Performance Evaluation

of

CHART

-The Real-Time Incident Management System-

Year 2001

(Draft Final Report)

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PERFORMANCE EVALUATION OF CHART 2001
THE REAL-TIME INCIDENT MANAGEMENT SYSTEM

LIST OF TERMS AND ABBREVIATIONS

0-9

10-46 – Incident code - Assistance to Driver
10-50 – Incident code - Minor Incident / Accident

A

AOC – Authority Operations Center
Arrival Time – Time when the response unit arrived to the scene
ATM – Asynchronous Transport Mode
ATMS – Advanced Transportation Management System
AVCM – ATM Video Control Manager
AVL – Automated Vehicle Location

B

BWI – Baltimore/Washington International Airport

C

C2IOC – CHART 2 Interim Operational Capability
CCTV – Closed Circuit Television
CHART – Coordinated Highways Action Response Team
Cleared Time – Time when the scene is cleared and normal traffic conditions are restored
COTS – Commercial Off-the-Shelf
CPOC – CHART Proof of Concept

D

DBM – Maryland Department of Budget and Management
DGS – Maryland Department of General Services

E

EOC – Emergency Operations Center
EORS – Emergency Operations Reporting System
ERU – Emergency Response Unit
ETP – Emergency Traffic Patrol

F

FITM – Freeway Incident Traffic Management
FMS – Field Management Station
FPU – Field Processing Unit

G

GIS – Geographic Information System
GUI – Graphical User Interface

H

HAR – Highway Advisory Radio

I

IEN – Information Exchange Network
IDT – Incident Duration Time
IOTC – Interim Operational Telecommunications Capability
ISP – Information Service Provider
ITS – Intelligent Transportation System

M

MDOT – Maryland Department of Transportation
MSHA – Maryland State Highway Administration
MdTA – Maryland Transportation Authority
MSP – Maryland State Police

N

NOVA – Northern Virginia Traffic Management System
NTSC – National Television Standards Committee

O

OOTS – Office of Traffic and Safety

P

PC – Personal Computer

R

RGB – Red, Green, Blue (computer graphics display)
Received Time – Time when the information on incident occurrence was received by the operator
Response Time – Time period between receiving information on incident and arrival of response unit on the scene

S

SNMP – Simple Network Management Protocol
SOC – Statewide Operations Center
SONNET – Synchronous Optical Network
SQL – Structured Query Language

T

TAR – Travelers Advisory Radio
TAT – Travelers Advisory Telephone
TOC – Traffic Operations Center

U

UMD – University of Maryland at College Park

V

VMS (DMS/CMS) – Variable Message Sign (Dynamic/Changeable Message Sign)

W

WWW – World Wide Web

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EXECUTIVE SUMMARY

- **Objectives**

This report presents the performance evaluation results of CHART in Year 2001, including both operations efficiency and the resulting benefits. This is part of the annual CHART performance review conducted by the Civil Engineering Department of The University of Maryland at College Park and MSHA staff 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 data available in the Year 2001 CHART incident operations record. 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 incident management data or derived with reliable statistical methods.

- **Available Data for Analysis**

In Year 1996, an evaluation study with respect to the incident response system of CHART was conducted by COMSIS (COMSIS, 1996). In performing the evaluation, the Year 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 information from other states or from nationwide average data 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 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 all 12 months' incident management reports from the SOC, TOC-3 (located in the proximity of the Capital Beltway), and TOC-4 (located near the Baltimore Beltway). 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. As an example, the data available for analysis of lane-closure incidents increases from a total of 2,567 reports in the year of 1997 to 9,313 reports in Year 2001. A summary of total emergency response operations that have been documented reliably from the year of 1997 to 2001 is presented below:

	1997	**1999**	**2000**	**2001**
- Incidents only	2,567	5,000	8,687	9,313
- Total	2,750	27,987	34,891	26,008

Note that the dataset available in the Year 1997 evaluation did not reflect the actual number of incident operations managed by CHART. It was mainly for a pilot study and served as the basis for subsequent evaluation analyses. Also 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 is expected to diminish after the operation of 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 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 one new subject, 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 estimated reliably and reported to the general public as well as policymakers.

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. Hence, Chapter 2 of this report is devoted to the following two vital subjects: the procedures to construct an emergency response report for each recorded incident and driver assistance request from CHART-II database, and the data quality of each critical performance-related variable. Overall, the quality of available data for evaluation has been improved significantly since the operation of CHART-II system. The efforts needed for performing the evaluation, however, have not been reduced, 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 analyses of incident characteristics by the blockage frequency, duration, and blocked lanes.

With respect to severe incidents, the analysis results indicate that in Year 2001 there were a total of **2,357** incidents resulting in one-lane blockage, **1,407** incidents causing two-lane closures, and about **835** incidents blocking more than two lanes. In addition, there were a total of 16,555 shoulder incidents during the same period due either to disabled vehicles or minor incidents.

Overall, the incidents, including shoulder-lane blockages, on freeways were mostly distributed along four major commuting corridors: I-495/95 experienced a total of **9,524** incidents; and I-695, I-270, and I-95 had **5,165**, **1,277,** and **2,296** incidents, respectively. Thus, CHART had managed, on average, **26** emergency response requests per day on I-495/95 alone, and **14**, **3**, and **6** responses along the other three main commuting freeways.

It should be mentioned, however, that most incidents on major commuting freeways did not block traffic for more than one hour. For instance, **about 96.8** percent of incidents responded to by TOC-3 in Year 2001 were recovered in less than 30 minutes. A similar pattern exists in the TOC-4 data, where about **95.5** percent of incidents had the duration, less than one hour. This could be attributed to both the nature of the incidents and, more likely, the efficient response of CHART emergency operations units.

Note that in comparison with other highways, drivers on I-495/95 clearly suffered from a higher frequency of long incident blockage than others. In the year 2001, there were a total of 203 incidents on I-495/95 covered by TOC-3 lasting over one hour, and 55 of those blocked traffic for more than 2 hours.

In brief, it is clear that the highway network covered by CHART remain plagued by a 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-495/95, 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 the incident site. The Year 2001 data indicated that on average it took **13.90 minutes** for the TOC-3, **14.53 minutes** for TOC-4, and **13.70 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 3 years:

Response time (min)	1999	2000	2001
TOC-3	16.95	14.96	13.90
TOC-4	NA	15.43	14.53
SOC	17.00	19.14	13.70
Average	**16.95**	**15.22**	**13.84**

To understand the contribution of the incident management program, this study has computed and compared the average incident clearance time of responded and non-responded incidents. For instance, for those two-lane-blockage incidents SHA patrol did not respond to, the average operation time was about **69 minutes**, significantly longer than the average of **32 minutes** for the same type of two-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 **29 minutes** and **51 minutes**, respectively. Thus, based on the available record in Year 2001, the operations of CHART/SHA resulted in about a **43** percent reduction of the average incident duration. The performance improvement of CHART/SHA from the year 1997 to 2001 is summarized below:

	with CHART (min)	without CHART (min)
1997	45	68
1999	42	93
2000	33	77
2001	29	51

- **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 2001 responded to a total of **9,313** lane blockage incidents, and provided **assistance to 16,274 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 **766** secondary incidents. In addition, efficient removals of stationary vehicles or large debris on travel lanes by CHART patrol units may have prevented **379** potential lane-changing-related collisions in Year 2001, 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 2001 resulted in a total delay time reduction of **25.80 million vehicle-hours,** and a total fuel consumption reduction of approximately **4.35 million gallons**.

- **Recommendations**

The primary recommendations based on the performance of CHART in Year 2001 are summarized below:

- *Training operators to effectively record all essential operations-related data such as cleared time.*

- *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 laborious manual search and input of associated highway segments.*

- *Developing an integrated performance database that consists not only of incident reports but of all data, such as traffic volume, needed for direct benefit computation or estimation of safety-related contribution, including potential reduction in secondary incidents and lane-changing-related accidents due to a quick removal of stationary vehicles or some debris on highway travel lanes.*

- *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 as expected.*

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/).

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CHAPTER 1: INTRODUCTION

1.1 Background

CHART (Coordinated Highways Action Response Team) is the highway incident management program of the Maryland State Highway Administration. Initiated in the mid 80's as "Reach the Beach," it has been extended to a statewide program headquartered in Hanover, Maryland, where the integrated Statewide Operations Center (SOC) is located. The SOC is also supported by three satellite traffic operations centers (TOC), one being seasonal. Most of the field operations of CHART are also supported by the maintenance units. The current network covered by CHART consists of both statewide freeways and major arterials.

CHART comprises 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 increasing attention from the general public, media, and transportation professionals.

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

1.2 Available Data for Performance Evaluation

In Year 1996, an evaluation study with respect to the incident response system of CHART was conducted by COMSIS (COMSIS, 1996). In performing the evaluation, the Year 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 information from other states or from nationwide average data 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 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.

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1.3 Evaluation Methodology

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

Task 1: Assessing Data Sources and Data quality

- Identifying the sources of the data and evaluating their quality
- Analyzing available data and classifying missing parameters

Task 2: Statistical Analysis and Comparison

- Performing the comparison based on the data available in Year 2000 and Year 2001 with emphasis on the following target areas:
    - Incident characteristics
    - Incident detection efficiency
    - Distribution of detection sources

- Incident response efficiency
- Effectiveness of incident traffic management

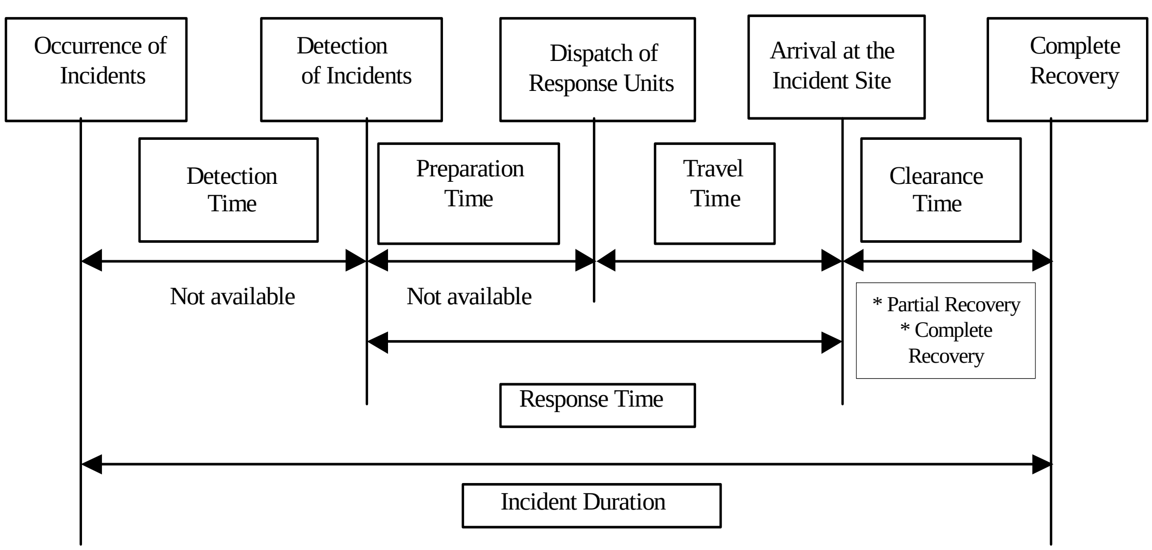
Task 3: Benefit Analysis

- Reduction in total delay time due to CHART/SHA operations
- Reduction in fuel consumption due to CHART/SHA operations
- Reduction in total emissions due to CHART/SHA operations
- Reduction in secondary incidents due to CHART/SHA operations
- Reduction in potential accidents due to the efficient removal of stationary vehicles in travel lanes by CHART/SHA response team

Note that the above tasks do not include the estimation of some indirect impacts such as the reduction in travel time and fuel savings from potentially reduced secondary incidents, the associated medical and legal costs, and improvement of the commuting environment. This is understandably due to the fact that most of such data are not available at that 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 MSHA in identifying and collecting additional critical data for future analysis.

Figure 1.1 lays out the major parameters necessary for evaluating the effectiveness and efficiency of an incident management system. It should be mentioned that in most cases the incident occurrence time is not available, the exception being those detected by CCTV. Another parameter that is difficult to measure is the preparation time – the time period between detection of an incident and dispatch of the response units. Thus, this evaluation does not include the efficiency of incident detection and response preparation.

Figure 1.1 Graphical Illustration of Technical Terms Associated with Incident Operations



1.4 Literature Review

Despite the increasing investment in incident management by most state highway agencies, comprehensive evaluations for assessing the effectiveness of such programs are not available in the literature. 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, nor did they compare the incident duration with and without the response of an incident management system. Public opinion and personnel input from relevant agencies were collected to estimate the perceived benefits.

Cuciti et al. (1993) performed an evaluation of the 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, and comparison of alternative service delivery modes and their impacts on traffic conditions. However, it did not include the estimation of such direct and indirect benefits 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 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 the active level, i.e., actually performing the evaluation.

Along the same lines, Karimi et al. (1993) pointed out four important elements of the incident management system for Santa Monica Smart Corridor, those being detection, verification, response, and monitoring. They proposed that response plans must be dynamic to reflect the evolving characteristics of the incident. To do so, an 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 an 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 operation, 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, 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 consumption were converted to monetary benefits. They also measured the average time-savings for vehicles assisted by freeway service patrol.

CHART/SHA since Year 1997 has emerged as one of the primary agencies consistently performing its performance evaluation and identifying areas of operations improvement. 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 records from CHART and accident reports from the state police office (Chang and Point-du-Jour, 1998). 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 evaluation for the Year 1997 CHART performance (Chang and Point-du-Jour, 2000) had the advantage of receiving relatively rich information. Also, the 1997 accident reports were provided by Maryland State Police for secondary incident analyses. The data set for the Year 1999 and Year 2000 evaluation (Chang and Point-du-Jour, 2000, 2001) had increased substantially as CHART had started to record its own emergency response operations from Year 1999, including not only major incidents involving the police and other support units in its *extensive incident reports* (named Long forms) as in previous years, but also those incidents or driver assistance handled by SHA alone in *concise incident reports* (named Short forms).

CHAPTER 2: DATA QUALITY FOR THE EVALUATION STUDY

This chapter presents the data quality available for the CHART 2001 performance evaluation study, including a comparison with the data from the same study in Year 2000. The analysis and comparison will be focused on the following two aspects:

1. Available data for analysis: In the year 2001, CHART performance evaluation study received a total of 26,008 reports. A small part of this data (2,029 reports), which was reported in January and early February, was in the same paper form as in the year 2000. The remaining 23,979 reports collected since mid-February of Year 2001 were obtained from the CHART II Database.

A more detailed analysis on data availability will be given in Section 2.1. Also provided is a brief illustration of the data processing procedures that have been implemented to construct incident reports for the new CHART II system.

2. A detailed data quality analysis: To ensure the quality of the evaluation results, a detailed analysis with respect to each critical information item is provided in Section 2.2. Because the newly introduced CHART II Database will be the sole data for evaluation of performance in Year 2002 and subsequent years, the chapter has extended the analysis to review the data quality improvement since the application of the CHART II system.

2.1 Data Availability and Data Processing Procedures

In the year 2001, CHART performance evaluation study received a total of 26,008 emergency response reports for analysis. A small part of the data (i.e., 2,029 reports), recorded in the January and early February, was in the same paper form as used in previous years. Among these, a total of 1,763 reports including either minor traffic blockages or assistance requests from drivers, were recorded in concise short forms. The remaining 266 reports concerning mainly major traffic blockages were reported with extensive long forms.

A total of 23,979 emergency response reports in Year 2001 were constructed from the information in the CHART II Database. These reports covered either incidents or disabled vehicles from mid-February to the end of Year 2001.

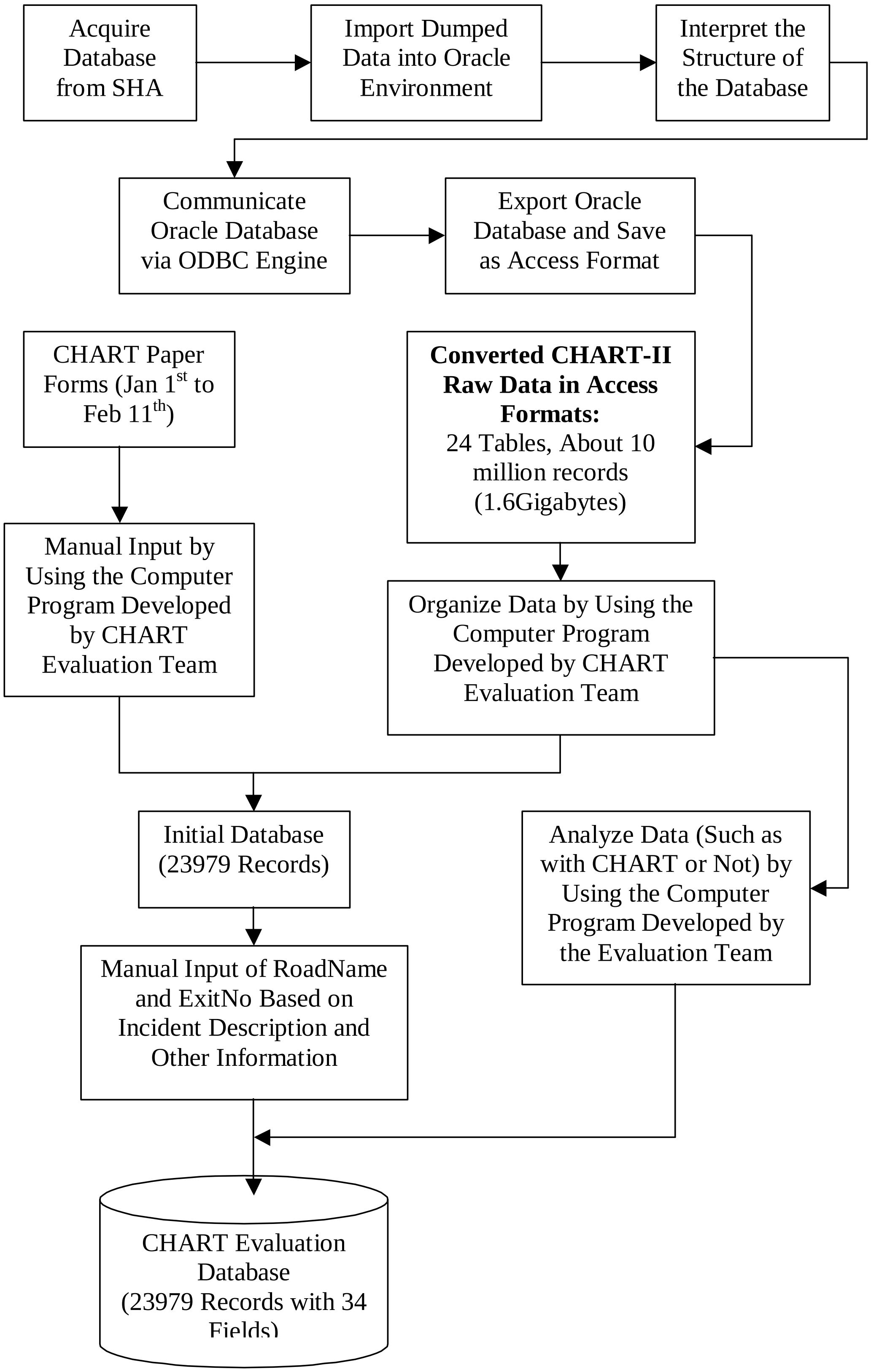
A summary of a total available data for performance evaluation in Year 2001 and Year 2000 is shown in Table 2.1.

Table 2.1 Comparison of Available Data between Year 2001 and Year 2000

Available Records		Year 2001		Year 2000	
		No. of Rec.	% of total	No. of Rec.	% of total
CHART II Database		23,979	92.2	---	---
Paper Form	Short Form	1,763	6.8	32,440	93.0
	Long Form	266	1.0	2,451	7.0
Total		26,008	100	34,891	100

Since the available data for CHART 2001 performance evaluation were collected in different data formats, the research team has developed and implemented preprocessing procedures to convert both the paper forms and the new CHART II Database into a consistent format for analysis. A flowchart illustrating the data processing procedures is shown in Figure 2.1.

Figure 2.1 Data Processing Procedure



2.2 Comparison of Key Performance-Related Data

A detailed evaluation of data quality with respect to the following information items is presented in sequence in this section:

- Detection source of incidents/disabled vehicles
- Type of reports (i.e., incident or disabled vehicle)
- Nature of incidents/disabled vehicles
- Road name of incident/disabled vehicle sites
- Location of incidents/disabled vehicles
- Lanes/shoulder blocked by incidents
- Received/confirmed time of incidents/disabled vehicle requests
- Dispatched/arrival time of response units
- Incident/disabled vehicle request cleared time

Figures 2.2 and 2.3 illustrate the data quality of all available reports with respect to the above critical indicators for the CHART performance evaluation in Year 2000 and Year 2001.

Figure 2.2 Summary of Data Quality Based on All Available Reports

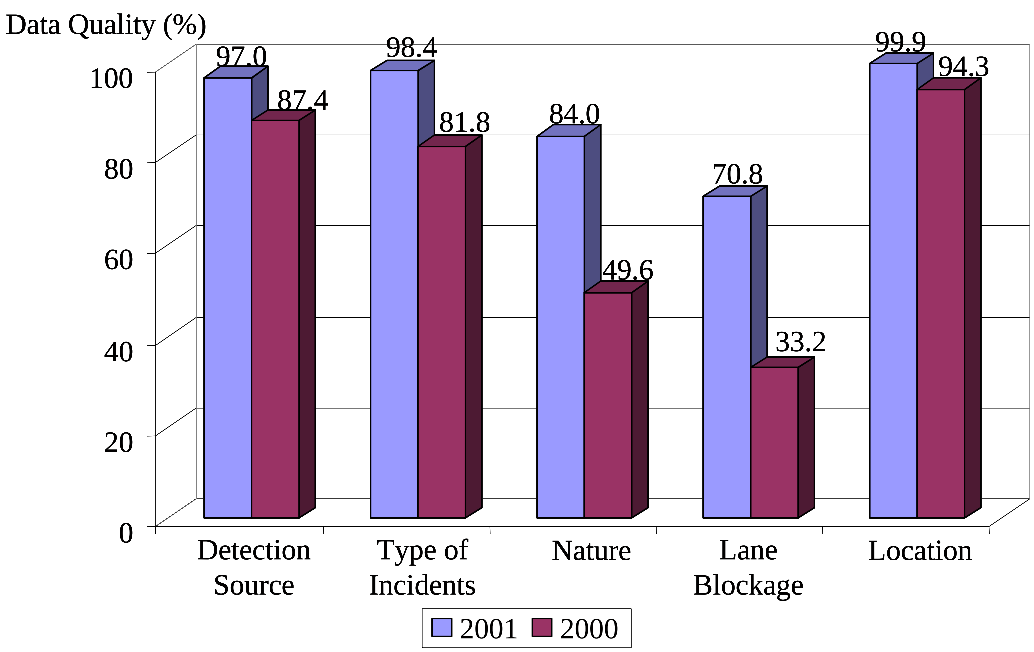
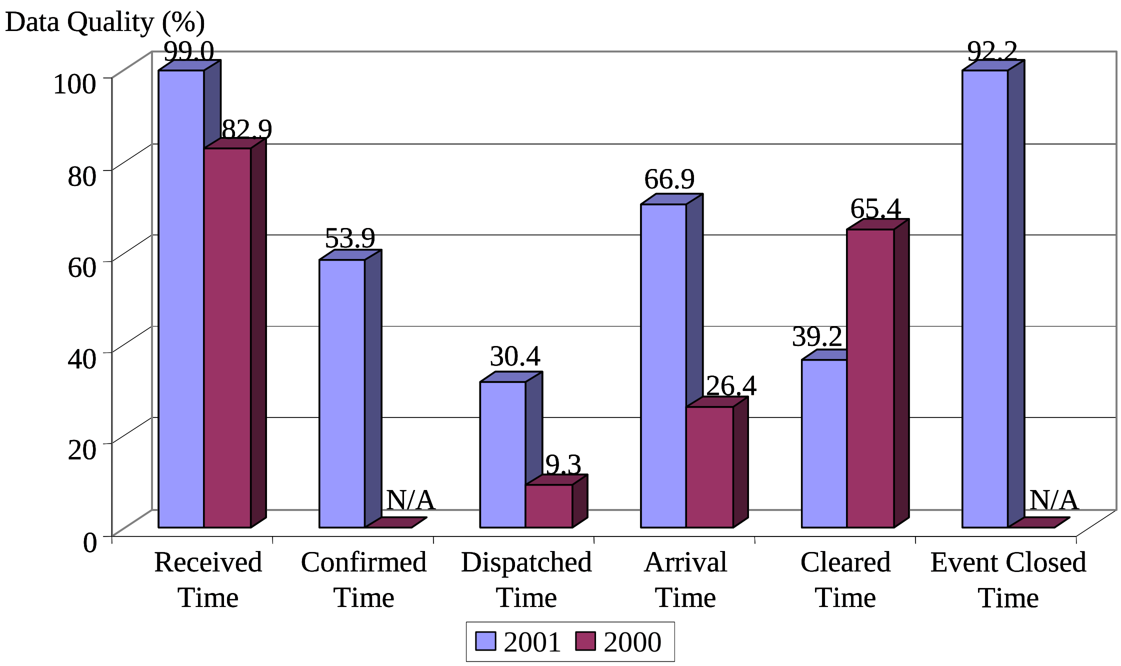


Figure 2.3 Summary of Data Quality Based on All Available Reports (Cont.)



<u>Detection Source</u>

The detection source is necessary to evaluate the effectiveness of various available detection means. As shown in Figure 2.2, about 97.0% of all the reports in Year 2001 contain this vital information, reflecting a substantial improvement over 87.4% in Year 2000.

Table 2.2 shows the percentages of reports in CHART II Database that clearly indicated the detection source, including those for incidents and disabled vehicles. About 97.0% of the reports in CHART II Database in Year 2001 contain the detection source information, about the same level as in the overall data set.

Table 2.2 Data Quality Analysis with Respect to Detection Source in Year 2001

Data Quality	CHART II Database			All Data
Detection Source	Incident	Disabled Vehicle	Total	Total
	93.2%	99.2%	97.0%	97.0%

<u>Type of Report</u>

The total number of incidents/disabled vehicle requests managed by each operation center during the year 2001 is summarized in Table 2.3.

Table 2.3 Distribution of Emergency Responses by Each Operations Center in Year 2001

Operations Center	Data Type	Disabled Vehicles	Incidents	Unknown	Total
TOC3	Chart II Database	7,455	4,430	–	13,792 (18,544)
	Short Form	1,038	304	421	
	Long Form	–	144	–	
TOC4	Chart II Database	6,408	1,915	–	8,370 (14,271)
	Long Form	–	47	–	
SOC	Chart II Database	315	1,760	–	2,150 (786)
	Long Form	–	75	–	
TOC5	Chart II Database	933	210	–	1,143 (1290)
Other	Chart II Database	125	428	–	553
Total		**16,274** (20,428)	**9,313** (8,687)	**421** (5,776)	**26,008** (34,891)

Note: The numbers in parentheses show the corresponding data from Year 2000

The incident/disabled vehicle reports provided by CHART in Year 2001 cover a total of 9,313 incidents over the entire year, including both major incidents and minor incidents. Over the same period, 16,274 reports were associated with disabled vehicle requests, which bring the total percentage of reports with valid type information up to 98.4%.

As to those reported in a paper form during January and February of Year 2001, there are a total of 266 extensive incident reports for major incidents that involved police and other CHART response units (in long forms) and a total of 1,763 concise incident reports (in short forms). Note that the latter includes both driver assistance with the response code of 1046 and minor incidents with the response code of 1050.

The CHART II Database classifies all records into two types, namely, incidents and disabled vehicles/driver assistance. However, major incidents and minor incidents are not distinguished in the CHART II Database. According to this classification, the CHART II Database includes 8,743 incidents for both major and minor incidents, and 15,236 driver assistance requests.

Nature of Incidents/Disabled Vehicles

This field of data can be used to classify the nature of incidents, which include vehicle on fire, debris in roadway, collision-personal injury, collision-property damage, collision-fatality, disabled on road, emergency roadwork, police activity, off-road activity, and other. The reports for disabled vehicles actually cover all the following emergency response operations: abandoned vehicle, tire change, hot shot, water shortage, gas shortage, directions, own disposition, call for service, relay operators, gone on arrival, and others.

As shown in Figure 2.2, it has been found that about 84.0 percent of emergency response reports in the year 2001 indicated the nature of operations. Compared with only 49.6 percent in Year 2000 and only 29 percent in Year 1999, CHART has sustained its improvement in this regard.

Table 2.4 shows the percentage of data with valid nature information for incidents, disabled vehicles, and total reports in CHART II Database. In the CHART II Database, up to 88.9 percent provided the information about the nature. Compared with 84.0 percent in the total available data set, CHART II Database has exhibited some improvement on this information item over the traditional paper forms.

Table 2.4 Data Quality Analysis with Respect to Nature in Year 2001

Data Quality	CHART II Database			All Data
	Incident	Disabled Vehicle	Total	Total
Nature	79.7%	94.1%	88.9%	84.0%

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 2.2, about 99.9 percent of data have valid location information, slightly higher than 94.3 percent in Year 2000.

Overall, all emergency response reports in the CHART II Database indicate the location of incidents or disabled vehicles. However, this location information associated with each response operation is structured in a descriptive text format that cannot be processed automatically with a computer program. Some examples of such location information are reported as *"GOODLUCK ROAD"* or *"BW PARKWAY/MD 212."* Hence, the research team members have to manually perform the following activities:

- Manually search the name of a highway segment that covers a reported location for an incident/disabled vehicle

- Manually input these locations and road names into a database, so that one can perform the analysis of incident distributions on each highway

Note that with the best effects we can manage, only 88.9% of highway segments that contain incident locations reported in the year 2001 CHART II Database can be identified. The remaining 11.1% of incident locations, either unclear or not specific, cannot be used for a reliable performance analysis.

Table 2.5 shows the percentage of data with valid location information or road information for incidents and disabled vehicles in the CHART II Database.

Table 2.5 Data Quality Analysis with Respect to Road and Location in Year 2001

Data Quality	CHART II Database			All Data
	Incident	Disabled Vehicle	Total	Total
Location	100.0%	100.0%	100.0%	99.9%
Road	79.2%	94.5%	88.9%	89.1%

Lane/Shoulder Blockage Information

The information regarding the number of lanes or shoulder lanes being blocked is essential for computation of additional delay and fuel consumption due to incidents. Analysis on all available data in Year 2001 shows that up to 70.8 percent of available emergency response reports provided the lane/shoulder blockage information, substantially higher than 33.2 percent in Year 2000 and 26.6 percent in the year 1999.

Table 2.6 shows the percentage of data with valid lane/shoulder blockage information for incidents, disabled vehicles, and total reports in the CHART II Database. About 70.6 percent of available incidents in CHART II Database in Year 2001 provided the lane/shoulder blockage information. Note that because of the lack of lane-blockage information in disabled vehicle reports, they all are classified as shoulder lane blockages in the ensuing analysis.

Table 2.6 Data Quality Analysis with Respect to Lane/Shoulder Blockage in Year 2001

Data Quality	CHART II Database			All Data
	Incident	Disabled Vehicle	Total	Total
Blockage	70.6%	N/A	70.6%	70.8%

Operational Time-Related Information

To evaluate the efficiency and effectiveness of emergency response operations, CHART 2001 used the following six time parameters for performance measurement: **Received Time**, **Dispatched Time**, **Arrival Time**, **Cleared Time**, **Confirmed Time**, and **Event Closed Time**. Among those time parameters, two new time parameters, **Confirmed Time** and **Event Closed Time,** have been introduced in the CHART II Database. The "confirmed time" is defined as the time when the incident/disabled vehicle is confirmed, and the "event closed time" is the time when the event (i.e., incident/disable vehicle) is closed. It is not the actual time when the lane blockage is cleared.

The data quality analysis with respect to these six performance parameters is illustrated in Figure 2.3, which indicates that the data quality for Received Time and Event Closed Time is sufficient for a reliable analysis. The data quality with respect to Dispatched Time and Arrival Time also shows a significant improvement over these reported in Year 2000. As to the quality of cleared time, it has been documented in 39.2 percent of the total available reports, much less than 65.4 percent in Year 2000. This may be attributed, in part, to the introduction of the "event closed time" in the CHART II Database.

Table 2.7 shows the percentage of data with valid time information for incidents and disabled vehicles in the CHART II Database. Overall, except for the cleared time, the application of the CHART II Database has improved the quality of available data.

Table 2.7 Data Quality Analysis with Respect to Time in Year 2001

Data Quality	CHART II Database			All Data
	Incident	Disabled Vehicle	Total	Total
Received Time	100.0%	100.0%	100.0%	99.0%
Confirmed Time	53.5%	61.2%	58.4%	53.9%
Dispatched Time	48.8%	22.0%	31.8%	30.4%
Arrival Time	66.7%	73.1%	70.7%	66.9%
Cleared Time	31.3%	39.7%	36.6%	39.2%
Event Closed Time	100.0%	100.0%	100.0%	100.0%

In summary, CHART staff have made significant progress in documenting its performance and keeping incident-operations-related information in Year 2001. The use of the CHART II Database for Year 2001 has an obvious positive impact on data quality improvement. But much remains to be improved, 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 environments of the highway networks would not be underestimated if only more quality data were available for analysis and for justifying the resulting benefits.

CHAPTER 3: ANALYSIS OF DATA CHARACTERISTICS

To improve both incident management and traffic safety, the evaluation work starts with a comprehensive analysis of the spatial distribution of incidents/disabled vehicles and their key characteristics, which are

- Distribution of incidents/disabled vehicles by weekday and weekend
- Distribution of incidents/disabled vehicles by peak and off-peak hours
- Distribution of incidents/disabled vehicles by road
- Distribution of incidents/disabled vehicles by location
- Distribution of incidents/disabled vehicles by lane blockage
- Distribution of incidents/disabled vehicles by blockage duration

With the above information, one can certainly better design the incident management strategies, including distributing 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.

3.1 Distribution of Incidents and Disabled Vehicles by Weekday and Weekend, and by Peak and Off-Peak Hours

This study has analyzed the distribution of incidents/disabled vehicles between weekdays and weekends. As shown in Table 3.1, most incidents/disabled vehicles (about 94%) occurred on weekdays. Thus, more resources and manpower are needed on weekdays than on weekends to manage those incidents/disabled vehicles effectively. The patrol vehicles, response units, and operators in the control center may be reduced during weekends so as to minimize the operating costs of the Program.

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

Center	TOC 3		TOC 4		TOC 5	SOC		Other*	Total	
Year	2001	2000	2001	2000	2001	2001	2000	2001	2001	2000
Weekdays	100%	99%	100%	98%	26%	68%	71%	76%	94%	98%
Weekends	0%	1%	0%	2%	74%	32%	29%	24%	6%	2%

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

As defined in the 1999 CHART evaluation, peak hours in this study were set to be from 7:00 AM to 9:30 AM and from 4:00 PM to 6:30 PM. About 49% of overall incidents/disabled vehicles reported in Year 2001 data set occurred during such congested periods, slightly higher than that of 38% in Year 2000 (see Table 3.2).

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

Center	TOC 3		TOC 4		TOC 5	SOC		Other*	Total	
Year	2001	2000	2001	2000	2001	2001	2000	2001	2001	2000
Peak	53%	37%	59%	41%	15%	25%	9%	20%	49%	38%
Off-Peak	47%	63%	41%	55%	85%	75%	49%	80%	51%	59%
No Info	0%	0%	0%	4%	0%	0%	42%	0%	0%	3%

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

3.2 Distribution of Incidents and Disabled Vehicles by Road

Figures 3.1 and 3.2 present the distribution of incident/disabled vehicles frequency by road, where the distribution of incidents and disabled vehicles for the new CHART II Database is presented in Figure 3.1, and the comparison of the entire record of Year 2001 with Year 2000 is shown in Figure 3.2.

Figure 3.1 Distribution of Incidents/Disabled Vehicles by Road in Year 2001 (CHART II Database)

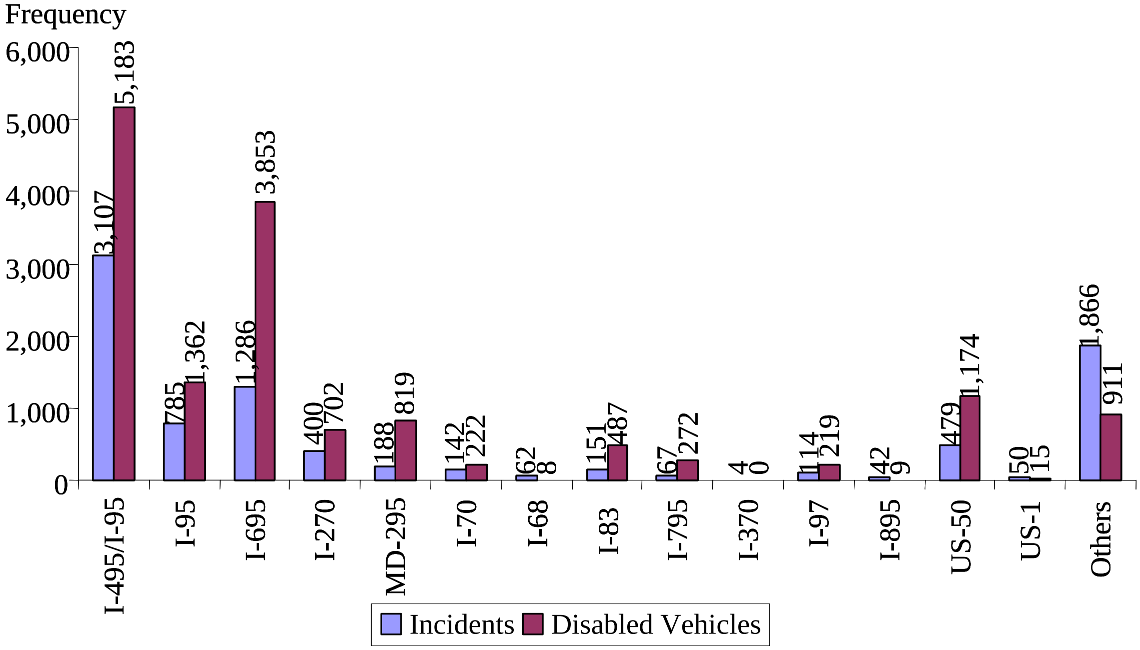
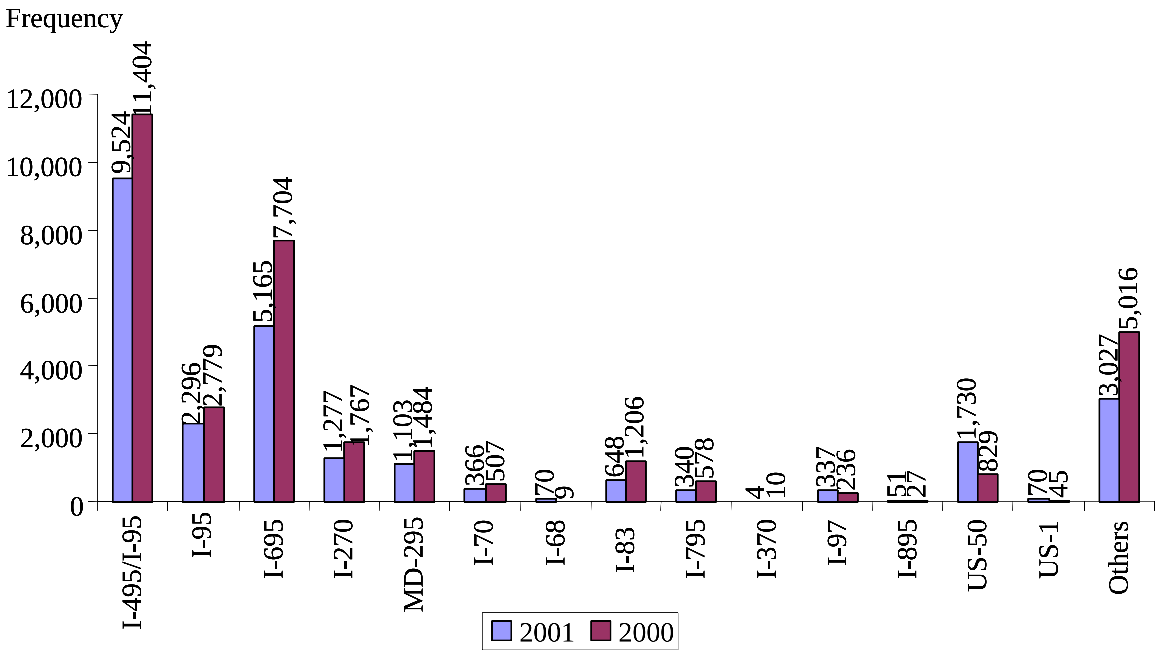


Figure 3.2 Comparison for the Distribution of Incidents/Disabled Vehicles by Road



Based on the statistics in these figures, it is clear that the four major commuting freeways, I-495/95 (Capital Beltway), I-695 (Baltimore Beltway), I-95 (from Delaware border to Capital Beltway), and I-270, had a very large number of incidents/disabled vehicles, significantly higher than all other highways. For example, I-495/95 experienced a total of 9,524 incidents/disabled vehicles in the year of 2001, and I-695 had a total of 5,165 incidents/ disabled vehicles during the same period. I-95 and I-270 were plagued by 2,296 and 1,277 incidents/disabled vehicles, respectively, in Year 2001.

The frequency distribution of incidents/disabled vehicles indicates that CHART responded to about **26** incidents/disabled vehicles per day for I-495/95 alone, about 14 incidents/disabled vehicles per day along I-695; and 6 and 3 incidents/disabled vehicles per day, respectively, for I-95 and I-270. Other major freeways, such as I-70, I-83, I-795, US-50, and MD-295, also experienced a large number of incidents/disabled vehicles during Year 2001.

It should be noted that both I-95 and I-270 are connected to I-495/95, and are the main contributors of traffic congestion on I-495 during daily commuting periods. Because of the high traffic demand on I-495, any incurred incident is likely to have vehicles queued back to both I-95 and I-270, thus causing serious congestion on those two freeways. Such an interdependent nature of incidents between primary commuting freeways should be taken into account in prioritizing and implementing incident management strategies.

Conceivably, contending with such a high frequency of incidents on all those major commuting freeways is a challenging task from either the traffic safety or congestion mitigation perspective. Development of effective strategies to improve both the driving conditions and driver behavior will be regarded as priority tasks. Since those incidents also resulted in lane blockage on congested freeways, all agencies responsible for highway operations and safety ought to take the implementation of an efficient incident management program as one of their priority tasks.

3.3 Distribution of Incidents and Disabled Vehicles by Location

To best allocate patrol vehicles and response units to hazardous highway segments, this study has also analyzed the distribution of incidents/disabled vehicles by location along major freeways. By grouping the total number of incidents and disabled vehicles between two consecutive exits as an indicator, Figure 3.3 presents the geographical distribution of incidents and disabled vehicles on I-495/95 from the Chart II Database. Figure 3.4 illustrates the comparison results between Year 200 and Year 2001 with respect to the total emergency responses, including incidents and disabled vehicles.

Figure 3.3 Distribution of Incidents/Disabled Vehicles by Location on I-495/I-95 in Year 2001 (CHART II Database)

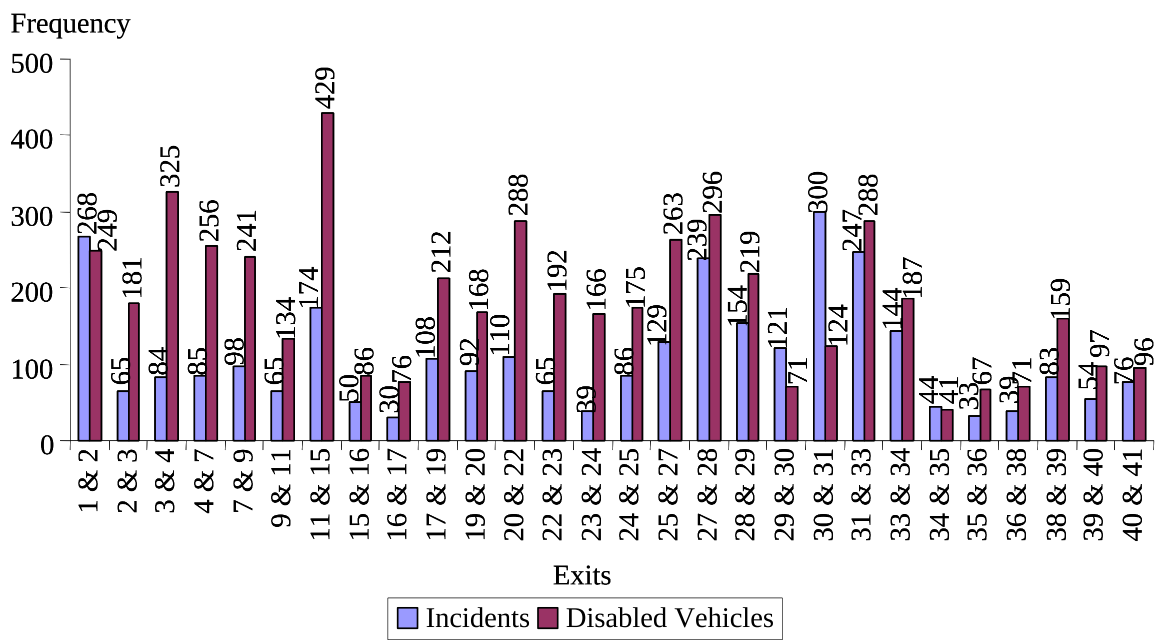
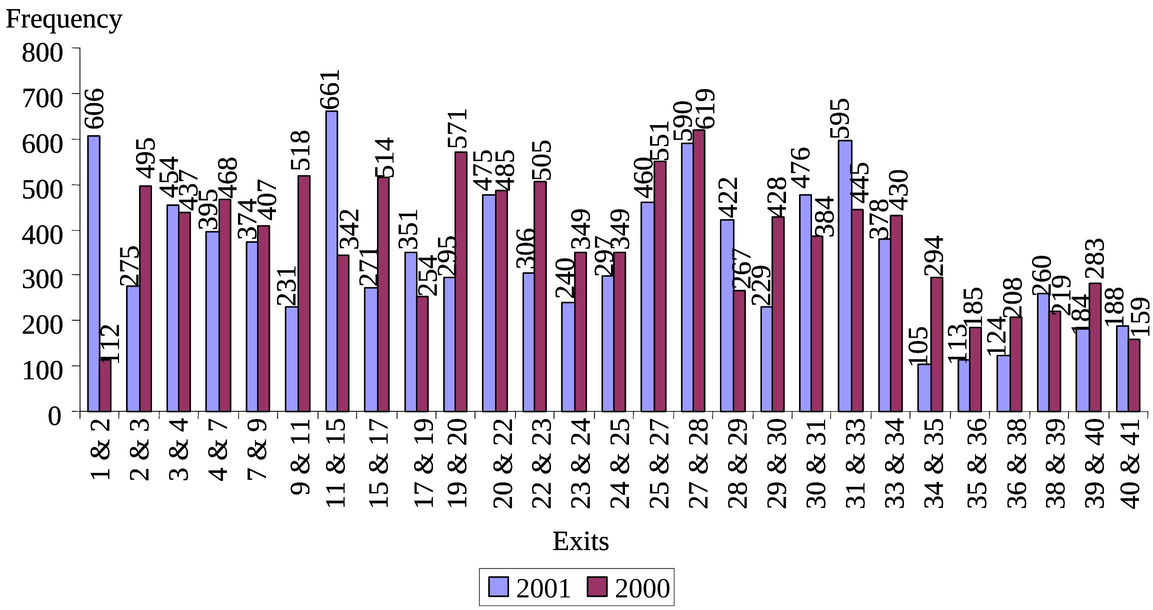


Figure 3.4 Comparison of Incidents/Disabled Vehicles Distribution by Location on I-495/I-95



In Figure 3.3, the highest frequency of incidents (300 cases) occurred between Exit 30 and Exit 31, including the I-495 segment between MD-29 (Colesville Rd.) and MD-97 (Georgia Ave.). On contrast, the location having the highest frequency of disabled vehicles (429 cases) was between Exit 11 and Exit 15, representing the I-495 segment between MD-4 (Pennsylvania Ave.) and MD-214 (Central Ave.).

Figure 3.4 illustrates the spatial distribution of all emergency response operations, including both incidents and disabled vehicles. Notably, the highest frequency (661 cases) in Year 2001 occurred between Exits 11 and 15, representing the I-495 segment between MD-4 (Pennsylvania Ave.) and MD-214 (Central Ave.). Freeway segments between Exits 1 and 2, Exits 27 and 28, and Exits 31 and 33, also experienced a comparable level of incidents/disabled vehicles frequency.

Figures 3.5 presents the distribution of incidents and disabled vehicles by location on I-95 from the Chart II Database. Figure 3.6 compares the distribution of the total incident/disabled vehicle data reported in Year 2001 with that from the Year 2000 data. As shown in Figure 3.5, the highest number of incidents happened between Exit 27 and Exit 29 (129 cases), and between Exit 29 and Exit 33 (130 cases). Both locations are closed to the interchange between I-95 and I-495. The segment between Exits 29 and 33 experienced the highest number of disabled vehicles (256 cases).

Figure 3.5 Distribution of Incidents/Disabled Vehicles by Location on I-95 in Year 2001 (CHART II Database)

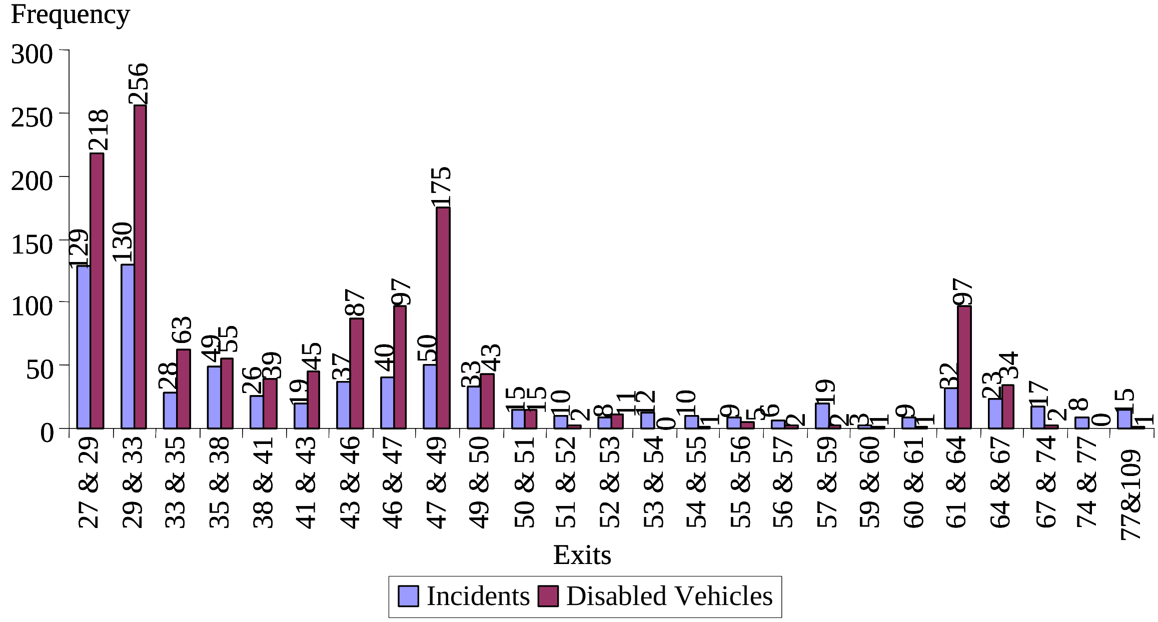
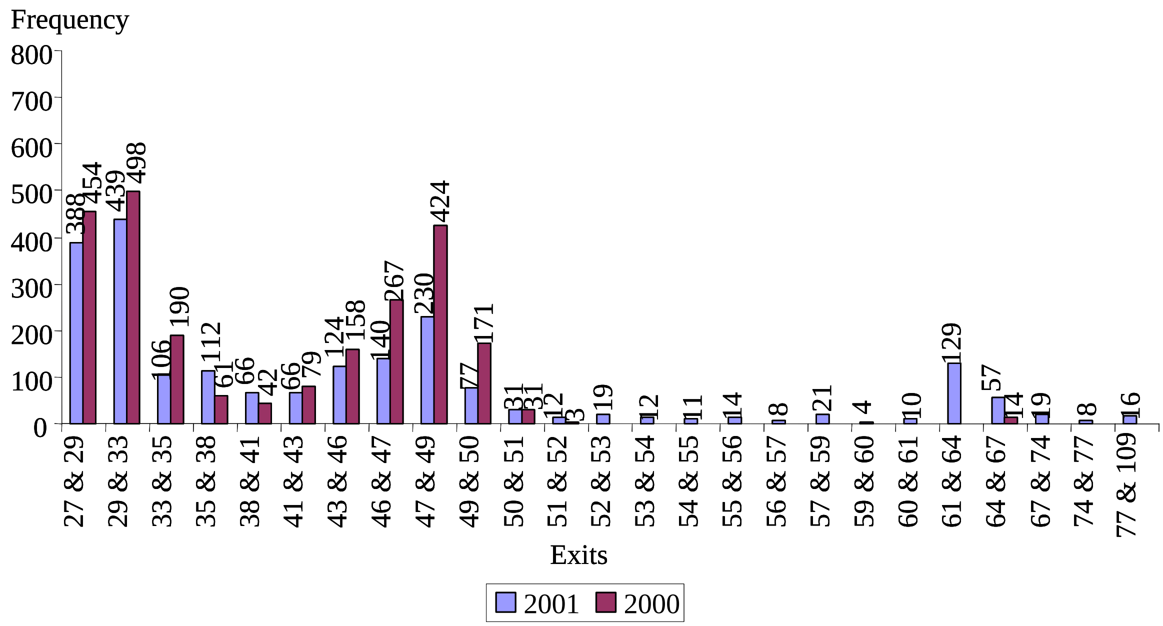


Figure 3.6 Comparison of Incidents/Disabled Vehicles Distribution by Location on I-95



Overall, meaning for both incidents and disabled vehicles, the segment of I-95 between Exits 29 and 33 experienced the highest number of incident responses, and had a total frequency of 439 in Year 2001 compared with 498 in the previous year. The segment near the interchange between I-495 and I-95 had the second largest number of overall incident responses, i.e., 388 in Year 2001 compared with 454 in Year 2000. The segment of I-95 between Exits 47 and 49 (between I-195 and I-695) suffered the third largest number, about 230 emergency requests in Year 2001.

Figure 3.7 represents the same spatial distribution of incidents/disabled vehicles data for Year 2001. The comparison of emergency operation data between Year 2001 and Year 2000 is shown in Figure 3.8. In Figure 3.7, the segment between Exits 1 and 4 on I-270 was recorded to have the highest numbers of incidents and disabled vehicles, being 128 and 195, respectively. In Figure 3.8 as well, the highest frequency occurred between Exit 1 and Exit 4, which is 353 compared with 410 in Year 2000. Overall, the incident/disabled vehicle frequency appears to decrease linearly with its distance from the Capital Beltway.

Figure 3.7 Distribution of Incidents/Disabled Vehicles by Location on I-270 in Year 2001 (CHART II Database)

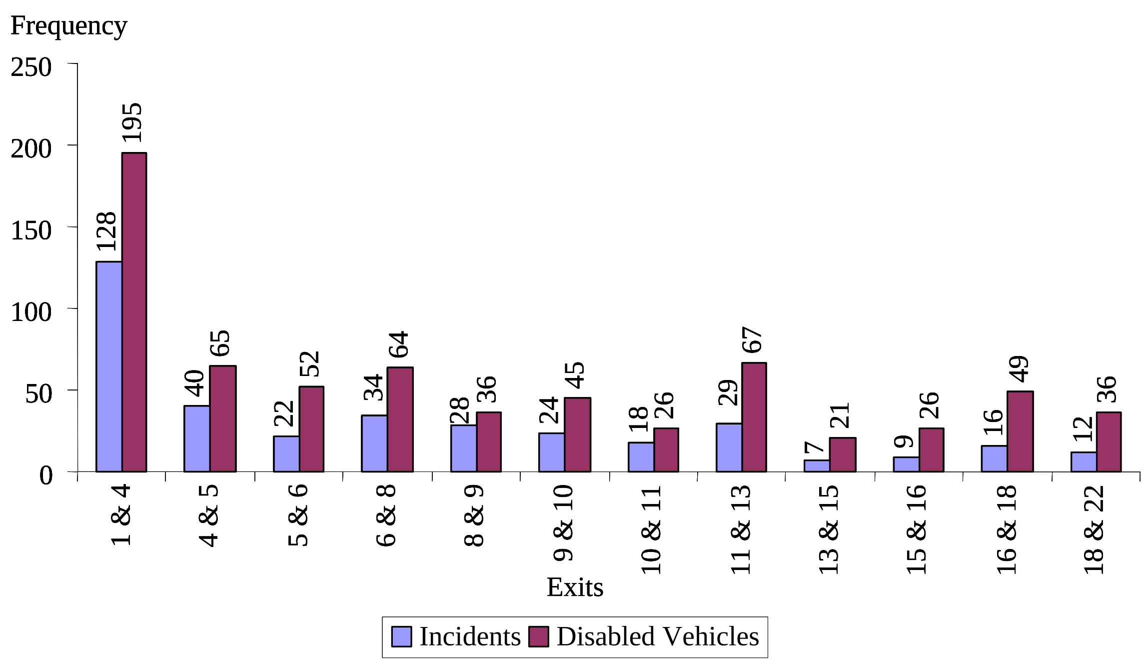


Figure 3.8 Comparison of Incidents/Disabled Vehicles Distribution by Location on I-270

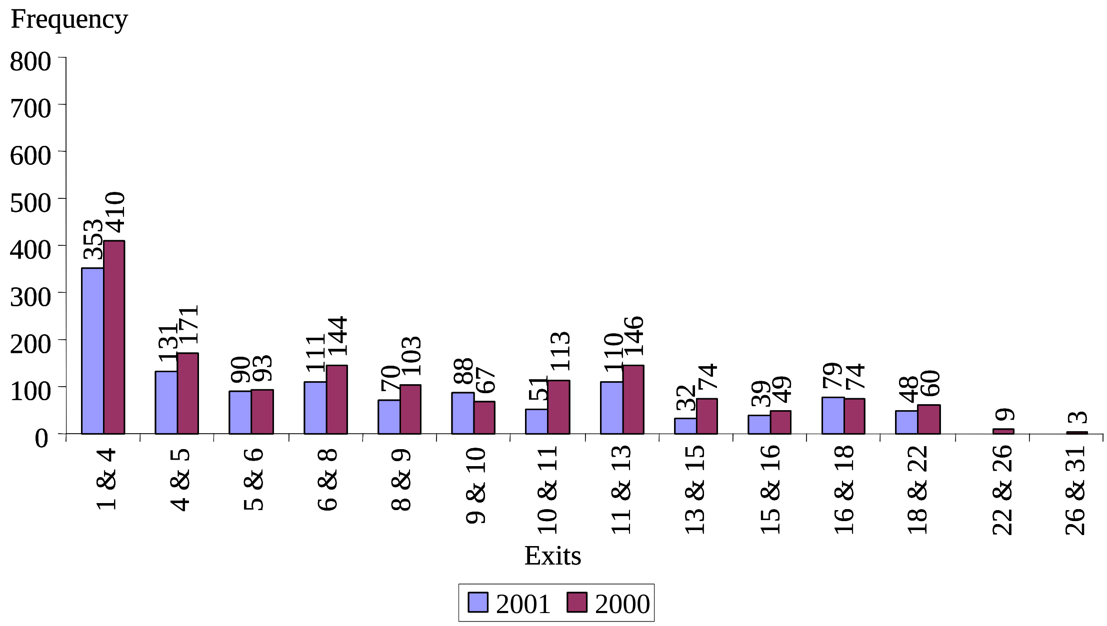


Figure 3.9 shows the distribution of incidents and disabled vehicles by location on I-695 from the Chart II Database in Year 2001, and Figure 3.10 shows the distribution of total incidents/disabled vehicles in Year 2001 and the comparison with Year 2000 results. The high-incident segments, as shown in Figure 3.9, are from Exits 11 and 12 (near I-95) to Exits 23 and 24 (near I-83). In Figure 3.10, the highest frequency (318 cases) is reported to exist on the segment between Exits 17 and 18, near the interchange to I-70. The segments showing the second highest (304 cases) and the third highest frequency are those between Exits 22 and 23 and between Exits 23 and 24, respectively. Both locations are near the interchange to I-83.

Figure 3.9 Distribution of Incidents/Disabled Vehicles by Location on I-695 in Year 2001 (CHART II Database)

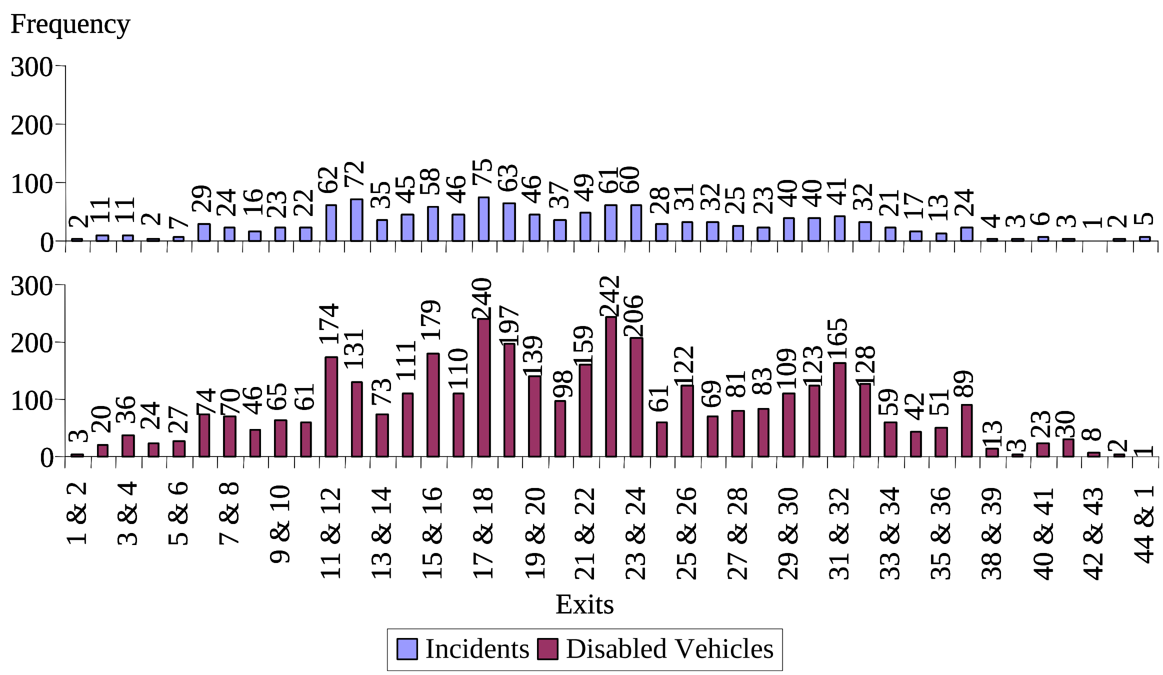
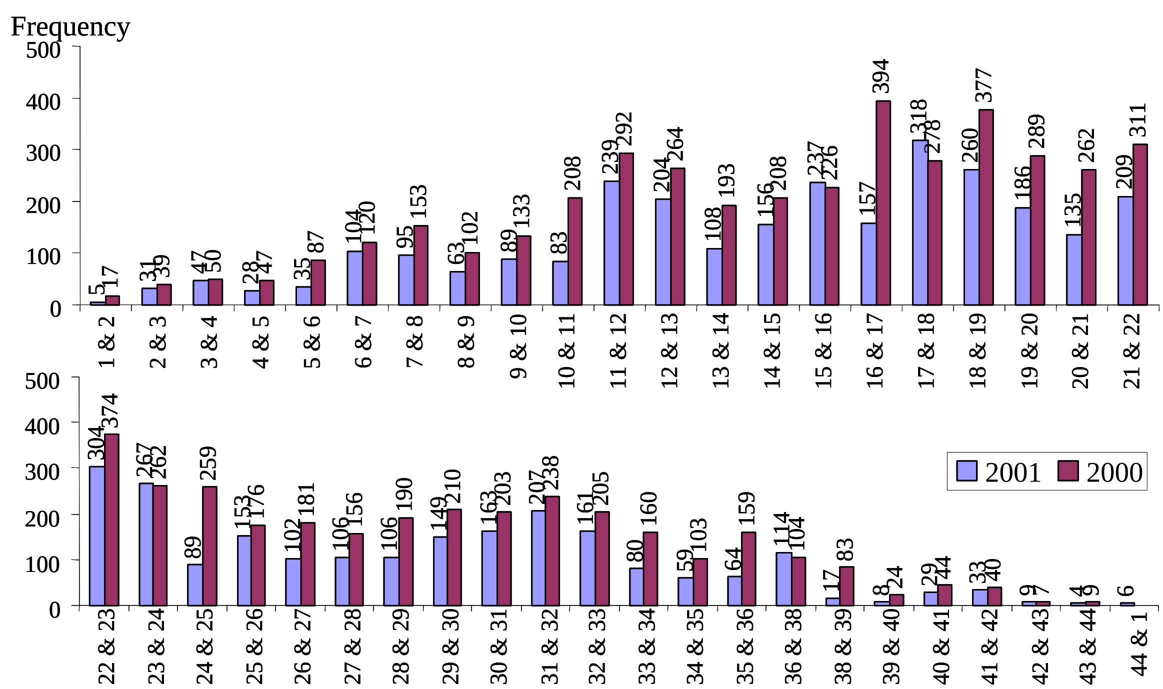


Figure 3.10 Comparison of Incidents/Disabled Vehicles Distribution by Location on I-695



3.4 Distribution of Incidents and Disabled Vehicles by Lane Blockage Type

Figure 3.11 illustrates the distribution of incidents by lane blockage, where most incidents out of 2,214 incidents were one-lane blockage. The overall distribution of incidents and disabled vehicles by lane blockage and the comparison with Year 2000 results is illustrated in Figure 3.12. Note that all reported disabled vehicles in Year 2001 are classified as shoulder lane blockage.

Figure 3.11 Distribution of Incidents by Lane Blockage in Year 2001 (CHART II Database)

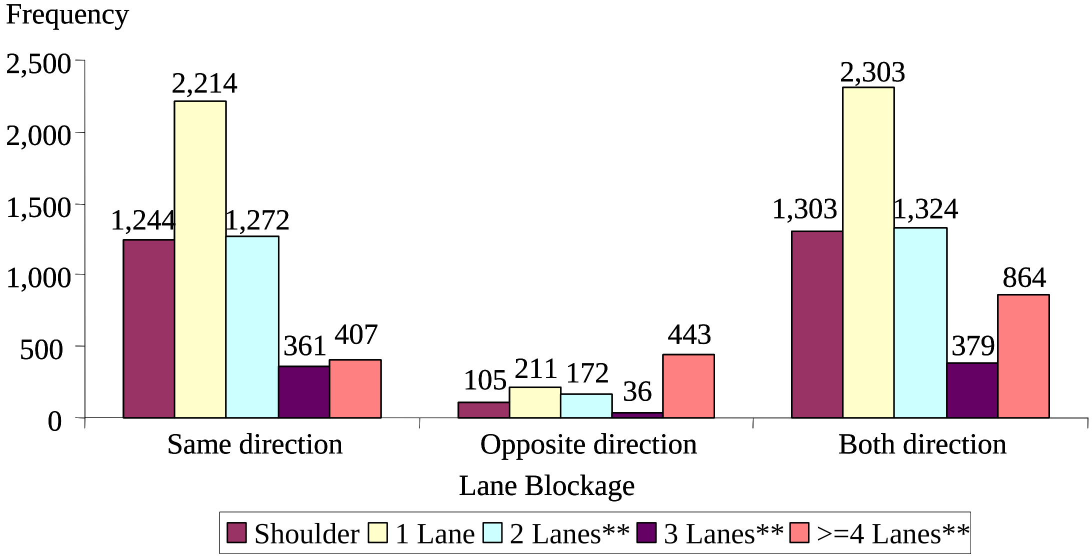
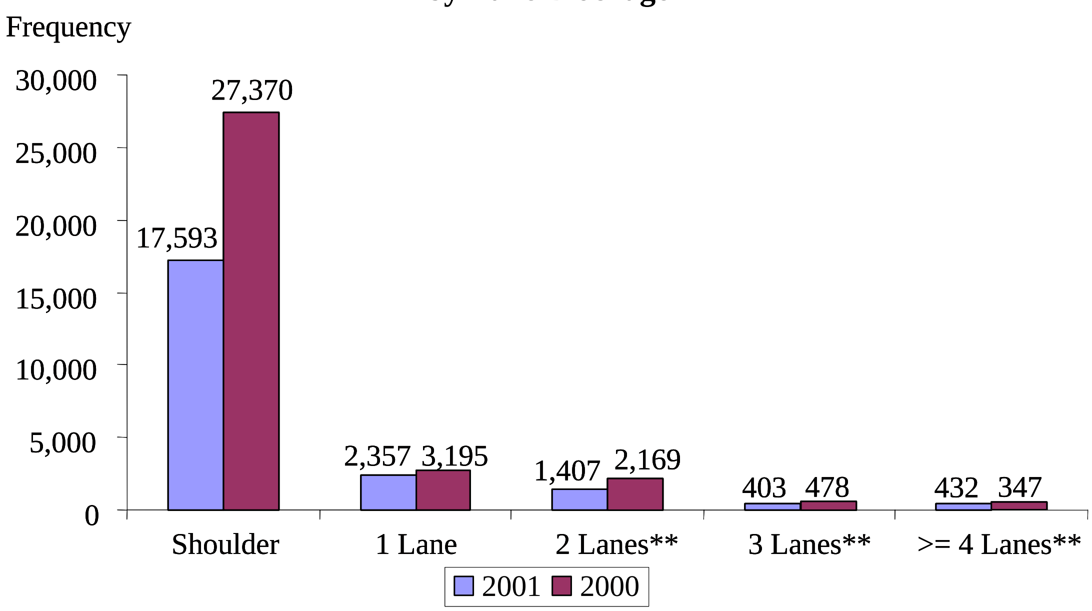
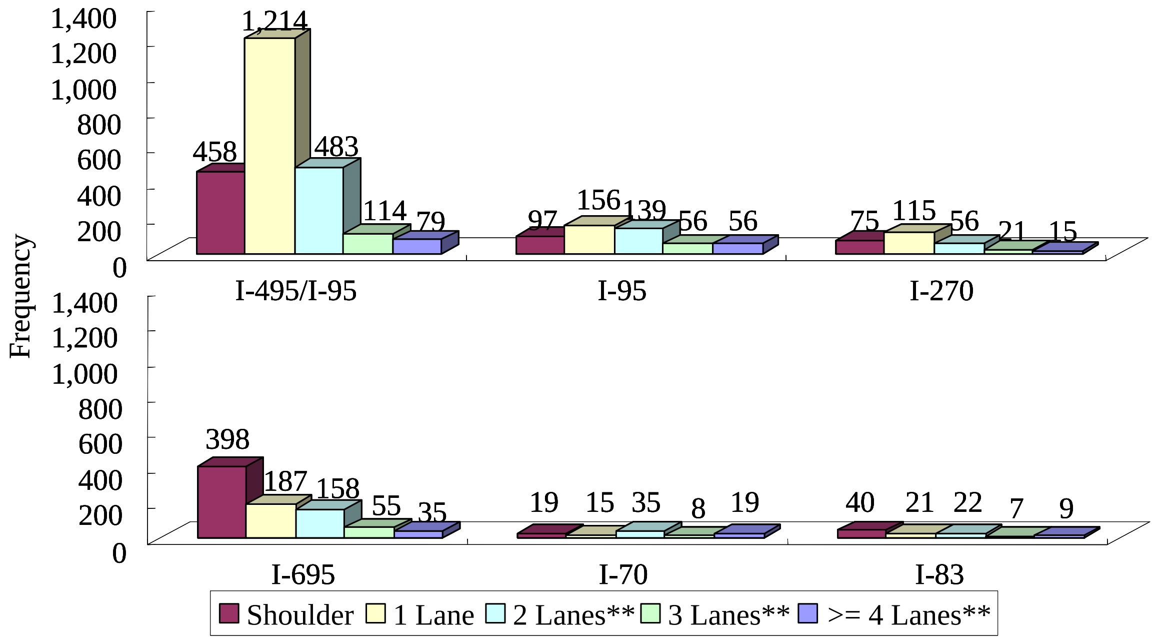


Figure 3.12 Comparison of Incidents/Disabled Vehicles Distribution by Lane Blockage



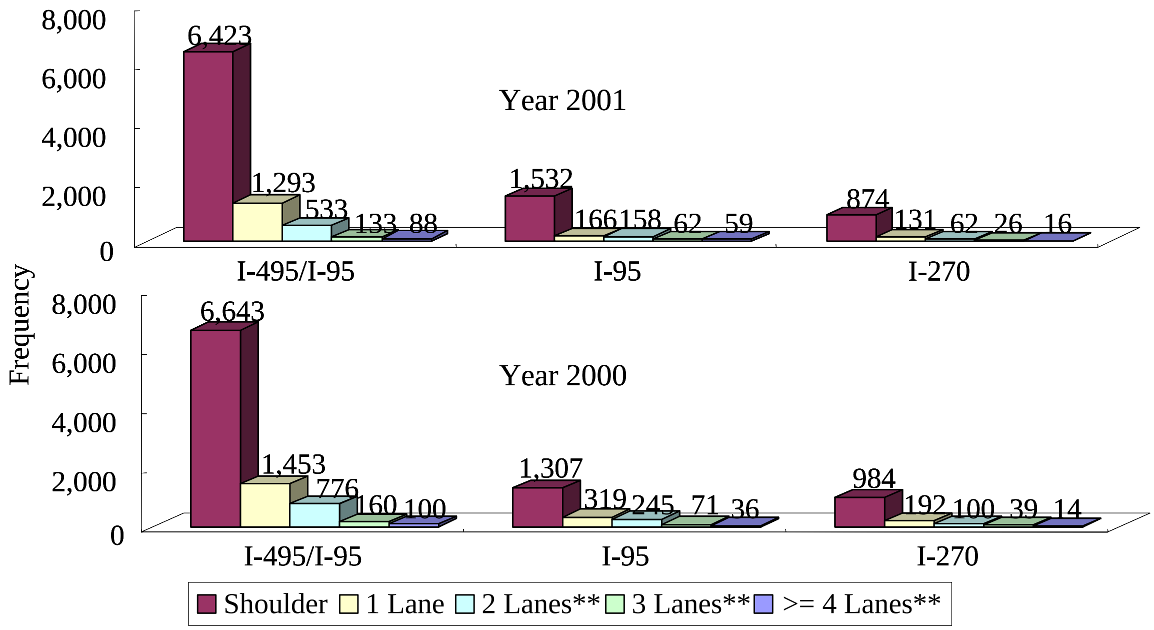
The distribution of lane blockages for each major road is illustrated in Figures 3.13 – 3.15. Figure 3.13 presents only the distribution of incidents from the Chart II database in Year 2001. Figures 3.14 and 3.15 present a comparison of lane-blockage incidents between Year 2001 and Year 2000 for major roads in the Baltimore and Washington metropolitan areas. It is evident that a very large number of incidents/disabled vehicles occurred only on shoulder lanes. For instance, as shown in Figures 3.14 and 3.15, shoulder lane blockage constituted about 76 percent of emergency operations on I-495/95; 90 percent for I-695; and about 77 percent on I-95. Most of such shoulder lane incidents were related to some type of driver assistance such as in the cases of a flat tire, minor mechanical problems, or running out of gas.

Figure 3.13 Distribution of Lane Blockages due to Incidents by Road in Year 2001 (Chart II Database)



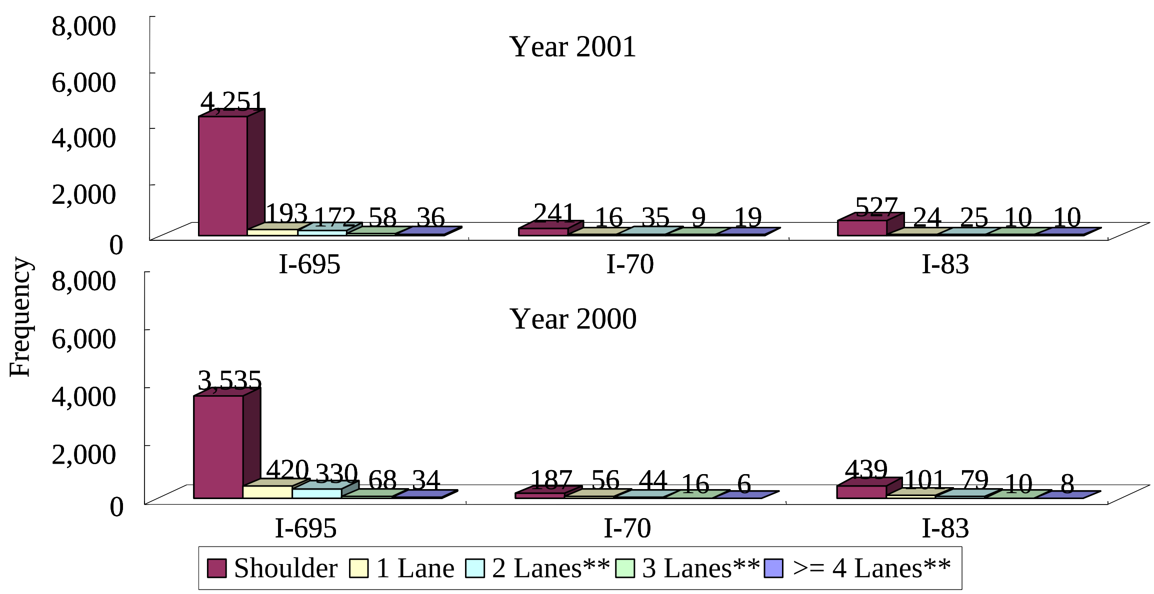
** Also includes shoulder lane blockages

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



** Also includes shoulder lane blockages

Figure 3.15 Distribution of Lane Blockages due to Incidents and Disabled Vehicles by Major Highways in the Baltimore Region

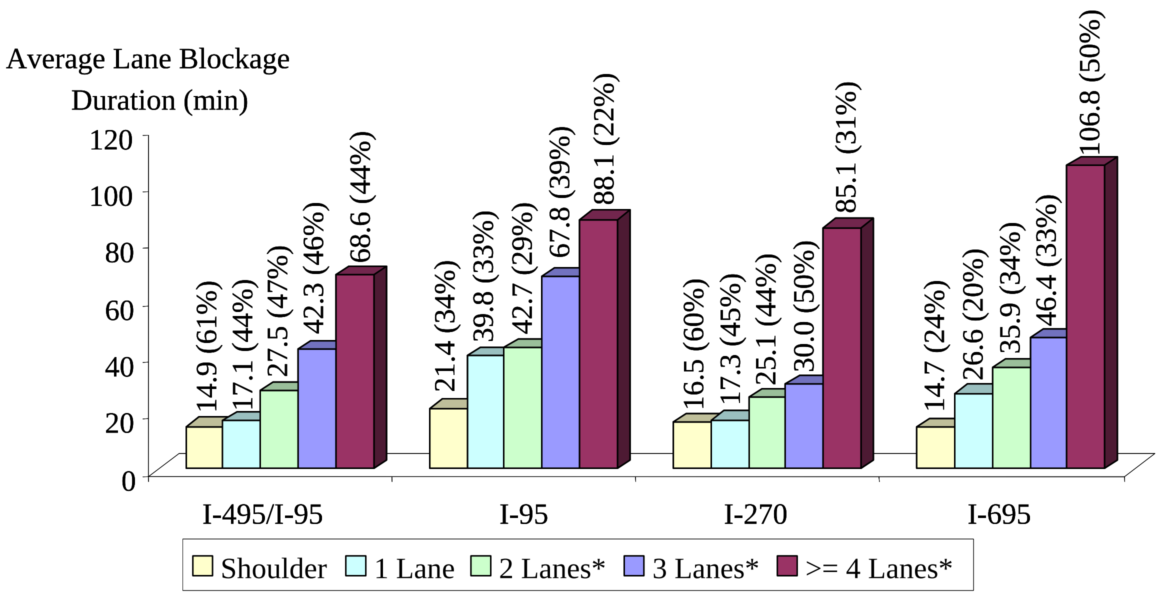


** Also includes shoulder lane blockages

3.5 Comparison of Incident Duration

The analysis of lane blockages naturally leads to the comparison of incident duration distribution. Figure 3.16 illustrates the distribution of lane blockages and their average duration on each major freeway. The numbers in parentheses denote the percentage of data available in each category for computing its average incident duration. For instance, among all one-lane blockage incidents on I-495/95 in Year 2001, CHART response units only recorded the incident duration over 44 percent of their total operations, compared with that of 36 percent recorded in Year 2000. Thus, it should be recognized that all reported statistics in Figure 3.16 may be subjected to some degree of sample bias.

Figure 3.16 Distribution of Lane Blockages and Duration by Road in Year 2001 (due to Both Incidents and Disabled Vehicles)



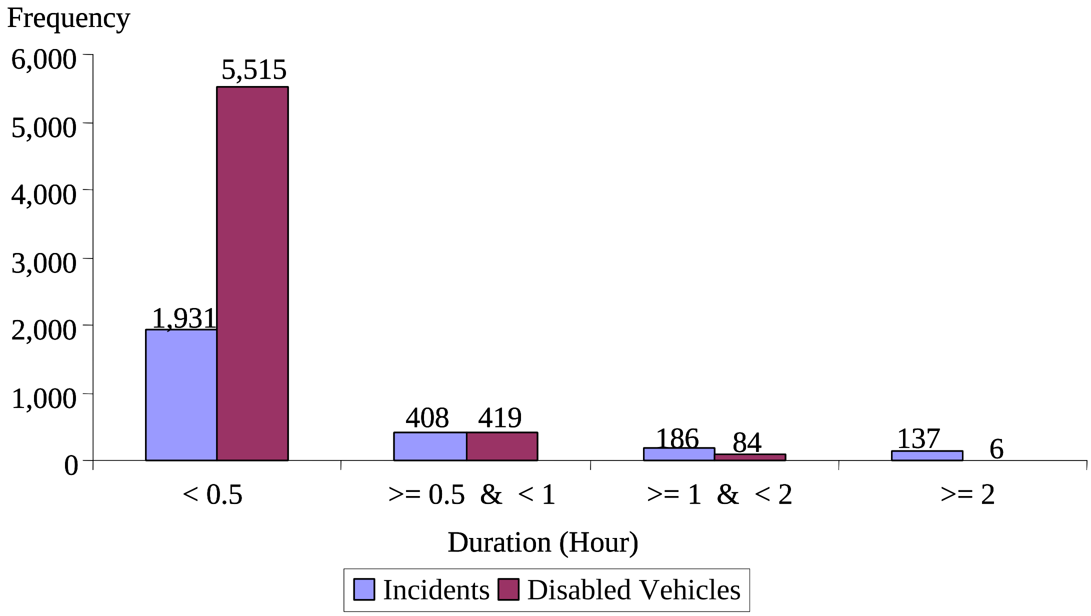
* The numbers in parentheses show the percentage of data available

Considering the commuting flow rate on I-495/95 and its incident frequency, one can recognize the urgent need to implement an efficient incident management program. The high frequency of incidents on I-495/95 also confirms the general perception that incident-related traffic blockage is the primary contributor to congestion on the Capital Beltway. It is clear that the highway network covered by CHART has been plagued by a high frequency of incidents, with their durations ranging from about 30 minutes to more than 3 hours. These incidents are apparently one of the primary contributors to traffic congestion in the entire region, especially on the major commuting-highway corridors I-495, I-695, I-270, and I-95. Thus, it is imperative to continuously improve both the traffic management and incident response systems.

3.6 Distribution of Incidents and Disabled Vehicles by Blockage Duration

This section presents the distribution of incidents by lane-blockage duration on the network covered by CHART. As shown in Figure 3.17, most disabled vehicles in the Chart II Database did not block traffic for more than half an hour. For instance, for the Chart II Database alone, the number of disabled vehicles with duration shorter than a half-hour was about 92%, while the number of incidents shorter than a half-hour was 73%. Although most incidents were minor incidents, their impacts were so significant as to cause traffic blockage and congestion during peak hours. The clearance of such blockages generally did not require special equipment, and hence the resulting incident duration depended mainly upon the travel time of incident response units.

Figure 3.17 Distribution of Incidents/Disabled Vehicles by Duration in Year 2001 (Chart II Database)



Note: Only available data are counted.

Table 3.3 represents the distribution of total records in Year 2001 and compares it with Year 2000 data. About 11% of reported incidents/disabled vehicles managed by TOC-3 had blocked traffic for more than 30 minutes for the same type of emergency requests in Year 2001, and about 14% and 10% for TOC-4 and TOC-5, respectively. For SOC, about 50% of reported incidents lasted more than one hour. Overall, about 33% of those responded to by CHART lasted more than 30 minutes in Year 2001. It should be noted that the number of incidents/disabled vehicles that plagued the traffic for more than 30 minutes, as shown in Table 3.3, seems to decrease across all regions in Year 2001, compared with those in Year 2000.

Table 3.3 Comparison of Incidents/Disabled Vehicles Distribution by Duration

Duration (Hr)	TOC 3		TOC 4		TOC 5	SOC		Other	Total	
	2001	2000	2001	2000	2001	2001	2000	2001	2001	2000
<0.5	5,682	1,194	2,038	5,782	745	95	81	21	8,581	7,057
>=0.5& <1	549	1,087	262	891	65	85	160	4	965	2,138
>=1&<2	148	290	86	268	21	83	185	2	340	743
>=2	55	149	22	123	1	97	246	3	178	518
N/A	7,358	15,824	5,962	7,207	311	1,790	114	523	15,944	24,435
Total	13,792	18,544	8,370	14,271	1,143	2,150	786	553	26,008	34,891

Considering the ever-increasing traffic demand and resulting incidents, it is likely that any investment for contending with such nonrecurrent congestion will yield tremendous benefits to both the highway users and the quality of transportation systems for the entire region.

CHAPTER 4: DETECTION EFFICIENCY AND EFFECTIVENESS

4.1 Evaluation of Detection Efficiency and Effectiveness

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

- The overall incident detection rate and false-alarm rate
- The average duration from the onset 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 to immediately by the incident response team
- 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 issue, concerning how long it takes the traffic control center to receive an incident report from various sources after it has occurred, also cannot be assessed in this study. This is because the current incident management report, completed by operators in the traffic control center, does not contain such information. As such, the evaluation of detection efficiency and effectiveness can focus only on the incident response rate and distribution of detection sources.

4.2 Response Rate for Detected Incidents

Note that the response rate discussed in this chapter is defined as the ratio between the total numbers of traffic incidents reported to the CHART control center and those managed by the CHART/MSHA incident/disabled vehicle response teams. Based on the Year 2001 incident management record, this overall response rate was about 85%.

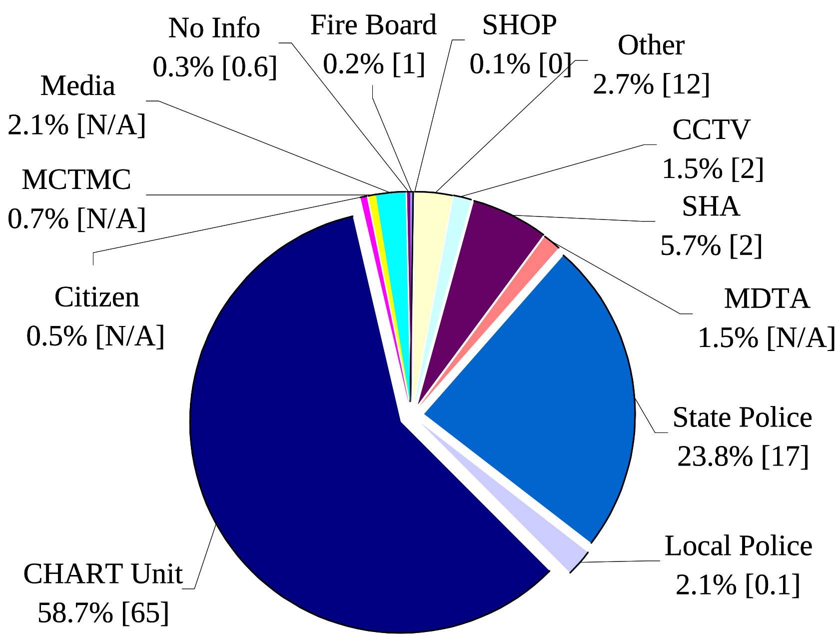
Similar to those in the previous year, existing incident reports available in CHART do not indicate the reasons for not responding to some incidents. It appears that most of such incidents were either incurred during very light traffic periods or were not so severe as to cause any significant traffic blockage or delay.

4.3 Distribution of Incidents and Disabled Vehicles among Detection Sources

Despite the lack of automated incident detection systems, it is notable that CHART has maintained quite an effective coordination with all other state and municipal agencies responsible for contending with traffic incidents and congestion. 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, the statistics in Figure 4.1 clearly show that about 59 percent of incidents were detected by MSHA patrols (Chart Unit), and about 24 percent were informed by the MSP in the year of 2001, compared with 65 percent and 17 percent in Year 2000.

Figure 4.1 Distribution of Incident/Disabled Vehicles by Detection Sources in Year 2001 [2000]



Although this 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-factor 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 time 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 the 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 4.2 illustrates the distribution of detection sources for the Traffic Operation Center 3, and Figure 4.3 does that for TOC 4. Numbers in parentheses indicate the data for Year 2000. As presented in those figures, it is evident that MSHA patrols (Chart Unit) in Year 2001 took the primary role for detecting and responding to reported highway incidents/disabled vehicles.

Figure 4.2 Distribution of Incident/Disabled Vehicles by Detection Sources from TOC-3 in Year 2001 [2000]

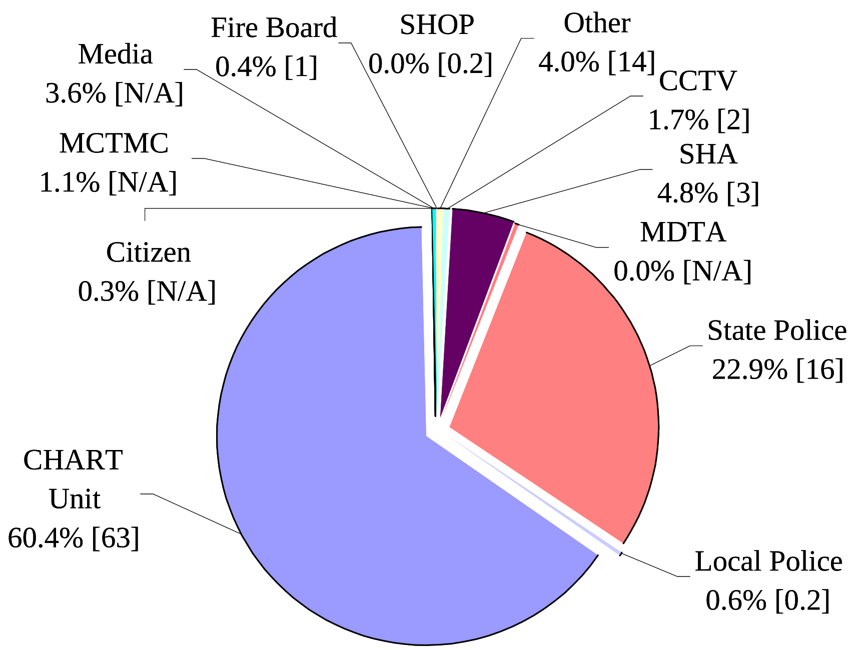
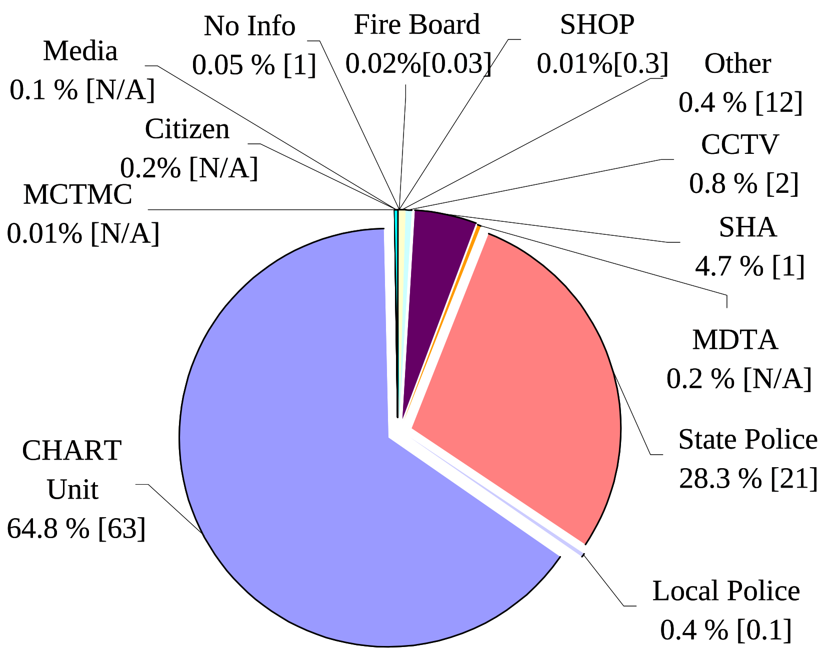


Figure 4.3 Distribution of Incident/Disabled Vehicles by Detection Sources from TOC-4 in Year 2001 [2000]



CHAPTER 5: EFFICIENCY OF RESPONSE AND MANAGEMENT

5.1 Analysis of Response Efficiency

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

- Travel Time – or how long it takes an incident response unit to reach the reported incident site after the control center has been informed via various detection sources
- Response Travel Distance – what the average travel distance is for incident response units to reach the identified incident site
- Clearance Time – how long it takes the incident response team to clear various types of incidents
- Reduction in incident duration – how many minutes of the incident blockage time has been reduced due to the operations of CHART/MSHA incident response units

Having information on all the above vital aspects will enable MSHA to have a clear picture of the efficiency at every stage of incident management and operations. For instance, the information on the average travel time will shed light on the effectiveness of interactions between the traffic control center and the offices responsible for dispatching incident response units. If the time between the arrival of response units and the incident report was found to be unexpectedly long, it would be an indication of having inadequate response units, or an operating process that may easily cause operators to incur delay in calling for dispatching operations.

The information on the first aspect, along with the data on the distribution of Travel Distance to incident sites, shall also enable MSHA to evaluate its routing strategies for emergency response units and to assess whether the current equipment is sufficient to respond to the increasing number of incidents during peak periods. One may consider placing 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 incident response time.

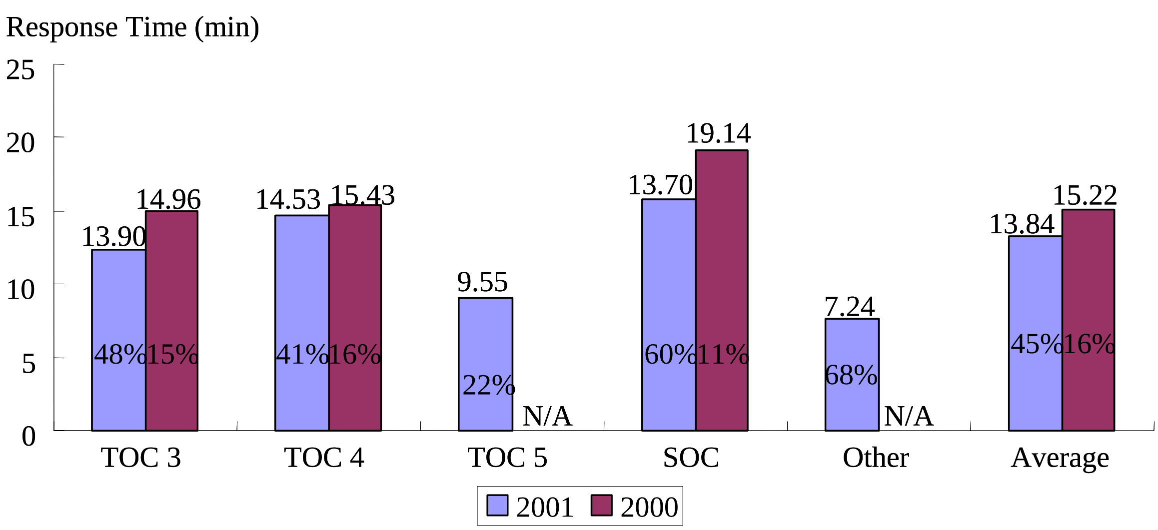
Since the current incident reports do not contain information on travel distance, the evaluation of management efficiency has focused mainly on the distribution of response times and incident duration. Note that the response time, as presented in Chapter 1, should be the time difference between the actual time the incident has occurred and the time the response vehicle arrives at the scene. Since it is difficult to know the actual time of the incident occurrence, the response time used in this study is based on the difference between the time the Response Center has received the call and the time the response unit has arrived at the site of the incident. The average response times for incidents and disabled vehicles were computed to be about 14.02 minutes and 13.61 minutes in Year 2001, respectively, as shown in Table 5.1.

Table 5.1 The Average Response Time for Incidents/Disabled Vehicles in Year 2001

Records Type	Incidents	Disabled Vehicles	Total
Average Response Time (min)	14.02	13.61	13.84
Number of Reports	4,517	3,184	7,738

The average response time for all types of incidents for Year 2001 is given in Figure 5.1. The average response time for all emergency operations by CHART in Year 2001 was 13.84 minutes, compared with 15.22 minutes in Year 2000.

Figure 5.1 The Overall Average Response Time



* The percentage shows the amount of data available

5.2 Reduction in Incident Duration

Aside from evaluation of the entire incident management process, one of the major performance indicators is the reduction in average incident duration due to the operations of CHART/MSHA response units. Theoretically, to have a reliable estimate for such an indicator one should perform a typical before-and-after analysis. 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 Year 2001 with and without the assistance from CHART/ MSHA response units, as preformed in previous evaluation.

Since the CHART incident management team responded to most incidents in Year 2001, the data associated with incidents not responded to, for performance comparison, are quite limited. As shown in Table 5.1, the average duration to clear an incident with and without the assistance of CHART was about **28.8** minutes versus **50.7** minutes, a substantial improvement as compared with 33 minutes versus 77 minutes in Year 2000. Note that this analysis excluded the outlier data with duration outside the range of (mean ± two standard deviations), which means that about 2.2 percent of data were eliminated from the final analysis.

Table 5.2 Comparison of Incident Durations for Various Types of Lane Blockages (With and Without CHART/SHA)

Blockage	With SHA Patrol		Without SHA Patrol	
	Duration (min)	Frequency	Duration (min)	Frequency
1 lane	17.0 (20)	882	23.9 (46)	54
2 lanes	32.2 (35)	507	69.3 (80)	54
3 lanes	51.7 (39)	144	74.1 (93)	15
>=4 lanes	79.7 (70)	106	56.4 (102)	17
Weighted Average	**28.8 (33)**		**50.7 (77)**	
Total Samples		1,639		140

Note: The numbers in parentheses show the data in Year 2000.

Based on the results shown in Table 5.1, it seems that with the assistance of CHART/MSHA response units, the clearance duration was substantially reduced for all types of incidents, ranging from one-lane to multiple-lane closures. On average, CHART contributed to about a **43** percent reduction in its incident blockage duration in Year 2001, a slight decrease compared with the Year 2000 record, which was about 57 percent. Overall, the reduction in incident recovery time has certainly contributed to a significant savings on travel time, fuel consumption, and other related social-impact costs due to nonrecurrent congestion.

In reviewing of the above statistics, one notices that the average incident duration for those without assistance from CHART/SHA has also been reduced significantly across most types of lane-blockage incidents. For instance, the average unresponded to incident duration was 50.7 minutes in Year 2001, much shorter than the average of 77 minutes in Year 2000. This seems to reflect the fact that efficient response to incidents so as to minimize nonrecurrent congestion and its impacts on the driving population has received increasing attention among all responsible agencies.

CHAPTER 6: BENEFITS FROM THE INCIDENT MANAGEMENT BY CHART

6.1 Estimation of Benefits

Despite the well-recognized benefits from an efficient incident management system, 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, quantifying the benefits from the operation of an incident management system is one of the essential tasks for CHART evaluation.

Because of the concern for ensuring the quality of analysis under the data limitations as well as resource constraints, the benefit assessment of CHART has always focused only on those either directly measurable or quantifiable from the incident reports. Such direct benefits, both to roadway users and to the entire community, are classified as follows:

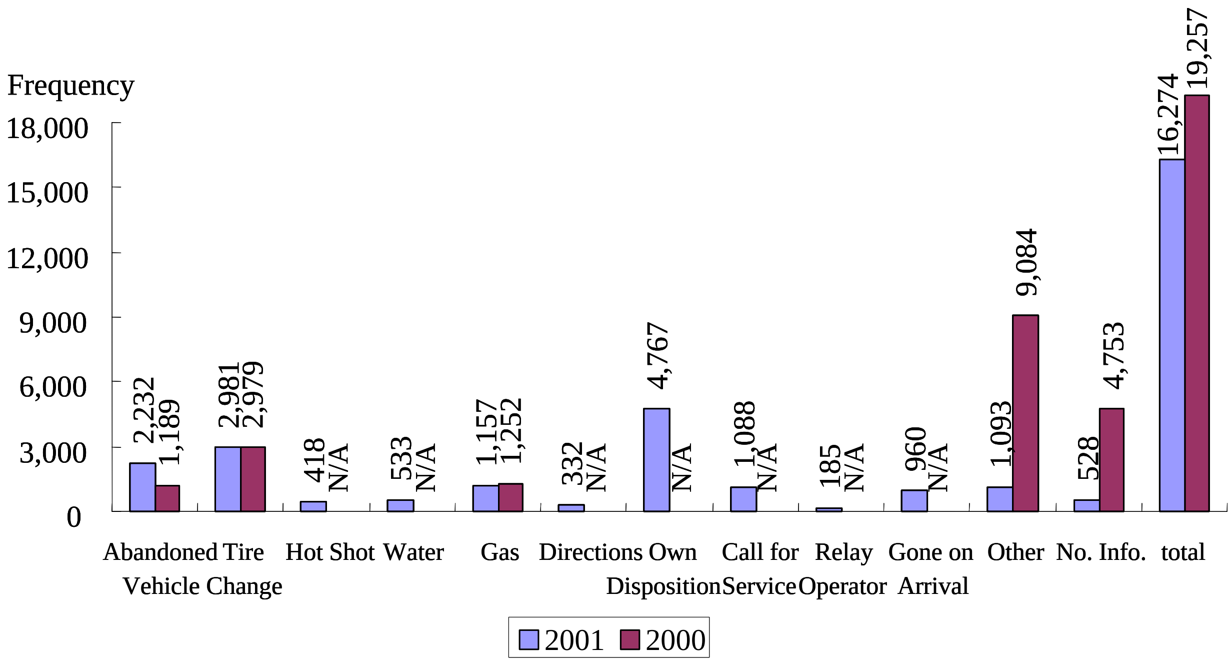
- Assistance to drivers
- Reduction in secondary incidents
- Reduction in driver delay time
- Reduction in vehicle operating hours;
- Reduction in fuel consumption
- Reduction in emissions

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

6.2 Assistance to Drivers

Among all 26,008 incident reports available in the CHART Database, it has been found that there were a total of 16,274 incidents associated with requests from drivers for some types of assistance such as flat tire, shortage of gas, or mechanical problems, as shown in Figure 6.1. This number is lower than the 19,257 assistance requests from drivers in Year 2000. Note that the introduction of the new Chart II Database has resulted in a substantial reduction in unknown types of incident reports in the database, i.e., from 4,753 cases in Year 2000 to 528 cases in Year 2001. Out of 16,274 assistance requests from drivers, a total of 4,138 were related to “out of gas” and “tire changes” of vehicles, compared with 4,231 cases in Year 2000.

Figure 6.1 Nature of Driver Assistance Requests in Year 2001 and Year 2000



Note that according to CHART operators, its response teams actually responded to many more assistance requests from drivers than the documented 16,274 assists. However, most of those unreported driver assists did not need major effort or equipment from the response team, and thus were not always recorded.

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

The overall distribution of assistance requests from drivers (named Disabled Vehicle in the Chart II Database) by nature in Years 2001 and 2000 can be seen in Figure 6.1. Among those, the distribution managed by TOC-3 and TOC-4 is illustrated in Figures 6.2 and 6.3, respectively.

Figure 6.2 Nature of Driver Assistance Requests for TOC-3

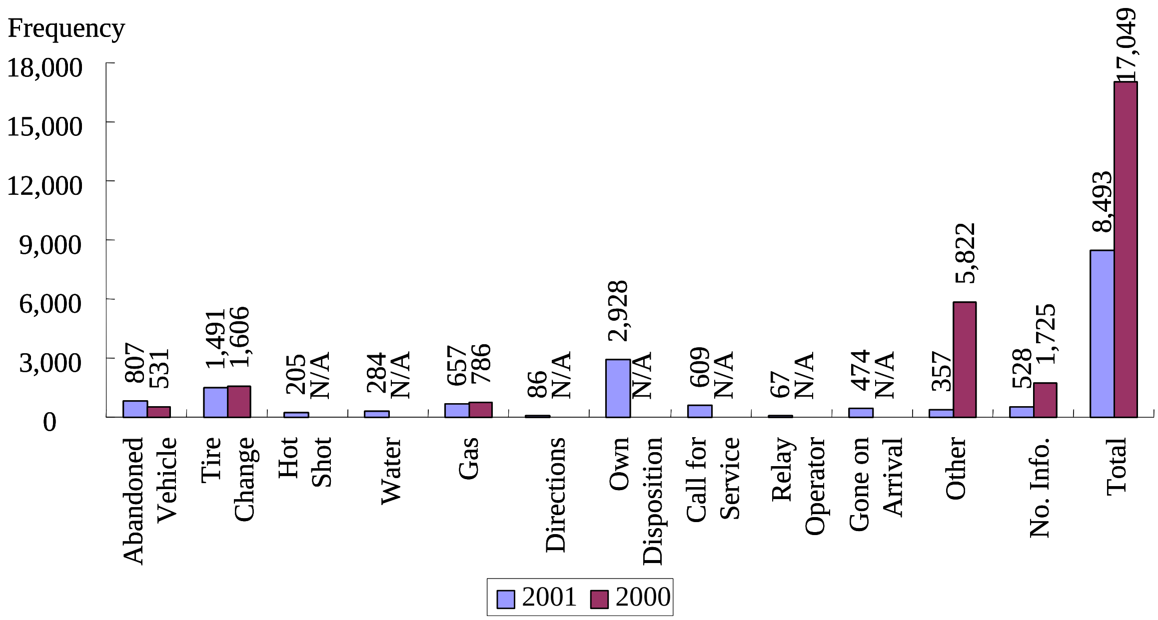
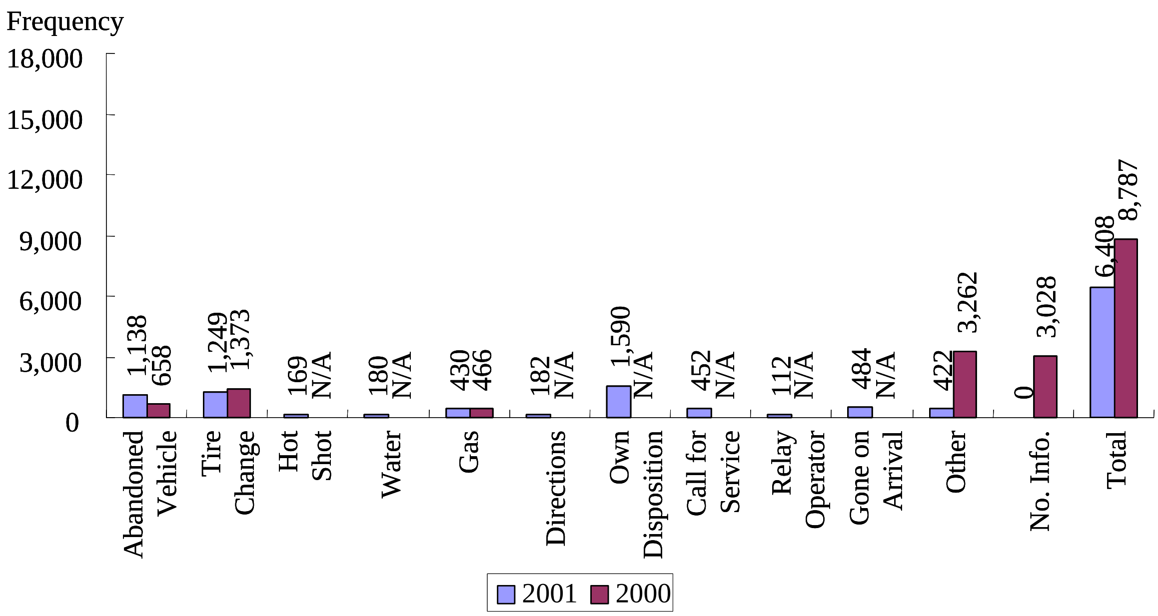


Figure 6.3 Nature of Driver Assistance Requests for TOC-4



6.3 Potential Reduction in Secondary Incidents

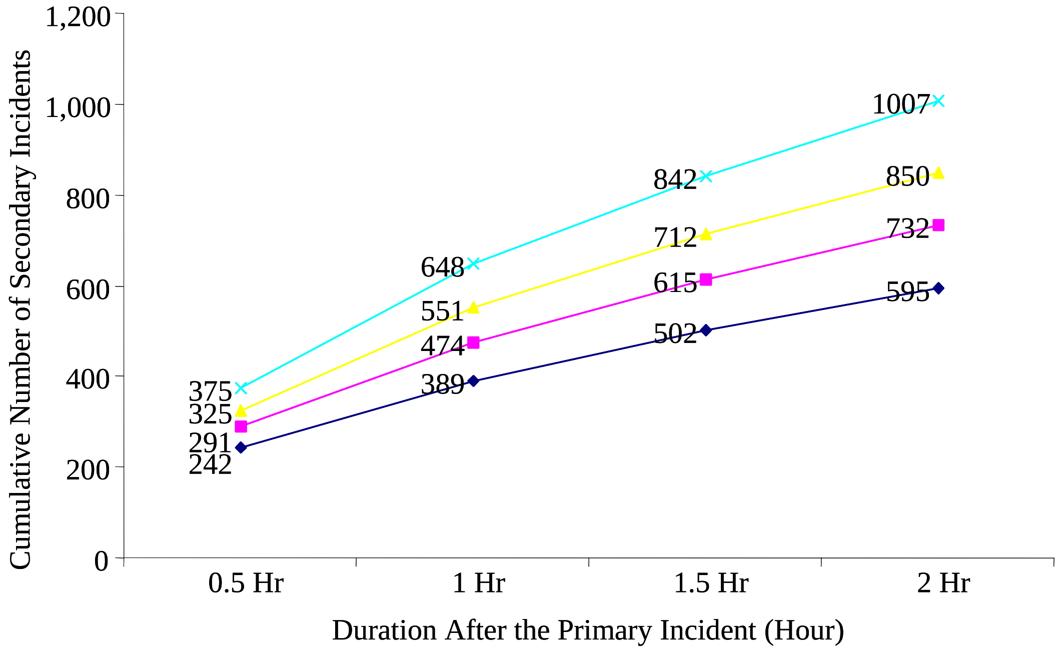
It has been well recognized that one major accident may produce a number of relatively minor secondary incidents due to a dramatic change in the traffic condition, such as the rapid spreading of queue length and a dramatic drop in the traffic flow speed. The likelihood of having such incidents increases consistent with the incident duration and the congestion level. Thus, an efficient recovery of incident blockage may not only directly benefit drivers in the traffic queue, but also reduce potential incidents involving 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. Grounded in the experience from our previous work, this study has adopted a definition for secondary incidents that can also account for incidents caused by rubbernecking effects in the opposite traffic direction:

- Incidents arising within two hours from the onset of a primary incident and also within two miles downstream of the primary incident location; or
- Incidents arising 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 of the primary incident location.

For convenience of comparison, Figure 6.4 presents the distribution of secondary incidents under different definitions based on the Year 2001 Accident Database provided by the Maryland State Police Department. Notably, under the selected definition, there were 1,007 secondary incidents that occurred in Year 2001. 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 significantly higher.

Figure 6.4 Distribution of Reported Secondary Incidents



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

- Reported number of secondary incidents: 1,007
- The estimated number of secondary incidents without CHART/MSHA response units (that has resulted in a 43.2% reduction on the average incident duration): 1,007/(1-0.432) = 1,773
- The number of potentially reduced secondary incidents due to the operations of CHART: 1,773 – 1,007 = 766

Note that each of those 766 secondary incidents, if it actually occurs, may further prolong its primary incident duration and result in additional loss of travel time, additional fuel consumption, and more congestion on surface streets. Such impacts and accompanying benefits are not computed in this report, due to data limitations, but should be investigated in a future study.

6.4 Estimated Benefits due to Efficient Removal of Stationary Vehicles from Travel Lanes

As have 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 have happened from improper lane changes, it is likely that a prolonged incident operation may result in accidents. Thus, the operation of CHART/MSHA that has contributed to efficient removals of stationary vehicles in travel lanes may directly prevent some potential lane-changing-related accidents around incident sites. This study has attempted to explore such a benefit with limited available data. The research method and procedures are summarized below:

Scope of Analysis: Only those incidents taking place on I-495/95, I-95, I-270, I-695, I-70, I-83, MD-295, US-50, I-795, and I-97 during peak periods are included in the analysis.

Procedures:

- Performing field observations of lane-changing frequency, flow rate, speed, and density on a segment I-495/I-95 over both peak and off-peak periods

- Developing a statistical relation between the number of nonmandatory lane changes and traffic conditions

- Computing the ratio between the total number of lane-blockage-related incidents and the total number of lane changes over the given freeway segment estimated with the developed statistical models; for instance, the analysis result indicates that about 5,330 nonmandatory lane changes on I-495/95 will cause one accident

- Computing the number of lane changes for those incidents resulting in lane blockages, based on the incident duration, number of lanes being blocked, and the approximate traffic volume on those blocked lanes

- Estimating the potentially reduced accidents for each freeway, based on the estimated number of lane changes for each recorded incident and the ratio between an accident and the number of undesirable lane-changing maneuvers

An illustration of the estimation procedures is presented in Figure 6.5, and the estimated results for those target freeways are reported in Table 6.1. Note that this estimation has focused only on the peak period, as the relation between lane-changing maneuvers and accidents during the off-peak hours is found to be statistically uncorrelated in our limited data set.

Figure 6.5 Flow Chart of the Procedures for Approximating the Potentially Reduced Lane-Changing-Related Accidents due to Operations of CHART

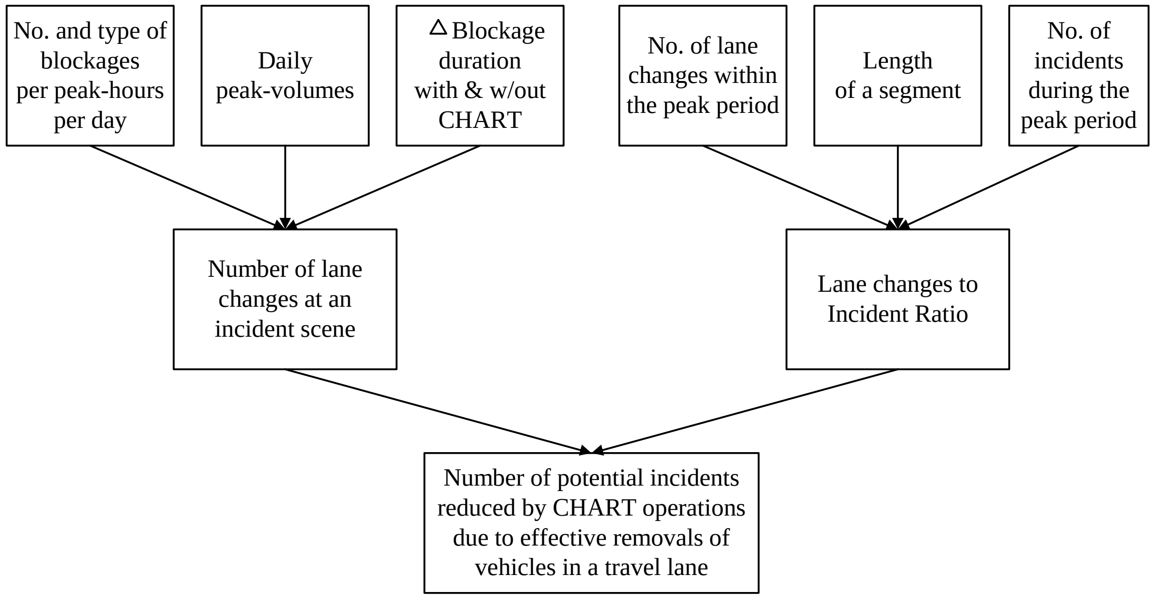


Table 6.1 Reduction of Potentially Incidents due to CHART Operations

Road Name		I-495/ I-95	I-95	I-270	I-695	I-70	I-83	MD-295	US-50	I-795	I-97	Total
Mileage		41	63	32	44	13	34	30	42	9	17	--
Number of Potential Incidents Reduction	Year 2001	174	79	13	65	2	10	7	20	3	6	**379**
	Year 2000	297	12	14	47	7	8	N/A	N/A	N/A	N/A	**385**

6.5 Direct Benefits to Highway Users

As reported in previous CHART evaluation studies, the computation of additional delays and fuel consumption due to CHART operations is performed with the following models:

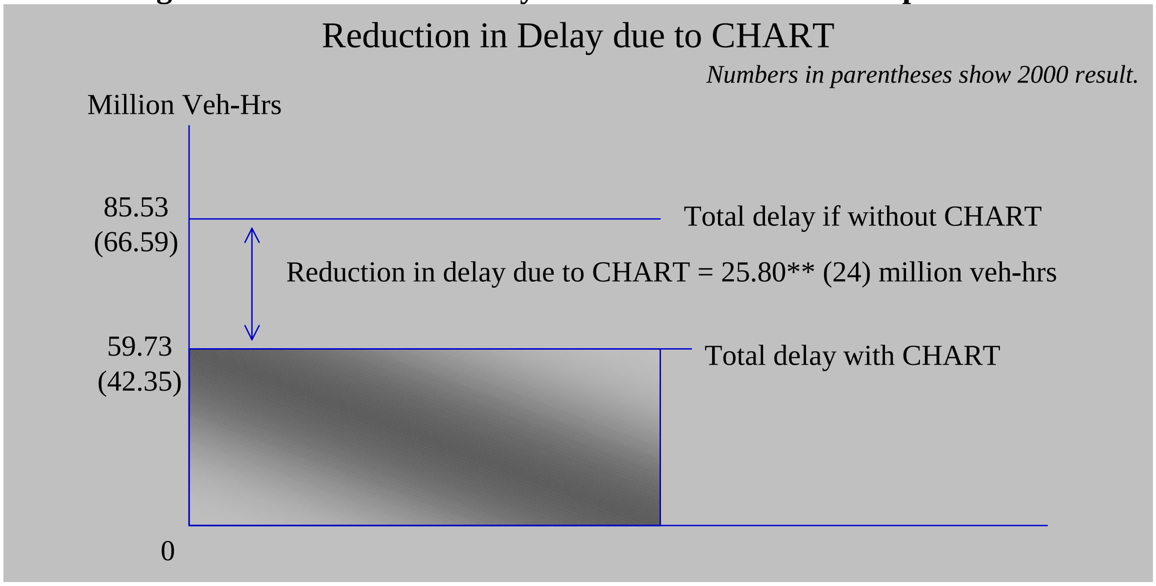
$$\Delta \mathrm{Delay} = e^{-10.19} \times (\mathrm{Traffic\,Volume})^{2.8} \times \left(\frac{\mathrm{No.\,of\ Lane\,Blocked}}{\mathrm{Total\ No.\,of\ Lanes}}\right)^{1.4} \times (\mathrm{Incident\ Duration})^{1.78}$$

$$\Delta \mathrm{Fuel} = e^{-10.77} \times (\mathrm{Traffic\,Volume})^{2.27} \times \left(\frac{\mathrm{No.\,of\ Lane\,Blocked}}{\mathrm{Total\ No.\,of\ Lanes}}\right)^{0.9} \times (\mathrm{Incident\ Duration})^{1.69}$$

where ΔDelay is excessive delay due to incidents and ΔFuel is additional fuel consumption due to incidents.

Prior to use of above equations, all roads covered by CHART were divided into homogenous segments based on geometry (number of lanes) and volume (peak-hour). The overall computation results indicate that all incidents that occurred in Year 2001 may result in a total of 85.53 million veh-hr delays without CHART/MSHA operations. In contrast, due to the efficient response and management of CHART, the total vehicle delay has been reduced to 59.73 million hours, about 25.80 million hours less than without the assistance of CHART/MSHA.

Figure 6.7 Reduction in Delays due to CHART/MSHA Operations



Overall, the total benefits in term of reduction in total delay time and fuel consumption, based on the same parameters used in Year 2000, for convenience of comparison can be summarized as follows:

- Total delay savings: 25.80 million hours = $ 369.97 million ($14.34/hour)
- Total fuel consumption reduction: 4.35 million gallons = $ 4.35 million ($1/gal.)

6.6 Emission Reduction Benefits

The estimated reductions in vehicle emissions were based on the following parameters provided by MDOT (which have been used for air pollution evaluation in both the Baltimore and Washington D.C. areas) and the total delay reduction of 25.80 million vehicle hours due to CHART/MSHA operations:

HC: 316.9 tons (13.073 grams per hour of delay);

CO: 3559 tons (146.831 grams per hour of delay);

NO: 151.8 tons (6.261 grams per hour of delay).

Using the cost parameter of $6,700/ton for HC, $6,360/ton for CO, and $12,875/ton for NO (Patrick, 1998), the above reduction in emission has resulted in a total savings of **28.43** million dollars.

Thus, as shown in Table 6.2, the operation of CHART/MSHA in Year 2001 has generated a total benefit of **402.75** million dollars (= $369.97 M + $4.35 M + $28.43 M), higher than the benefit of 378.4 million dollars in Year 2000.

Table 6.2 Total Direct Benefits to Highway Users in Year 2001

Reduction due to CHART		Amount	Unit rate	in dollar (million)
Delay (million veh-hrs)		25.80 (24.24)	$14.34/hour	369.97 (347.62)
Fuel consumption (million gallons)		4.35 (4.09)	$1/gal.	4.35 (4.09)
Emissions (million tons)	HC	337.3 (316.9)	$6,700/ton	28.43 (26.7)
	CO	3,788 (3,559)	$6360/ton	
	NO	161.5 (151.8)	$12,875/ton	
Total (million dollars)		$ **402.75** (378.4)		

Note: The numbers in parentheses show the result in Year 2000

In addition to the above total benefits, this study has further computed the reduction in delay emissions in the Baltimore and Washington regions due to CHART/MSHA operations. The results are summarized in Table 6.3. As shown in that table, the delay reduction for the Washington region in Year 2001 was 65,640 hours/day compared with 58,560 in Year 2000; however, for the Baltimore region, the delay reduction remained at almost the same level as at the previous year (33,590 vs. 33,800). The emissions reduction for the Washington region was 72,180 dollars/day compared with $ 61,100 in the previous year. For the Baltimore region, the emissions reduction was 37,190 dollars/day in Year 2001 compared to $ 37,300 in Year 2000.

Table 6.3 Delay and Emissions Reductions due to CHART/MSHA Operations for Washington and Baltimore regions

		Total by Chart		Washington Region		Baltimore Region	
		Year 2001	Year 2000	Year 2001	Year 2000	Year 2001	Year 2000
Annual Delay Reduction	hours	25,799,000	23,775,000	17,065,000	14,966,000	8,734,000	8,790,000
Daily Delay Reduction	hours	99,230	91,360	65,640	58,560	33,590	33,800
Emissions Reduction							
HC Reduction	ton/day	1.297	1.195	0.856	0.753	0.441	0.442
	$/day	8,690	8,000	5,740	5,000	2,960	3,000
CO Reduction	ton/day	14.570	13.416	9.616	8.452	4.954	4.964
	$/day	92,670	85,400	61,160	53,800	31,510	31,600
NO Reduction	ton/day	0.62	0.57	0.41	0.36	0.21	0.21
	$/day	8,000	5,000	5,280	2,300	2,720	2,700
Total	$/day	**109,360**	**98,400**	**72,180**	**61,100**	**37,190**	**37,300**

CHAPTER 7: COMPARISON OF CHART PERFORMANCE

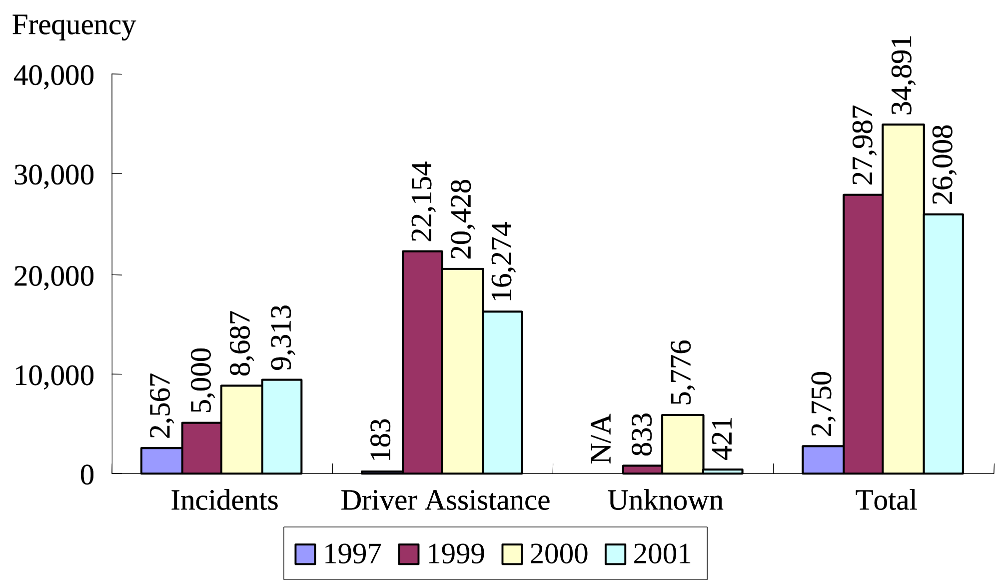
The purpose of this chapter is to present the evolution of CHART performance from Year 1997 to Year 2001. The presentation will focus on the following subjects:

- Data availability
- Data quality
- Response time
- Incident duration
- Driver Assistance
- Direct benefits (delay reduction, fuel consumption reduction, and emissions reduction)

7.1 Data Availability and Quality

Figure 7.1 is a graphic of data availability from Year 1997 to Year 2001.

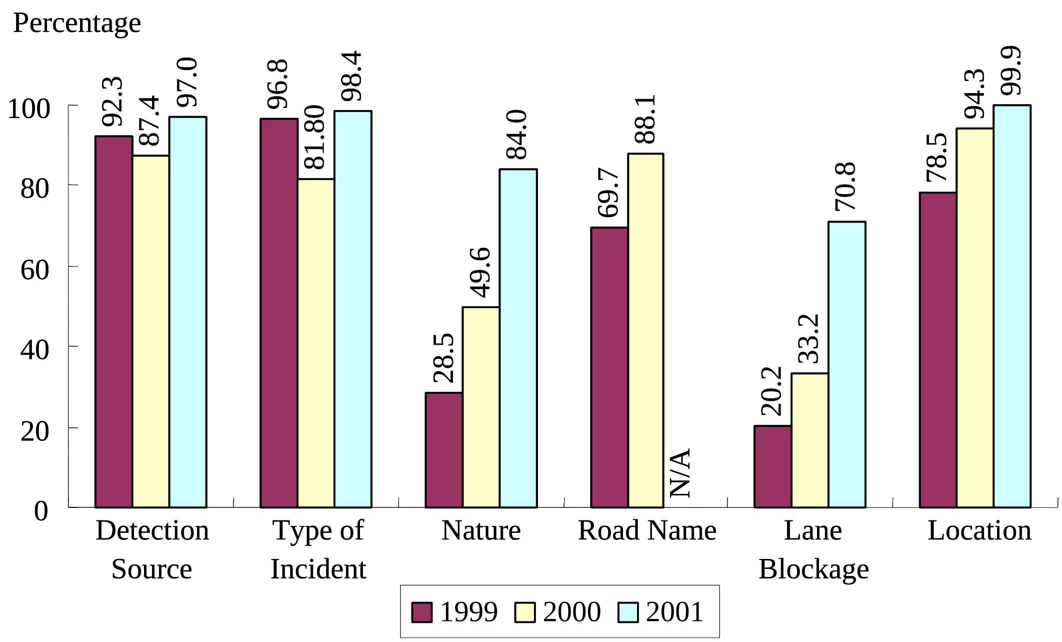
Figure 7.1 Comparison of Available Data by Type from Year 1997 to Year 2001



As shown in the above figure, in the Year 1997 pilot study, only 2,750 reports that recorded the major incidents were available. Overall, the number of incidents data available for analysis seems to increase over time, while the number of driver assists exhibits a decreasing trend. On average, CHART responded to more than 25,000 requests of driver assistance from Year 1999 to Year 2000.

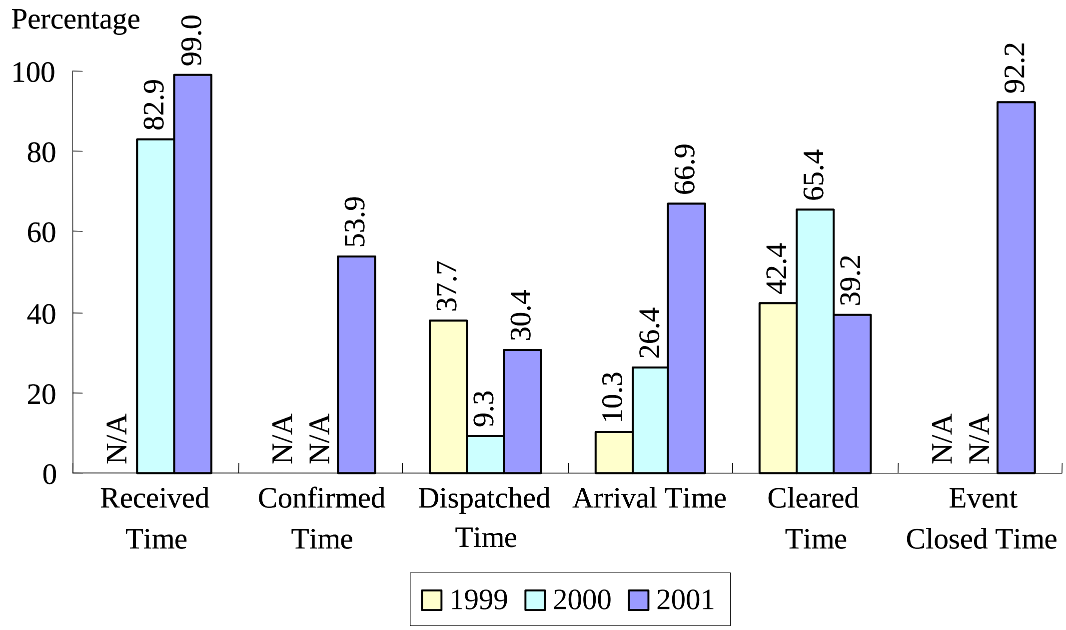
Figure 7.2 and Figure 7.3 illustrate the data quality with respect to all critical parameters used in the CHART performance evaluation from Year 1999 to Year 2001. These critical parameters include detection source, type of incidents, nature, lane blockage, location, received time, confirmed time, dispatched time, arrival time, cleared time, and event closed time.

Figure 7.2 Comparison of Data Quality



Note that since Year 2001, a major part of emergency response reports was from the CHART-II Database. Among these key parameters, the road name parameter is not available in the current CHART-II database. Thus, one needs to manually search the road name associated with each location parameter and input it in the database. The quality of all other critical parameters in the available reports has shown a steady improvement over time.

Figure 7.3 Comparison of Data Quality – Time Parameters



In Year 2001, two parameters related to operating time were added to the CHART II Database: the confirmed time and the event closed time. The most critical time parameters are received time, arrival time, and cleared time, as those are essential for computing the response time and incident duration. As shown in Figure 7.3, the percentages of data with well-documented received time and arrival time have increased over time; but the cleared time has dramatically decreased in Year 2001, due likely to the introduction of "event closed time."

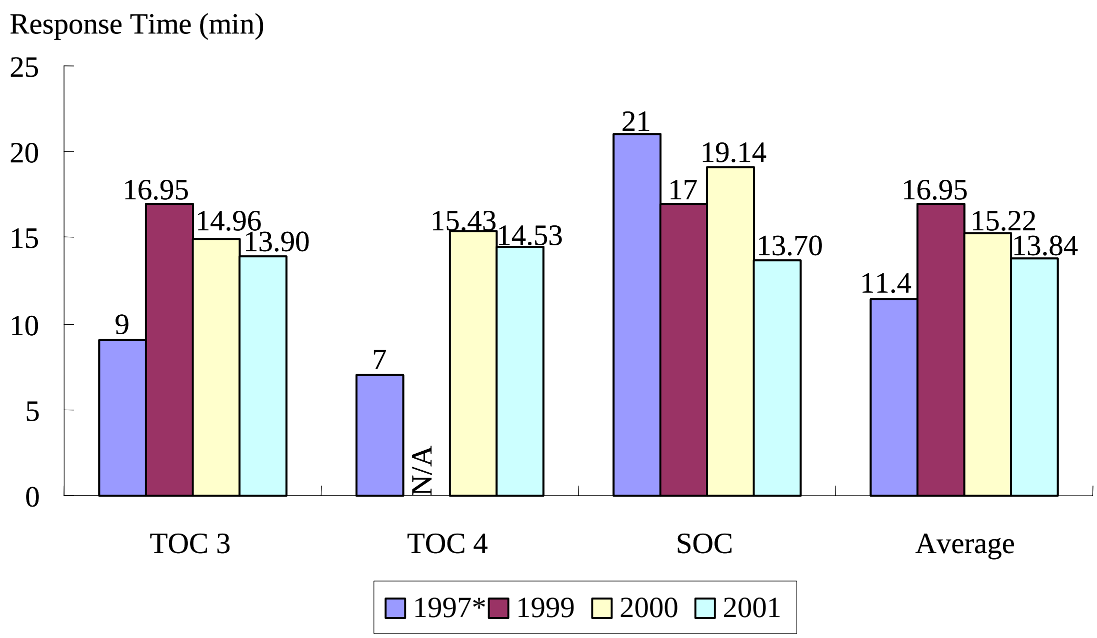
7.2 CHART Performance

This section summarizes the statistics associated with the response time for each operations center, the incident duration with and without SHA patrol by lane blockage type, the driver assistance, and the direct benefits to highway users.

Response Time

Figure 7.4 presents the average response time for all emergency operations centers from Year 1997 to Year 2001.

Figure 7.4 Comparison of Average Response Time by Emergency Operations Centers



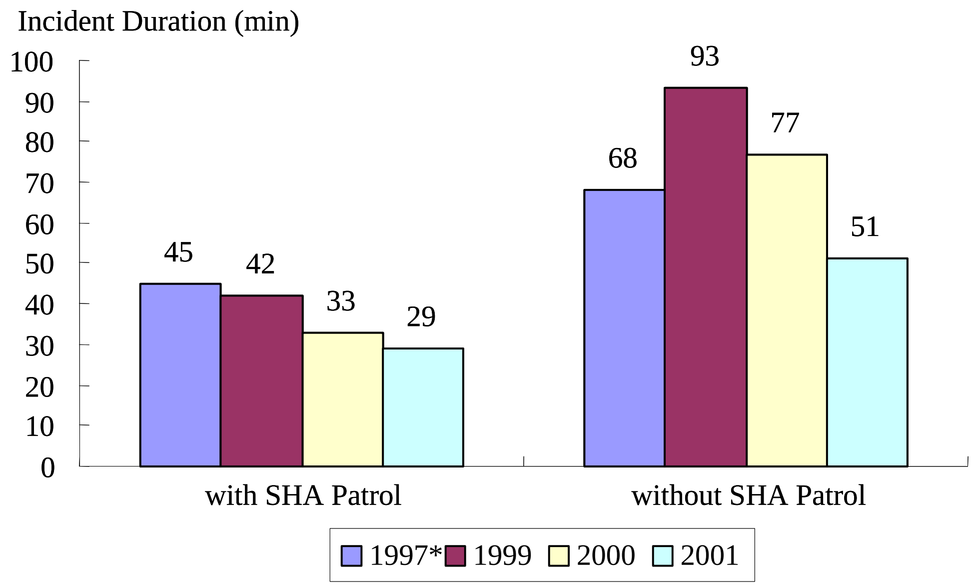
* Insufficient sample – a pilot study only

Overall, the average response times for all operations centers except SOC have reduced steadily over time. For instance, the average response time of TOC-3 has gone from 16.95 minutes in Year 1999 to 13.90 minutes in Year 2001.

Incident Duration

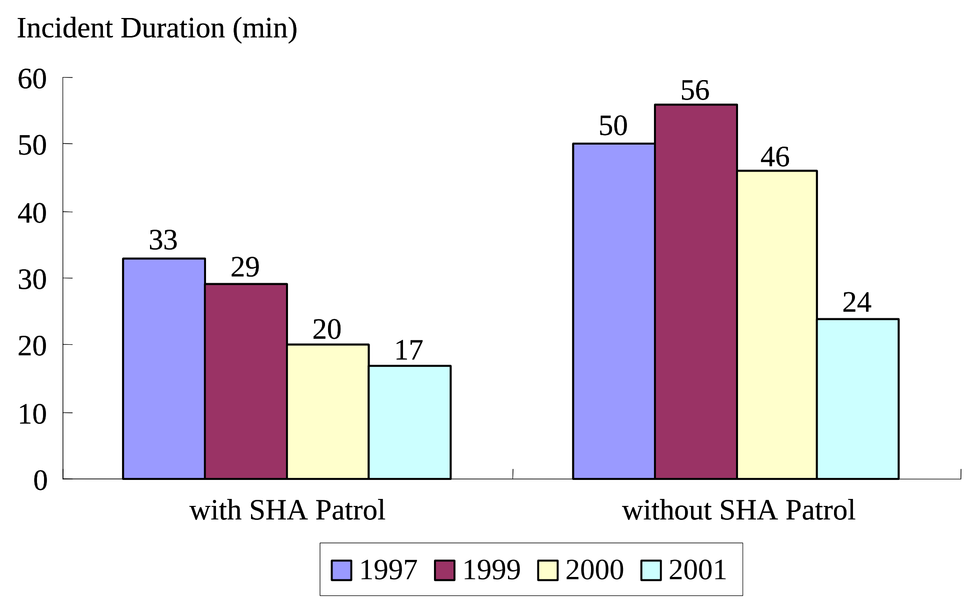
Figure 7.5 illustrates the average incident duration with and without SHA patrol participation from Year 1997 to Year 2001. Figure 7.6 summarizes the comparison of incident duration for one-lane blockage with and without SHA patrol participation. As shown in Figures 7.5 and 7.6, the average incident duration either with or without CHART has been reduced significantly over the past five years, indicating that all agencies involved in incident response and operations have substantially improved their efficiency.

Figure 7.5 Comparison of Average Incident Duration with and without SHA Patrol



* Insufficient sample – a pilot study only

Figure 7.6 Comparison of Incident Duration with and without SHA Patrol (One-Lane Blockage)

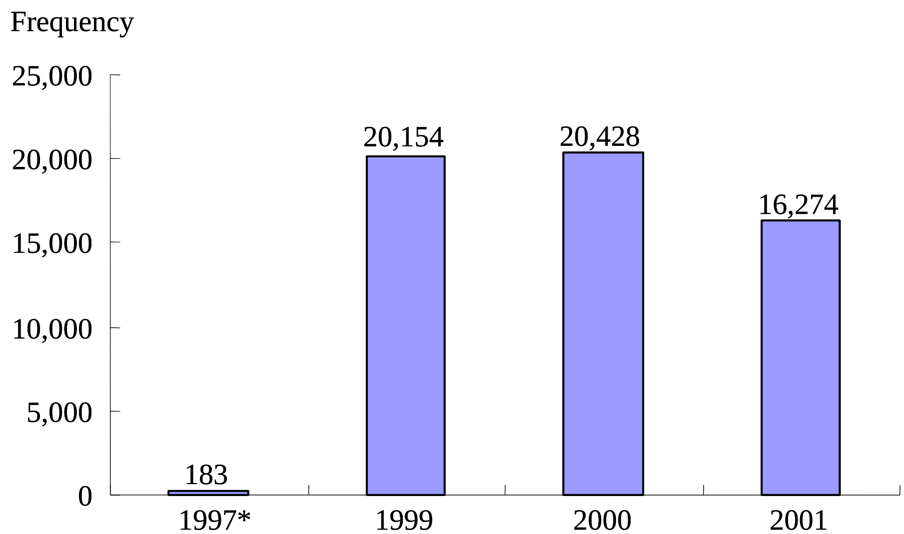


* Insufficient sample – a pilot study only

Driver Assistance

Figure 7.7 highlights the comparison of total driver assists from Year 1997 to Year 2001. Figure 7.8 and Figure 7.9 present the two most frequent assistance requests from drivers: flat tires and gas shortage. These two driver assistance categories were available only in Year 2000 and Year 2001. During these two years, the numbers of driver assistance requests remained approximately at the same level.

Figure 7.7 Comparison of Total Number of Driver Assistance Cases



* Insufficient sample – a pilot study only

Figure 7.8 Comparison of Driver Assistance – Flat Tires

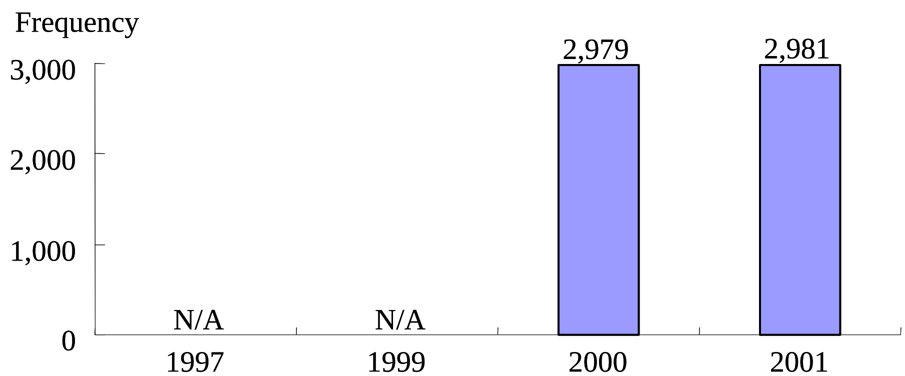
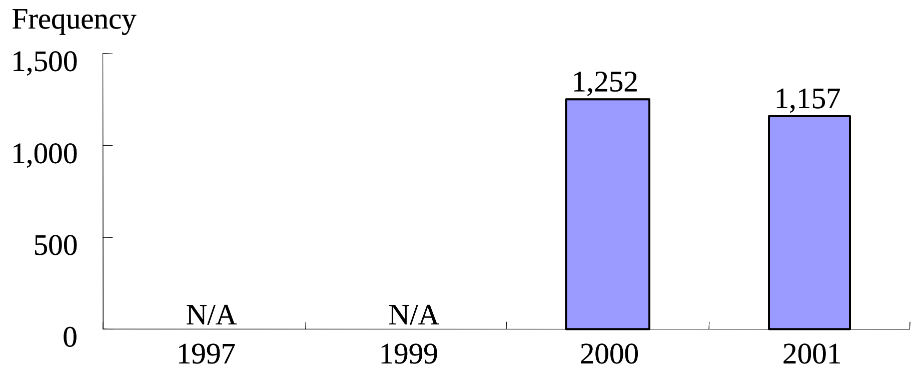


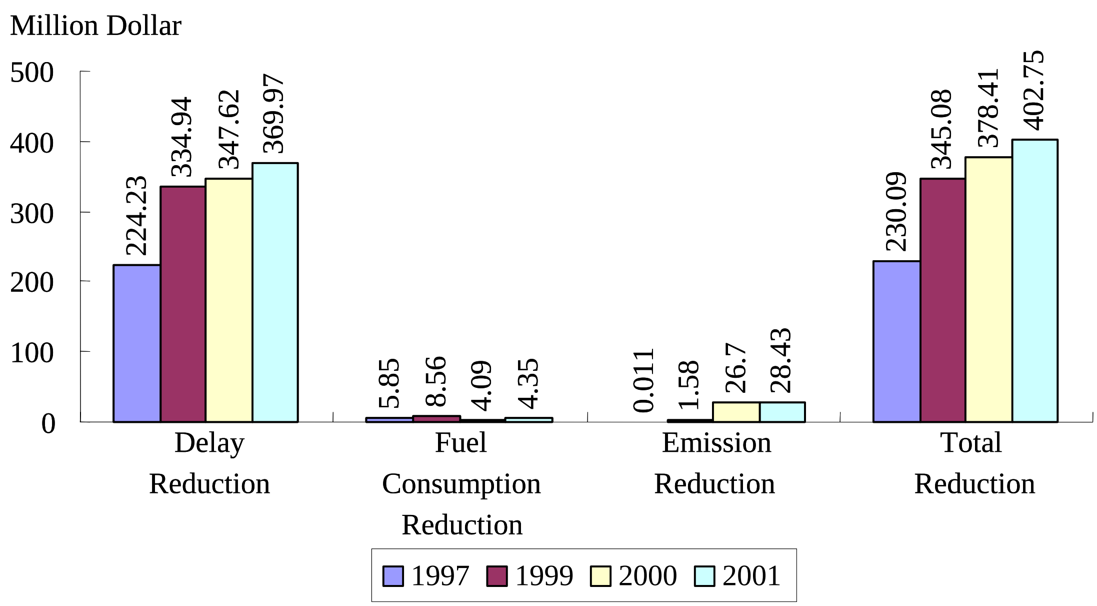
Figure 7.9 Comparison of Driver Assistance – Gas Shortage



Direct Benefits

Figure 7.10 shows direct benefits to highway users from Year 1997 to Year 2001, where the reductions in delay, fuel consumption, and emissions have all increased at a modest level over time.

Figure 7.10 Comparison of Direct Benefits to Highway Users



* Insufficient sample – a pilot study only

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Based on our previous research results and experience, this study has performed a rigorous evaluation of CHART's performance in the year 2001, and has computed the resulting benefits due to its operations under the constraints of the availability and quality of the data. In response to the availability of the CHART-II system, the study has expanded its research scope to include a comprehensive data quality evaluation, intended to provide the basis for further enhancement of the CHART-II Database.

Overall, CHART has made significant progress in both recording and quality improvement of the data, especially after the use of the CHAR-II Database, although much remains to be improved to reliably account for all associated benefits.

CHART's efficiency in responding to and managing incidents has also been improved substantially. For instance, the average response time has been reduced from 15.22 minutes in the year 2000 to 13.84 minutes in the year 2001, and the average incident duration has also been shortened from 33 minutes to 29 minutes over the same period. The total benefits due to CHART operations have also increased from $380 million in Year 2000 to around $ 400 million in Year of 2001.

In summary, the operations of CHART by MSHA in the year 2001 have yielded significant benefits in the following areas:

- Assistance to drivers' service requests
- Reduction in the trip delay time
- Reduction in the fuel consumption cost
- Reduction in emissions

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

- All impacts associated with secondary incident
- Potential impacts on neighboring surface streets during incidents
- Reduction in the overall stress to drivers in major commuting corridors

The aforementioned benefits, along with ever-increasing congestion and incidents, certainly justify the need to better manage and continuously upgrade the current incident response program. However, "an efficient incident response" cannot alone effectively reduce the number of primary highway incidents. Considering the current volume level on major commuting highways, it is undoubted 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 be viewed, at least, as necessary as implementing an incident management program. An in-depth analysis of the nature of incidents and their spatial distribution has offered some insight into developing safety-improvement measures.

8.2 Recommendations and Further Development

The primary recommendations based on the performance of CHART in the year 2001 are summarized below:

- *Training operators to effectively record all essential operations-related data such as cleared time.*

  Although the overall data quality has been improved significantly in the year 2001, many vital information items in the CHART II Database were either missed or undocumented. For example, more than 60% of incident-cleared times were reviewed in the Year 2001 CHART-II Database. Such information is essential for computation of operational efficiency and the resulting benefits.

- *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 laborious manual search and input of associated highway segments.*

- *Developing an integrated performance database that consists not only of incident reports but also all data, such as traffic volume, needed for direct benefit computation or estimation of the safety-related contribution, including potential reduction in secondary incidents and lane-changing-related accidents due to a quick removal of stationary vehicles or debris on highway travel lanes.*

- *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 as expected.*

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