reduction	Year 2004	112	81	16	104	20	20	14	17	**384**
	Year 2003	171	92	20	147	9	39	7	25	**510**
	Year 2002	107	105	10	71	12	10	5	23	**343**
	Year 2001	174	79	13	65	2	10	7	20	**370**

5.4 Direct Benefits to Highway Users

Figure 5.5 illustrates the computation that shows a reduction in delays due to CHART/MSHA operations. The overall computation results indicate that without the intervention of CHART/MSHA operations, all incidents that occurred in the year 2004 may have resulted in a total of 263.24 million veh-hr delays. In contrast, due to CHART's efficient response and management, the total vehicle delay has been reduced to 231.19 million hours, about 32.05 million hours less than without the assistance of CHART/MSHA.



Note: The number in each parenthesis shows the result in year 2003.

Figure 5.5 Reduction in Delays due to CHART/MSHA Operations

Overall, the benefits in terms of reduction in delay time and fuel consumption, based on the same parameters used in year 2003, are summarized in Table 5.2. To account for the cost of delays associated with commercial vehicles, we estimated the truck driver's cost at $19.58/ hour and the cargo's cost at $45.40/hour to compute commercial truck-related benefits.

Table 5.2 Total Direct Benefits to Highway Users in Year 2004

Reduction due to CHART		Amount	Unit Rate	In Dollar (million)
Delay (million veh-hrs)	Truck	2.236 (2.009)	$19.58/hour (truck driver's cost)	43.78 (39.34)
			$45.40/hour (cargo's cost)	101.52 (91.21)
	Car	23.709 (24.811)	$14.34/hour (car driver's cost)	339.99 (355.79)
Fuel consumption (million gallons)		5.41 (5.39)	$1/gal.	5.410 (5.39)
Emissions (million tons)	HC	418.99 (417.63)	$6,700/ton	35.32 (35.21)
	CO	4,706 (4,691)	$6,360/ton	
	NO	200.67 (200.01)	$12,875/ton	
Total		$ **526.02** (526.94)		

Note: The numbers in parentheses show results for year 2003.

The estimated reductions in vehicle emissions were based on parameters provided by MDOT and on the total time delay reduction due to CHART/MSHA operations. Using the cost parameters shown in Table 5.2 (Patrick, 1998), the above reduction in emissions has resulted in a total savings of **35.32** million dollars. Thus, CHART/MSHA's operations in year 2004 have generated a total savings of **526.02** million dollars, which is at about the same level as the savings in year 2003, at 526.94 million dollars.

In addition to the above savings, a reduction in emissions due to reduced time delays in the Baltimore and Washington regions because of CHART/MSHA operations have also been computed. The results are summarized in Table 5.3.

Table 5.3 Time Delay and Emissions Reductions due to CHART/MSHA Operations for Washington and Baltimore Regions

		Total by Chart		Washington Region		Baltimore Region	
		Year 2004	Year 2003	Year 2004	Year 2003	Year 2004	Year 2003
Annual Delay Reduction	hours	32,050,143	31,945,820	14,368,130	14,761,838	17,682,012	17,183,983
Daily Delay Reduction	hours	123,270	122,869	**55,262**	56,776	**68,008**	66,092
Emissions Reduction							
HC Reduction	ton/day	1.612	1.606	0.722	0.742	0.889	0.864
	$/day	10,797	10,762	4,840	4,973	5,957	5,789
CO Reduction	ton/day	18.100	18.041	8.114	8.337	9.986	9.704
	$/day	115,115	114,740	51,606	53,020	63,509	61,720
NO Reduction	ton/day	0.772	0.769	0.346	0.355	0.426	0.414
	$/day	9,937	9,904	4,455	4,577	5,482	5,328
Total	$/day	**135,849**	135,407	**60,901**	62,570	**74,948**	72,837

As shown in Table 5.3, the time delay reduction for the Washington region in year 2004 was 55,262 hours/day, slightly less than that of 56,776 hours/day in year 2003. The delay reduction for the Baltimore region has increased from 66,092 hours/day in year 2003 to 68,008 hours/day in year 2004. The reduction in emissions for the Washington region was $60,901/day, lower than that of $62,570/day in the previous year. For the Baltimore region, the emissions reduction was $74,948/day in year 2004, compared to $72,837/day in year 2003.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on our previous research results and experience, this study has performed a rigorous evaluation of CHART's performance in year 2004 and outlined the resulting benefits due to its operations under the constraints of data availability and quality. Overall, CHART has made significant progress in recording reliable incident reports, especially after the implementations of the CHART-II Database, although there is room for improvement to reliably capture all associated benefits.

CHART's efficiency in responding to and managing incidents has also been maintained at a relatively stable level. For instance, the average response time was 11.38 minutes in the year 2004, which is at about the same level as (11.50 minutes) in year 2003. The total aggregate benefits due to CHART operations in year 2004 have also remained at the same level as in the year 2003.

In summary, CHART's operations by MSHA in the year 2004 have yielded significant benefits in the areas of assistance to drivers, and in the reduction in delay time, fuel consumption, as well as emissions. More indirect benefits could be estimated if essential data regarding traffic conditions before and after incidents were collected during each operation. Such benefits include all impacts associated with secondary incidents, potential impacts on neighboring surface streets during incidents, and reduction in the overall stress to drivers in major commuting corridors. In addition, an in-depth analysis of the nature of incidents and their spatial distribution may offer some insightful information for developing safety-improvement measures.

6.2 Recommendations and Further Development

The primary recommendations based on CHART's 2004 performance are summarized below:

- Provide feedback on CHART's performance evaluation to CHART operators so that they can improve their performance on response operations.
- Train operators to effectively record all essential operations-related data such as incident cleared time, response unit arrival time and lane-blockage type.
- Improve the data structure used in the CHART-II system for recording incident location since the current narrative text format requires a laborious manual search and input of associated highway segments.
- Improve the use of freeway service patrols and dynamically assign their locations based on both the spatial distribution of incidents along freeway segments and the probability of having incidents at different times of day to reduce the average response time.
- Efficiently integrate the CHART incident response database with police accident data in order to capture a more comprehensive view of statewide incident records.
- Include the benefits of reduced time delay and fuel consumption due to a potential reduction in secondary incidents in the CHART 2005 evaluation.

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