CHART

Incident Response Evaluation
Final Report

prepared by

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1. EXECUTIVE SUMMARY

The MaryIand State Highway Administration (MSHA) has been an active player in Intelligent Transportation Systems (ITS), largely through the success of ‘its CHART Program (Chesapeake Highway Advisories Routing Traffic), which to&y is the highway operations element of Maryland’s ITS Program. It is CHART’s mission to improve efficiency and safety on Maryland’s major highways through the application of ITS technology and interagency teamwork. With principle emphasis on the Washington, Baltimore, Annapolis and Frederick Transportation grid, CHART focuses on approximately 375 miles of interstate bighways and 170 miles of state highway arterials in this area.

The CHART program relies on communication, coordination, and cooperation among agencies and disciplines, both within Maryland and with neighboring states, to foster the teamwork necessary to achieve its goal. CHART combines the resources of traffic management, emergency management, maintenance, engineering, enforcemenet, and education. Figure I-1 illustrates the roadway network covered by the CHART program

1 .1 CHART Program Components

CHART is comprised for four major components:

Traffic Monitoring: Using remote sensors, information received from agency field units, and information received from individual travelers to assess real-time traffic flow and weather conditions. Supporting this detection with closed circuit television cameras to verify conditions and initiate a response.

Incident Response: Once the surveillance/detection system has identified a problem, an immediate response is initiated to clear the incident and reopen lanes as quickly as possible, while protecting the safety of victims, travelers and emergency personnel. **CHART** operates a very successful incident management program which depends heavily on the cooperation and teamwork developed among the Maryland State Highway Administration the Maryland State Police and the Maryland Transportation Authority.

Traveler Information: CHART provides real-time information concerning travel conditions on the main roads in the primary coverage area This information can be used both prior to leaving (pre-trip) and en-route. Traveler information focuses upon traffic conditions related to weekday commuting periods, major special events, seasonal recreational peaks, accidents, severe weather, and roadway construction.

Traffic Management: The CHART system mamages freeway and arterial traffic flows with the goal of greater efficiency and safety. When freeways and other primary routes are unexpectedly congested, some traffic will shift to surface arterials.

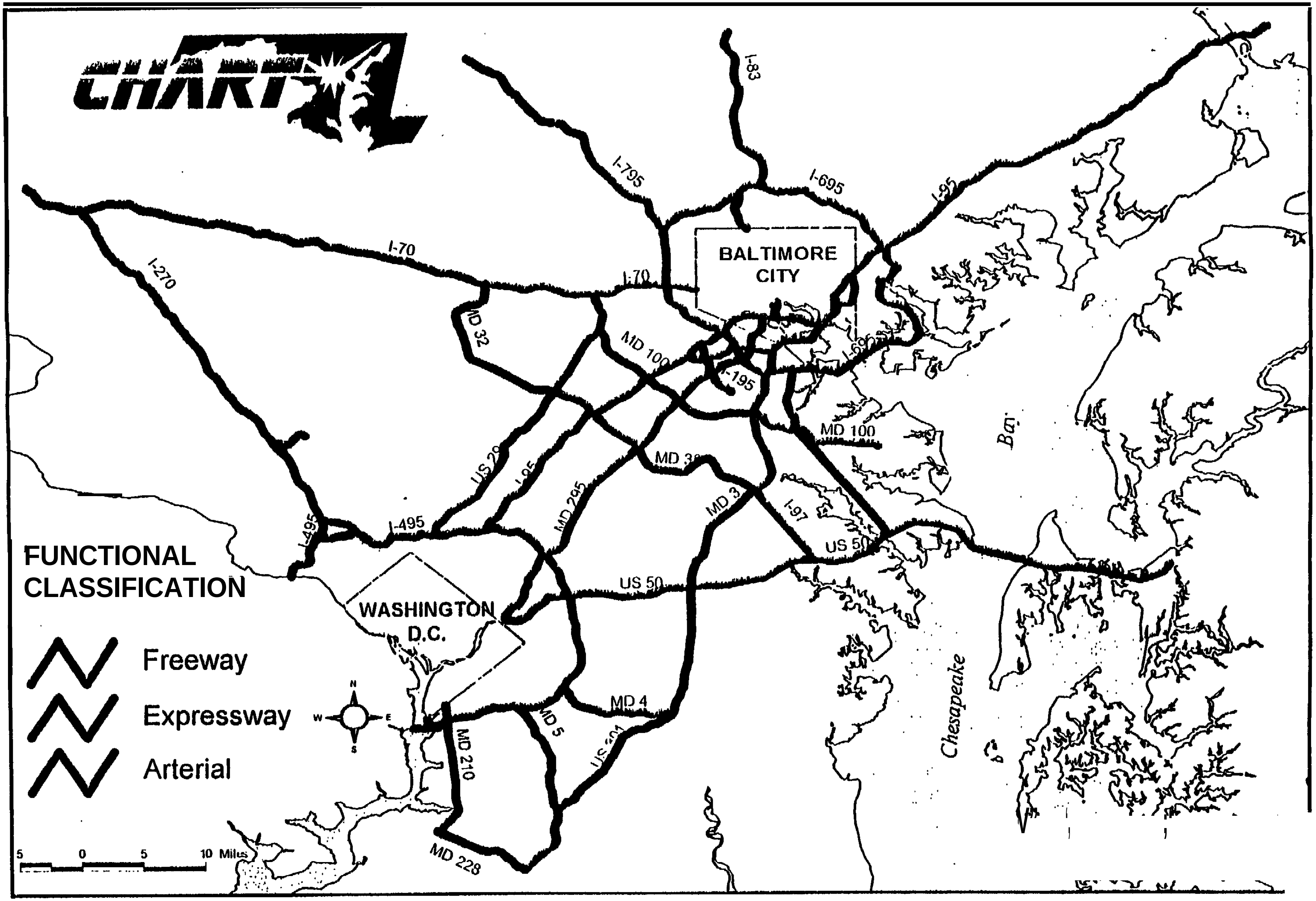
CHART
I-83
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I-695
I-95
BALTIMORE CITY
I-70
I-70
I-270
MD 32
MD 100
I-195
MD 100
I-495
US 29
I-95
MD 295
MD 3
I-97
US 50
I-495
US 50
WASHINGTON D.C.
MD 4
MD 5
MD 210
MD 228
Chesapeake
Bay
FUNCTIONAL CLASSIFICATION
Freeway
Expressway
Arterial
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Arterial signal systems are being installed statewide to provide remote and adaptive traffic signal control and coordinated signal timing. Traffic signal technicians and **CHART** system operators can better balance demand and capacity by adjusting traffic signal timing romotely .

This study focused on the incident response component of the CHART program, and specifically, the ability of the CHART program to respond to unplanned incidents. Unplanned incidents include accidents, disabled vehicles, roadway debris, and roadway failure, but do not include construction, maintenance, or special events. The rime frame for the study focuses on the period between 1990 and 1994.

The purpose of the study was to assess the performance of the **CHART** Program from the highway user's perspective, determine if there are benefits, and, if there are benefits, quantify them using Maryland data, supported by national studies of comparable programs. The methods used to evaluate the program as well as the results, conclusions, and recommendations of the study were to be understandabl***e,*** believable, and defensible.

In situations where Maryland data was not available, or where it was necessary to develop assumptions, conservative estimates were used to avoid inflating the estimated benefits of the CHART program. Some examples of conservative assumptions applied are that:

- the net expansion factor to estimate the number of incidents from the number of accidents was 14 to 1 (other studies use figures as high as 25 or 30 to 1);
- potential cost savings from reducing the number of secondary incidents were not included in the monetary value of WART incident management program benefits;
- medical and legal costs associated with reducing the number of secondary accidents involving property damage. injury or death were not included in the benefits.

The evaluation was performed at three levels; system-wide, corridor-level, and site-specific, and comparisons were made of the findings and conclusions from each level of evaluation. The primary measures of efktiveness (MOEs) considered important to the CHART program were reduction in delay, e.g. extra time spent on the CHART network as the result of incidents, reduction in secondary incidents, e.g. those caused or the result of a primary incident, and reduction in fuel consumption. The bottom line question to be answered was:

> "Has or will implementation of the CHART program resulted in cost savings to the users of the system, the traveling public who use the **CHART** roadway network?"

1.2 Findings and Conclusions

- The most significant finding of the evaluation was that the benefits of the CHART incident response program, supported by the currently deployed elements of the traffic surveillance program, exceed the system's capital, operating and maintenance costs to date by a ratio of over 7 to 1 in terms of the estimated reduction in delay, fud consumption and secondary incidents.

- The incident management patrols that are deployed on the CHART network are being used where they are needed most, in that they are covering the segments of the network, specifically the Capital Beltway (I-495) and the Baltimore Beltway (I-695), that experience the most non-recurring delay and the highest number of incidents per mile.

- There appear to be more delay reduction benefits from serving an incident past the location of recurring congestion than serving the same incident prior to the location of that same recurring congestion. Often, the delay reduction benefits of serving an incident located prior to recurring congestion are limited since incident-related delay may reduce the delay caused by recurring congestion, with the net result being little change in total delay. This general statement is less true of accidents (a sub-set of incidents). Accidents often generate larger capacity losses. Therefore, serving accidents is usually beneficial from a delay perspective regardless of the location of the accident with respect to recurring congestion.

- Increasing the number of incidents served by the freeway service patrols would have ***a*** direct impact on the annual delay and fuel savings. Additional ATMS components will increase the utilization of existing patrols by accelerating detection, verification, and response rates.

- A key finding of the site-specific analysis of three incident videos on the CHART network was that the capacity remainging during an incident as determined from the videos was comparable to data obtained from national data of observed incidents.

1.3 Recommendations

The primary recommendations based on the analyses, findings, and conclusions are as follows:

- continue to improve the utilization of existing freeway service patrols and install additional surveillance/detection devices to support their efforts
- periodically record and retain video tapes of incidents visible from video cameras for further benefits analysis
- develop a simplified incident recording form for use by CHART service patrols, State police, and private sector support units
- develop a recurring/non-recurring congestion monitoring program using detector data to back-up the system-wide estimation procedure
- issue a motorist mail-in survey to those served by freeway service patrols
- use CHART assets and resources to monitor other aspects of transportation efficiency, e.g. vehicle occupancy, operational improvements
- evaluate other components of the CHART program, i.e. traffic monitoring, traveler information traffic management, as they are implemented and/or enhanced
- refine the system-wide benefits estimation procedure to incorporate other factors, e.g. truck traffic, surveillance and detection coverage, secondary incident reductions, recurring congestion, and the effects of recurring congestion on non-recurring congestion.

2. INTRODUCTION

2.1 Roadway Network Coverage

In 1994, the CHART roadway network covered 550 miles of freeway and expressway facilities in the Frederick-B&more-Annapolis-Washington "diamond", consisting of 77 percent freeways, 17 percent expressways and six percent arterial roadways. Fifty-four percent of the network is classified as interstate highway and all CHART ***roadways are*** part of the approved National Highway System (NHS) for Maryland

An evaluation study prepared by JHK based on 1994 traffic volumes and lane configurations concluded that 385 ***miles (70 percent) of the CHART network roadways experience recurring congestion,' as*** shown in Figure 2-l. The JHK evaluation also investigated accident trends between 1990 and 1992. This investigation identified the roadway sections with more than 15 accidents per mile per year and provided a summary of the accident characteristics for each section. The study identified roadway sections with more than 15 accidents per mile per year as sections that suffer from significant non-recurring congestion. Based on the results of this evaluation, 210 ***miles (38 percent) of the CHART roadway network suffer from significant non-recurring congestion,' as shown in*** Figure 2-2.

Based on 1993 data, Maryland has 29,3 13 miles of public roadways, carrying 33.4 billion vehicle miles of travel per year. Based on 1994 traffic volumes, the 550-mile CHART network carries 14.7 billion vehicle miles of travel per year: or about one-third of the total vehicle miles of travel on public highways in the State. Freeways in the Washington, DC and Baltimore areas covered by the CHART program comprise only 34% of the total roadway miles and yet carry 40-45% of the daily vehicle miles of travel.'

2.2 CHART Incident Management Program Coverage

Washington DC and Baltimore Metropolitan Areas (excluding Baltimore tunnels)

The **CHART** incident management program provides Emergency Response Units (ERUs) and EmergencyTraffic Patrols (ETPs) in both metropolitan areas. Emergency Traffic Patrols (ETPs) assist motorists with disabled vehicles, minor repairs and fuel. The Emergency Response Units (FRUs) set up temporary traffic control at the incident site to free up other assets to deal with the incident itself

1 CHART Vision and Deployment Plan, Draft Report JHK & Associates, Oct. 1995
2 CHART Vision and Deployment Plan, Draff Report, JHK 8 Associates, Oct. 1995
3 1993 Highway Statistics, FHVVA-PL-94-023, 1994

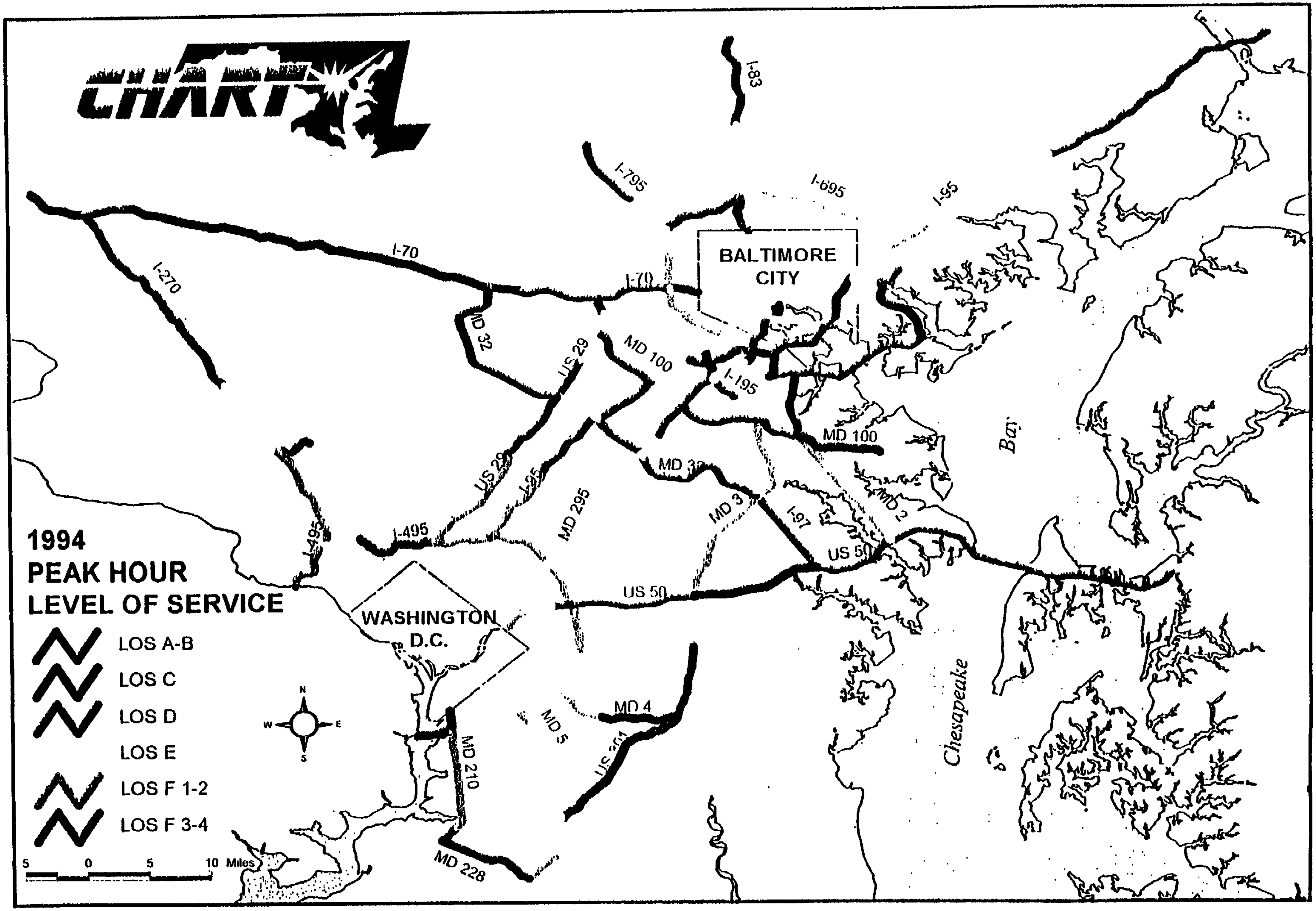
CHART
I-83
I-795
I-695
I-95
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I-270
BALTIMORE CITY
MD 32
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US 29
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Bay
US 29
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MD 295
MD 3
I-97
MD 2
I-495
US 50
US 50
WASHINGTON D.C.
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MD 5
MD 210
MD 228
Chesapeake
1994
PEAK HOUR
LEVEL OF SERVICE
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LOS C
LOS D
LOS E
LOS F 1-2
LOS F 3-4
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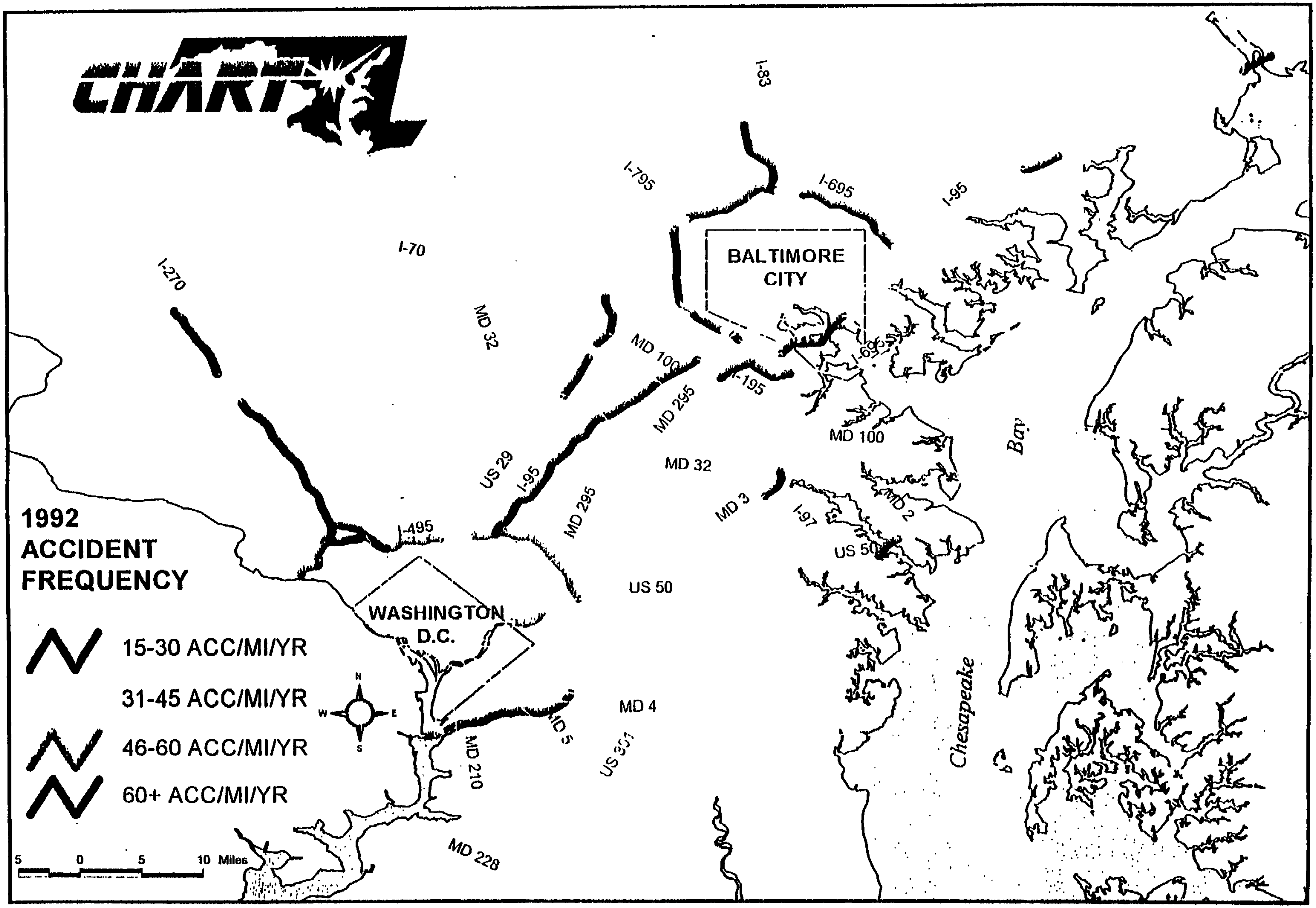
CHART
1992
ACCIDENT
FREQUENCY
15-30 ACC/MI/YR
31-45 ACC/MI/YR
46-60 ACC/MI/YR
60+ ACC/MI/YR
BALTIMORE
CITY
WASHINGTON
D.C.
I-83
I-795
I-695
I-95
I-70
I-270
MD 32
MD 100
I-195
MD 295
US 29
I-495
MD 3
I-97
MD 2
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One ERU patrols each beltway (I-495 and I-695). A second unit is available if the local traffic operations center supervisor is operating the second vehicle. Three to four ETPs patrol each beltway. ERU and ETP patrol areas include their respective beltways and radial routes connected to that beltway. The Washington, DC units occasionally provide services to adjacent sections of the Capital Beltway in Northern Virginia. Emergency units can be called to respond to major incidents that occur far from their normal patrol areas.

2.3 Application of CHART Assets to Incident Management

Incident management programs are implemented to accelerate the process of clearing incidents. From the standpoint of incident management, the four stages of an incident are ***detection, response, management*** and ***recovery.*** CHART assets are applied to manage incidents during each stage.

Detection

Incidents on the CHART roadway network can be detected by CHART surveillance component assets (pavement and radar detectors), by State Police or emergency patrols, or by citizens calling in from cellular phones. The application of these technologies accelerates the process of detecting and responding to incidents.

Response

Once an incident is detected, either surveillance cameras or the first arriving response units verify the incident and determine what assets are required to deal with the situation. This may include calling for an ambulance, a fire truck, a CHART Emergency Traffic Patrol (ETP), a specific type of tow truck or wrecker, a hazardous materials unit, and/or traffic control support.

Management

Management includes set up for minor incidents consisting of disabled vehicles or road debris, and clearance of an incident. CHART Emergency Traffic Patrols (ETP) deal with all aspects of the incident's management For major incidents, the CHART Emeergency Response Unit (ERU) works to direct traffic to detours and to expedite the restoration of normal capacity as soon as possible.

Recovery

Recovery occurs after the incident has been completely removed and the full capacity of the highway has been restored.

3. MEASURES OF EFFECTIVENESS FOR CHART EVALUATION

Measures of effectiveness (MOE's) evaluate performance of the CHART incident management program. The criteria for selecting measures of effectiveness are related directly to the goals of the CHART program. The MOE's demonstrate whether or not the CHART goals are being achieved, and whether the traveling public is benefiting from the services provided by the CHART program.

CHART's primary goals are to minimize congestion and improve safety on Maryland's highway system. With respect to incident management, specific objectives of CHART include the following:

- Reduce probability of secondary incidents
- Reduce detection/verification, response and management times
- Improve travel time reliability
- Maintain peak period capacity of strategic transportation corridors
- Reduce motorist delay
- Improve accessibility for emergency response vehicles
- Provide incident impact information to motorists in a timely manner so that they can change their trip plans and avoid delays.

3.1 Recommended Measures of Effectiveness (MOEs)

Based on research of other comparable programs and the goals of the CHART program, MOE's for evaluating the CHART incident management program's ability to respond to unplanned incidents were recommended. The MOE's were categorized based on the study area in which they apply. ***The three category*** groupings were ***system-wide, corridor-level and site-specific.***

- ***System-wide MOE's were*** based on a system-wide analysis of the CHART program using typical delay relationships published in research, Maryland traffic and accident data, and m-house survey opinions.

- ***Corridor-level MOE's were*** used to evaluate three individual freeway corridors, and account for the impact of typical incidents on normal traffic operations on those corridors.

- ***Site-specific MOE's were obtained*** from traffic simulations of real freeway incidents based on flow data recorded on tape. These traffic simulations account for the travel time and delay impacts of variations in traffic flow passing the incident, and other effects that are diffucult to measure using field data.

Table 3-1 summarizes the recommended MOE's approved by SHA staff for this study. The table also identifies the procedures used to estimate each MOE.

Table 3-1

Recommended Measures of Effectiveness for Evaluating the Maryland CHART Incident Management Program's Ability to Respond to Unplanned Incidents

System-Wide Evaluation (using estimation procedure)

- **Vehicle Hours of Delay due to Non-recurring Congestion**
- Excess Fuel Consumption over Normal Travel Conditions

System-Wide Evaluation (using empirical data)

- Potential Reduction of Secondary Incidents (analysis of **MAARs** data)
- Reduction in Time for Detection/Verification, Response and Management (SOC Staff experience)

Corridor-Level Evaluation (scenario comparison using a traffic model FREQ))

- Corridor Travel Time
- Passenger Hours of Travel Time and Delay
- Vehicle Miles of Travel Served versus Vehicle Miles of Demand
- VMT-Weighted Average Speed

Site Specific Evaluation (based on actual incidents recorded on tape)

- Variations in Traffic Flow Rates (average lane capacity) Passing the Incident
- Events During Management Stage that Trigger Increases/Decreases in Traffic Flow Rates Passing the Incident Site
- Lane Utilization and Truck Impacts

3.2 Evaluation Methods

The methods for performing an evaluation may be based on empirical data, estimation procedures; or the application of ***traffic models.*** ***Empirical data collected in the*** field using manual or automated equipment can be used to directly or indirectly compute MOE's Field data collection is generally too costly to appiy on a system-tide basis, but a planned program of occasional field data collection can be used to validate and supplement estimates of MOE's obtained from the other two methods (estimation procedures and traffic models). Empirical data collected from automated methods can be a very cost effective way of obtaining data. Automated means include the use of automatic traffic counting station data, and data from the surveillance and detection field equipment of and advanced traffic management system (ATMS) such as CHART.

Estimation procedures ate necessary when the MOE cannot be obtained directly through field measurement, but can be estimated because of a well-established relationship between the MOE and other traffic characteristics that can be measured through direct data collection. Commonly available data that support these estimation procedures include traffic volumes, accidents, roadway geometry, roadway improvement schedules,. traffic growth characteristics and vehicle elassification. Examples of MOE's that can be predicted using estimation procedures include incident characteristics (type, frequency and duration), capacity reductions due to incidents, motorist delay due to incidents, fuel consumption and emissions.

Traffic models provide a powerful means of estimating a wide variety of MOE's that cannot be estimated easily from field data collection or estimation procedures. Traffic models often include algorithms to estimate various energy, air quality and economic MOE's including fuel consumption, pollutant and noise emissions, and user costs. Once coded and calibrated, traffic models can be used to assess various "what-if" scenarios involving different traffic control and incident management treatments.

3.3 Available Data

Traffic Volumes

The system-wide estimation procedure developed to assess the delay benefits of CHART used 1992 daily traffic volumes provided by Maryland SHA. 1992 data were used to be consistent with the accident data used for the study, which represented the years 1990 through 1992.

Traffic models require traffic volume data that are stratified by time intervals of five to 15 minutes. Volume data collected to this level of detail were not available from SHA. However, hourly counts were available for ramps and automatic traffic recording stations on various CHART network roadways. 1995 hourly mainline and ramp volumes were obtained for the Maryland portion of the Capital Beltway and for the southwestern portion of the Baltimore Beltway. Using interpolation techniques, these hourly volumes were smoothed to approximate 15-minute traffic flow rate distributions for use in simulation.

Roadway Geometry

Adequate geometric detail for purposes of traffic simulation was obtained using a drive-through survey of each applicable freeway segment. Key information included number of through lanes, ramp junction spacing, significant vertical profile features, ramp-junction configuration, merge/diverge free flow speeds, mainline free flow speeds, auxiliary lane configurations and ***cross*** section characteristics (lane width, lateral clearance, shoulder width).

Incident Data

Accident data for Maryland roadways were available on computer databases through 1994 in the Maryland Automated Accident Records System (MAARS). The most recent three years were stored in a format compatible with IBM PC computers.

CHART incident management patrol service records were the only source of data on the number of incidents that are not recorded as accidents. The data were limited by the current incident management patrol coverage area. Regardless of the degree of coverage, some minor incidents remain unrecorded. Because of these limitations, estimates of the total number of incidents on the CHART roadway network were based on a combination of MAARS accident data, and incident-to-accident ratios obtained from another source.'

CHART Operations Summaries

Each CHART Traffic Operations Center (TOC) produces a monthly report summarizing the number of reported incidents, the number of assists from emergency response teams, use of variable message signs (VMS) by purpose and use of traveler advisory radio (TAR) by purpose. A separate tabulation was produced summarizing the type of assistance provided by emergency traffic patrols stratified by over 15 categories. The Baltimore and College Park TOC's (#3 and #4) also recorded average response and traffic management times for the Emergency Traffic Patrols and the Emergency Response Units. Based on statistics compiled monthly over the past one and one-half years, monthly response times average five to eleven minutes. Monthly average management times range from 15 to 45 munutes with an annual average of about 26 munutes per incident. These figures are in line with national statistics, and support assumptions made for this study.

4 Incident Management Study, Draft Final Report; Cambri dge Systematics, Inc. et.al. June, 1990

4. SYSTEM-WIDE EVALUATION

4.1 Delay Reduction

The primary objective of the system-wide evaluation of CHART benefits was to estimate the reduction in delay experienced with the existing incident management program covering a portion of the 550-mile CHART roadway network, and to estimate a benefit-cost ratio based on delay reductions and fuel consumption savings. Accident data were obtained from the system-wide accident evaluation prepared by JHK & Associates covering the years 1990 through 1992. The number of incidents currently served by the CHART program was estimated based on limited data from Maryland TOC records for the year 1995. Incident management program capital, operating and maintenance costs were obtained from Maryland SHA staff. Unit costs for delay time and fuel were developed by consensus with SHA staff.

The system-wide evaluation of benefits estimated the number of incidents on each CHART roadway segment based on available accident data, and the total delay experienced by motorists due to these incidents. The procedure for estimating these benefits was based on the steps outlined in Figure 4-1, a flow chart that summarizes the procedure. The procedure incorporates a four-step incident modeling process. Most of the process was adopted from research prepared by Cambridge Systematics, Inc. et. al. for the ***Trucking Research Institute, The ATA Foundation, Inc.***[5]

The factor-of-ten relationship between the total number of reported incidents and the total number of accidents is commonly recognized in both the Cambridge study and other studies. The expansion factor to go from reported incidents to all incidents is based on what is reported in the same Cambridge study. When the 10:1 factor is combined with the 30 percent expansion to account for unrecorded incidents, the total number of incidents is approzimately 14 times the total number of accidents. This is considered to be reasonably conservative when compared to ratios reported by others. In fact California uses ratios as high as 30:1 for estimation purposes.[6]

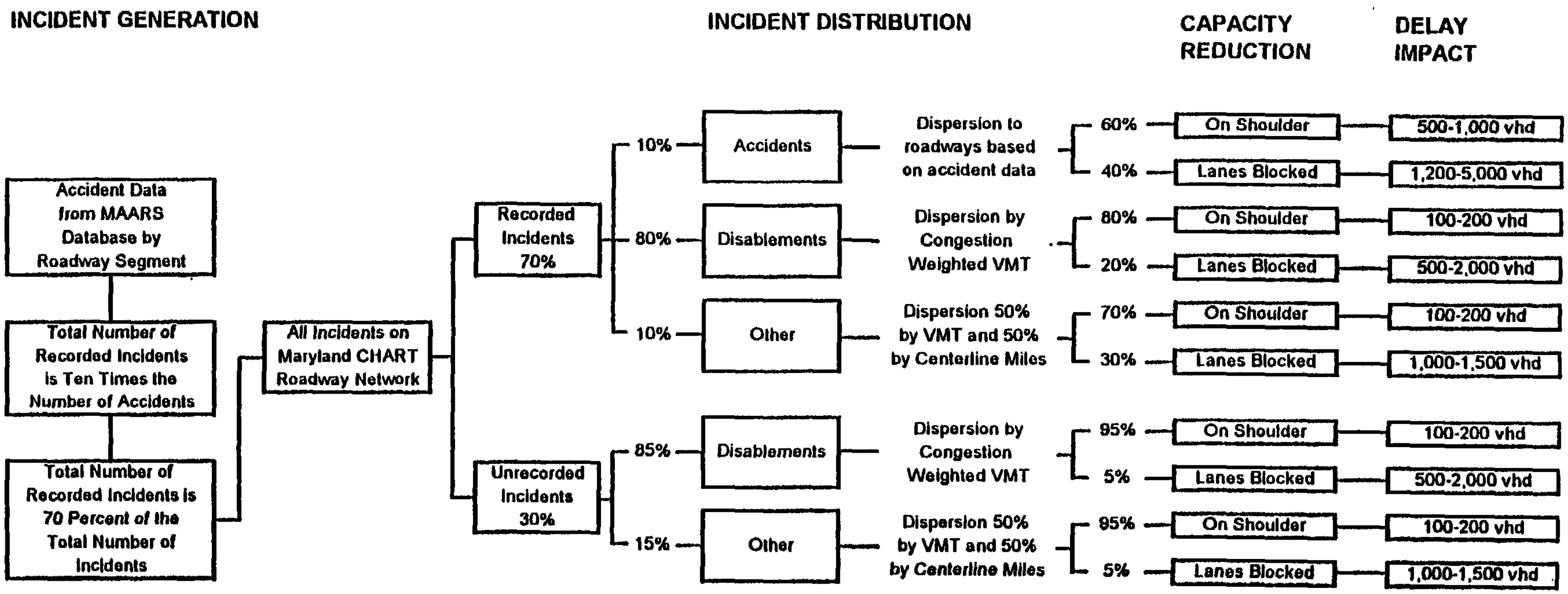
Since the published process did not include a breakdown of unreported incidents, a number of assumptions were incorporated to expand the process to estimate the number of unreported incidents by type and to quantify their respective impacts on non-recurring delay. These assumptions were selected to produce a conservative (potentially low) estimate of the number of incidents and non-recurriug delay. For example, it was assumed that no serious accidents go unreported. Therefore, all unreported incidents are assumed to

5 Incident Management Study, Draft Final Report, Cambridge Systematic& Inc. etai., June, 1990

6 A Epps, J.C. Cheng, AD. May, Developing Methodologies for Quantifying Freeway Congestion Delay, institute of Transportation Studies,. University of California at Berkeley, 1994.

Figure 4-1

Estimation Procedure for Computing Delay Impacts of Non-recurring Congestion due to Incidents on the Maryland CHART ATMS Roadway Network



Source: Adopted from "Incident Management Study" with assumptions regarding the distribution of unrecorded incidents.

be less severe in terms of delay impacts. It was also assumed that a majority of unreported incidents only affect the shoulder, and that very few unreported incidents block traffic lanes. These assumptions resulted in a conservative estimate of deiay, and a conservative estimate of the benefit-cost ratio of the CHART incident management program. These and other assumptions can be replaced by actual CHART performance data when this information becomes available.

4.1.1 System-wide Incident impacts without CHART

The first application of the estimation procedure for determining the system-wide impact of incidents on delay used the database of accident and traffic volume data compiled by JHK. This database was based on MAARS accident data from 1990 through 1992, and daily traffic volumes from 1992. A summary of the results is shown in TabIe 4-I.

Table 4-1

System-wide Incident Impacts Assuming No Incident Management Program

Daiiy Vehicle Miles Traveled	**38.1 million**
Annuai Number of incidents	**105,000**
Average Incidents per Mile per Year	**1 29.4**
Shoulder Incidents	**86,500 (82%)**
Shouider Incident Portion of Delay	**35%**
In-Lane Incidents	**18,500 (18%)**
In-lane Incident Portion of Delay	**65%**
CHART Network Annual Non-recurring Delay	**40.1 million vehicle hours**

The procedure predicted an overall network-wide delay of 40.1 million vehicle hours per year due to non-recurring incidents. The average delay per incident for shoulder incidents was 165 vehicle hours and the average delay for incidents blocking lanes was 1,403 vehicie hours per incident. 65 percent of motorist delay was incurred by incidents that block traffic lanes. even though these incidents comprised only 18 percent of all incidents.

In order to demonstrate the validity of the total delay estimate of 40.1 million vehicle hours per year, the results were compared to nation-wide estimates of deiay due to non-recurring congestion predicted by studies prepared by FHWA. During a 1984 study, the nation-wide total delay due to non-recurring congestion was estimated to be 1.6 billion vehicle hours per year.' An update to this study in 1987 predicted that the delay had increased to 2.0 billion vehicle hours per year. Based on traffic forecasts provided by all major metropolitan areas, the total nationwide delay was expected to reach 8.0 billion vehicle

7 Quantification of Urban Freeway Congestion and Analysis of Remedial Measures, Jeffrey A. Lindley. FHWA-RD-87/052. Oct. 1986

hours by 2005.8 Based on the trend exhibited by these figures, the 1992 annual delay was about 4.0 billion vehicle hours.

The State of Maryland has 1.9% of the nation's urban vehicle miles of travel (VMT), 2.2% of the nation's total VMT, and 1.9% percent of the nation's population Since delay is related to vehicle miles of travel and indirectly related to population, Maryland would bear about two percent of the nation's 4.0 billion vehicle hours of delay, or 80 million vehicle hours in 1992. This is a conservative estimate, since congestion in Maryland's major metropolitan areas is among the most severe in the country. In fact, Washington D.C. is rated #2 in the country behind Los Angeles in relative total congestion9

Since the CHART roadway network carries one-third of all of the vehicle miles of travel in the state," and this demand is carried by the most congested roadway facilities on the state highway system, it is reasonable to believe that at least one-half i.e. 40, of the 80 million vehicle hours of delay statewide occurred on the CHART roadway network, This is further supported by non-recurring congestion estimates for the Baltimore and Washington metropolitan areas prepared by the Texas Transportation Institute". This study concluded that over 75 percent of the non-recurring congestion in each of these two cities occurs on the freeway and ***expressway*** system (94 percent of the CHART roadway network is freeway and expressway). The remaining non-recurring delays were attributed to travel on principal arterial roadways.

The estimation procedure database also was used to obtain total delay and average delay estimates for the CHART roadway network by route number. Table 4-2 provides a summary of the results sorted by descending values of average delay per centerline mile per year. The tabulated results identify I-495 (Montgomery County) and I-695 as the facilities suffering from the most severe non-recurring congestion impacts. I-95 and I-295 rank third and fourth, followed by MD 295, US 29,1-83 and I-270 in the next grouping. The results are consistent with MAARS data and confirm that incident management patrols currently are deployed where they are most needed and most effective.

8 Urban Freeway Congestion Problems and Solutions: An Update, ITE Journal, Dec. 1989

9 D.L Schrank. S.M. Turner, T.J. Lomax, Urban Roadway Congestion-1982 to 1992, Volume 1: Annual Report, Research Report FHWA 95/l 131-7, Texas Transportation Institute September 1995

10Based on MOOT traffic volume data and statewide VMT estimates from 'Highway Statistics-1993'.

" (See Reference 9)

Table 4-2

1992 Distribution of Delay by Route Number

Route Number	Length (miles)	Daiiy Vehicle Miles Traveled	Annual Vehicle Hours of Delay	Vehicle Hours Delay per Mile
I-495 •	15.67	2,533,646	4,531,116	289,200
I-695	48.03	8,399,513	5,052,611	174,900
I-95 **	109.86	12,501,897	12,964,137	118,000
I-295	0.78	54,912	90,677	116,300
MD 295***	27.62	2,115,491	2,364,990	85,600
us 29	20.10	945,653	1,624,424	80,800
I-83	17.56	1,471,140	1,361,743	77,500
I-270	35.65	3,128,102	2,657,498	74,500
US 15	3.84	186,068	174,778	45,500
I-370	2.86	149,650	102,274	35,800
I-795	8.95	435,669	298,889	33,400
I-97	17.88	975,771	524,529	29,300
I-195	3.82	146,546	112,015	29,300
us 50	127.11	4,112,087	3,346,764	26,300
MD 32	17.44	462,455	285,112	16,300
I-70	90.49	3,443,308	1,125,305	12,400
US 340	4.08	123,216	46,604	11,400
I-895	14.96	247,109	97,922	6,500

* l-495 data includes only the Montgomery County section of the Capital Beltway
** l-95 data includes the Prince Georges County section of the Capital Beltway
*** MD 295 data includes the entire Baltimore-Washington Parkway in Maryland

4.1.2 System-wide Incident Impacts with Existing Program

The estimated system-wide delay assumed that no incident management program was available to serve incidents on the CHART roadway network. The impact of the current (1994) motorist service patrol coverage supported by limited traffic surveillance on non-recurring congestion was estimated.

The portion of the roadway network covered by existing service patrols was based on ***coverage*** maps from the current ***CHART Vision and Deployment*** plan being developed by

JHK & Associates.[12] The portion of incidents covered by the current service patrols was obtained by comparing the number of incidents served by the patrols (based on records from the Baltimore and College Park Traffic Operations Centers) and the estimated total number of incidents on the CHART roadway network from the estimation procedure.

Table 4-3 shows that the current service patrols are depioyed in areas of greatest need. Though the service patrols cover only 37 percent of the total CHART roadway network mileage, the roadways in the coverage area carry 57 percent of the total vehicle miles of travel on the CHART network, incur 57 percent of the number of incidents on the network, and incur 70 percent of the total non-recurring congestion on the network. The average number of incidents per mile is 60% higher in the area covered by service patrols than it is on a system-wide basis.

Table 4-3

Characteristics of Roadways with Service Patrols versus All CHART Roadways

Characteristic	CHART Roadways with Service Patrols	Overall CHART Roadway Network
Centerline Miles of Roadway	208 (37%)	567
Vehicle Miles Traveled per Day	21.8 million (57%)	38.1 million
Annual Number of Incidents	60,000 (57%)	105,000
Gross Non-Recurring Incident Delay (vehicle hours per year)	28.9 million (72%)	40.1 million
Annual Average Number of Incidents per Mile	205	129

Note: Based on accident data from 1990 through 1992 and daily traffic volumes from 1992

Table 4-4 shows the estimated delay reduction, fuel savings and cost savings resulting from the current service patrol coverage. Based on 1994 and 1995 records obtained from the Baltimore and College Park Traffic Operations Centers, approzimately 16,000 incidents are served by the current freeway service patrols each year. This is approximately 15 percent of the estimated 105,000 incidents on the CHART roadway network, and about 27% of the estimated 60,000 incidents that occur within the 208-mile CHART service patrol area. This 15 percent coverage affects incidents that cause 6.0 million of the e&mated 40.1 million annual vehicle hours of delay due to non-recurring congestion. After applying the delay reduction percentages due to the change in incident duration to those incidents sewed by the current freeway service patrols with existing (1994) ATMS support a net delay savings of 2.0 million vehicle hours per year was estimated. The delay reduction percentages were derived from an analytical study using

[12] CHART Vision and Deployment Plan, Draft Report, JHK 8 Associates, Oct. 1995

standard queuing theory of the relationship between incident duration, initial number of traffic lanes, number of lanes closed, the type of incident and total incident-related delay.

Table 4-4

Estimated Delay Reduction, Fuel Savings and Cost Savings due to Freeway Service Patrols with Existing (1994) CHART ATMS Support

Total Annual Delay due to Non Recurring Congestion	**40.1 million vehicle hours**
Percent of Incidents Sewed by CHART Service Patrols *	**15%**
Portion of Delay Susceptible to Mitigation by Current Service Patrol Coverage	**6.0 million vehicle hours**
Estimated Delay Reduction due to Current Service Patrol Coverage	**2.0 million vehicle hours**
Annual Fuel Savings due to Current Service Patrol Delay Reductions	**398,000 gallons**
Annual Public Cost Savings **	**$30.5 million**

* Incident coverage estimates based on available incident data from TOC 3 and 4

** Cost estimate based on $10 per person hour of delay, an average vehicle occupancy of 1.5 persons and $1.25 per gallon of fuel.

Fuel consumption savings were based on fuel economy rates for the year 1990 used by the FREQ freeway simulation model. These fuel rates account for the fuel consumption impact of speed changes on average travel speeds under congested conditions. The average fuel savings due to incident-related delay reductions is one gallon for every five vehicle hours of delay saved. A reduction of 2 million vehicle hours of delay produces a fuel savings of 398,000 gallons per year.

The estimated cost savings is based on an hourly cost of S15 per vehicle hour and a fuel cost of $1.25 per gallon The cost per vehicle hour is based on a 1990 national figure of S10.34 per vehicle hour for passenger cars and approximately S25.00 per vehicle hour for commercial trucks." Assuming 92 percent passenger cars and eight percent trucks, a composite cost of $11.5 1 per vehicle hour is obtained. Correcting this figure for a 3 percent annual inflation rate to 1994 dollars, and adjusting it 18 percent for the income differential between Maryland and the U.S. average, a net cost of $15.29 per vehicle hour is obtained. This figure was rounded to S15 per vehicle hour for use in this study. The approximate cost per person hour is $10. This is based on an average vehicle occupancy

13 Characteristics of Urban Transportation Systems, US DOT, Federal Transit Administration, 1992.

of 1.5 persons.14 The current freeway service patrol coverage produces an annual savings of $30.5 million dollars.

Based on estimates furnished by SHA staff, $8 million have been invested in capital purchases for the CHART program between 1990 and 1994. The current operating and maintenance cost for the program is approximately $2.5 million per year. Table 4-5 illustrates the derivation of the current benefit-cost ratio for the CHART program. The five percent interest me is consistent with current bonding practices associated with capital investments by the Maryland State Highway Administration. The benefit-cost ratio for the current incident response component of the CHART program is estimated to be 7.5 to 1.

Table 4-5

Estimated Current Savings due to Freeway Service Patrols

CHART Capital Investment Cost •	**$8.04 million**
Five-year Back Amortization of Capital at 5% per Year	**$1.6 million**
Annual Operating and Maintenance Cost •	**$2.46 million**
Total Annual Cost	**$4.05 million**
Annual Public Cost Savings (delay and fuel)	**$30.5 million**
Benefit - Cost Ratio (delay and fuel)	**7.5 to 1**

* Capital and O&M Costs based on data provided by Maryland State Highway Administration

A beneiit-cost ration of 7.5:1 verifies that the incident response component of the CHART program, supported by Iited traffic surveillance, has produced significant benefits in terms of reduced delay (time savings) and reduced fuel -consumption for users of the CHART network The above benefits assessment assumed that the freeway motorist patrols are supported by existing (1994) CHART ATMS traffic surveillance elements Asignificant increase in detection and verification hardware will occur over the next five years, as well as significant enhancements to the traveler information system. As these components are fully deployed, further reductions in incident-related delay should be realized.

Increasing the number of incidents served by the freeway service patrols would have a direct impact on the annual delay and fuel savings. Additional ATMS components will increase the utilization of existing service patrols by accelerating detection, verification and response rates.

14 Average occupancy figure provided by MDOT staff,

4.2 Evaluation of Secondary Accidents

Evaluation of potential reduction of secondary accidents on the CHART roadway network was done using accident data from the Maryland Automated Accident Reporting System (MAARS). Secondary accidents are those that occur due to unexpected circumstances created by the presence of a primary accident downstream of the secondary accident site. This evaluation considered only secondary accidents, which account for about seven percent of all incidents.

MAARS accident data from the years 1992 through 1994 were used. A database screening procedure was used to associate accident records such that a potential "market" of secondary accidents could be estimated. This market consisted of those accidents that occurred upstream of a primary accident within one hour after the primary accident and within three miles upstream of the primary accident.

Table 4-6 summarizes the result of the secondary accident evaluation. The total market of secondary accidents was estimated to be 563 per year, or 5.7% of the total. A previously completed evaluation of MAARS accident data based on data from 1990 through 1992 concluded that secondary accidents make up 5 to 15 percent of the total number of accidents, as shown in Table 4-7[15] Thus, it is a conservative assumption that 5.7% of all accidents on the CHART network were secondary.

Table 4-6

Evaluation of Secondary Accidents on the CHART Roadway Network

Secondary Accident Search Criteria	**up to 1 hour after primary accident up to 3 miles upstream of primary accident**
Total Number of Potential Secondary Accidents	**1,707 in three years or 569 per year**
Total Number of Accidents on CHART Roadway Network	**29,613 in three years or 9,871 per year**
Portion of Accidents that Could Be Secondary	**563 per year or 5.7%**
Current Freeway Service Patrol System-Wide Delay Reduction	**5.0%**
Potential Reduction of Secondary Accidents due to Service Patrols	**26 accidents per year**

* Based on annual delay reduction of 2.0 million veh hours per year out of 40.1 million (see Table 4.4).

15 Secondary Incidents: Queue Monitoring and Protection, Matamba Kabengele, Maryland State Highway Administration, 1994

The number of accidents on the entire CHART roadway network averaged 9,871 per year. Assuming that the secondary accidents resulted from the presence of delay due to non-recurring congestion from the primary accident, estimates of annual secondary accident reductions were prepared. The overall percentage reduction of ono-recurring congestion delay is based on the analysis results summarized in Table 4-4.

Table 4-7

Percent of All Accidents that are Secondary Accidents

Year	Roadways Studied: US 50	I-95 from I-495 to I-695	I-495 Capital Beltway in Maryland	I-695 Baltimore Beltway
1991	5.5%	5.5%	9.6%	9.7%
1992	5.0%	8.4%	8.8%	14.3%

The current freeway service patrol coverage produced a 5.0% reduction in ono-recurring congestion delays, which reduced secondary accidents by 28 each year. Based on results from the estimation procedure shown in Figure 4-1, the average delay incurred by an accident is 1,5 13 vehicle hours. The annual benefit of eliminating 28 accidents each year amounted to 42,400 vheicle hours of delay, 8,500 gallons of fuel, and $647,000 in delay and fuel cost savings.

The potential for reducing secondary accidents, and secondary incidents in general, is dependent on the ability of the CHART incident management program to reduce incident-related delays. Any improvement in the number of incidents served or the total incident response time will substantially increase the benefits realized by the traveling public.

5. CORRIDOR-LEVEL EVALUATION

5.1 Description of Corridor-level Evaluation Process

The corridor-level evaluation illustrated how a variety of incident scenarios on Maryland freeways affect traffic operations from the perspective of the user. The demonstration was applied to three specific lo-to-15 mile ***segments*** of freeway: These segments included the I-49.5 Capital Beltway (Montgomery County), the western haIf of the I-695 Baltimore Beltway, and the I-95 Capital Beltway (Prince Georges County). The first two corridors experience significant recurring congestion, and the third experiences little recurring congestion.

The impacts of several typical incident scenarios were assessed through the application of a freeway corridor simulation model (FREQ) developed by the University of California at Berkeley. The MOE's that were compared among the scenarios included average travel time, average travel speed, vehicle and passenger hours of travel and delay, fuel consumption, and pollutant emissions. User costs were developed from vehicle hours of delay and fuel consumption estimates from the model. Total vehicle hours of delay were based on a minimum average running speed of 50 miles per hour", and estimates of passenger miles traveled assumed an average peak period auto occupancy of 1.2 persons per vehicle. 17 Since the simulation period represents peak period traffic operations, the unit cost for delay (normally $ I5 per vehicle hour) was factored down to account for the ratio of peak period to average daily vehicle occupancy (1.2 ppv / I.5 ppv). This resulted in a peak period delay cost of S12 per vehicle hour. The cost of -gasoline remained at S 1.25 per gallon.

Simulations were developed for three scenarios, as follows:

- Incidents with no incident management program
- Incidents with freeway service patrols
- Incidents with freeway service patrols supported by CHART ATMS.

Two assumptions were made; no diversion of trips from the freeway to secondary routes, and no flow improvements around the incident during the management phase of incident response. Both of these actions could reduce incident-related delay on the freeway. Therefore, the results are considered to be conservative,

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16 This is the approximate speed at which freeway traffic flow operates at capacity.
17 Peak period average occupancy provided by Washington Council of Governments (WASHCOG).

5.2 Incident Scenarios

The incident scenarios selected for simulation represented a wide variety of situations that show the relative relationships between recurring and non-recurring congestion delay, and their impact on one another. Three or four scenarios were tested for each corridor, ranging from a shoulder incident, to a lane-blocking accident, to a primary accident that caused a secondary incident. The results from these scenario runs provided some interesting insights into the impact of incidents on congested and uncongested freeway corridors, and some unique events that can be triggered or prevented due to the presence of and incident.

Incidents were simulated in FREQ by reducing the capacity of the freeway section where the incident occurs for a length of time consistent with the incident duration. Incident durations were based on the table of durations used for the system-wide evaluation, except that durations were rounded to the nearest five-minute interval to match the five-minute simulation intervals modeled in FREQ. Table 5-l summarizes the durations used by incident type for three scenarios. The first scenario assumes no incident management program is present (pre-CHART). The second assumes freeway service patrols are present (current CHART). The third scenario assumes that a fully-functional ATMS is supporting the freeway service patrols with detection and verification equipment.

Table 5-1

Incident Durations* by Incident Type and Degree of Incident Management Program Development (minutes)

	Accident		Incident	
	Shoulder	**In-Lane**	**Shoulder**	**In-Lane**
No Incident Management	40	55	30	40
With Freeway Service Patrols	30	45	20	30
With Freeway Service Patrols and ATMS	25	35	15	25

Note: Incident duration is the sum of detection, response and management/clean-up times.
Sources: Compiled from assumptions used in bvo studies.[18,19]

18 A Methodology for Measurement and Reporting of Incidents and the Prediction of Incident Impacts on Freeways, Sullivan, Taff and Daly, Ball Systems Engineering Division, San Diego, California. 1995
19 Incident Management Alternatives Analysis for the George Washington Sridge and Cross Bronx Expressway, JHK 8 Associates, April 1992.

Capacity reductions are based on a table of reduced capacities developed by Ball Systems Engineering, Inc. as part of their non-recurring congestion delay algorithm called - IMPACT[20] The reduction capacities were compiled from two previous research efforts[21, 22] Table 5-2 shows the percent of capacity remaining as the result of several incident type/lane closure combinations.

Table 5-2

Percent of Original Capacity Remaining due to Incidents

	Original Number of Lanes			
	4+	**3**	**2**	**1**
Accident / Debris				
Median Shoulder	74	69	64	59
Right Shoulder	85	83	81	79
1 Lane Blocked	62	53	39	0
2 Lanes Blocked	27	18	0	
3 Lanes Blocked	14	0		
Other Incidents				
Median Shoulder	80	76	71	67
Right Shoulder	96	90	84	78
1 Lane Blocked	67	57	42	0
2 Lanes Blocked	29	20	0	
3 Lanes Blocked	15	0		

An example incident scenario for each of the three freeway corridors is described below.

5.2.1 I-495 (Capital Beltway)-Montgomery County

I-495 Outer Loop - AM Peak Period (7:00 to 9:00 AM)
I- 95 (College Park) to American Legion Bridge

<u>I-495 - Current Recurrine Congestion Patterns</u>

The outer loop of the 1495 Capital Beltway experiences recurring congestion during the AM peak period between I-95 at College Park and Georgia Avenue (MDI-97). The simulation model coverage included the I-495 outer loop from the 1-95 interchange at College Park to the American Legion Bridge (16.57 miles).

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20 A Methodology for Measurement and Reporting of Incidents and the Prediction of Incident Impacts on Freeways, Sullivan, Taff and Daly, Ball Systems Engineering Division, San Diego, California, 1995

21 Lari Adeel, David Christianson and Sue Porter. I-35W Incident Management and Impact of Incidents on Freeway Operations. Minnesota Dept Of Transportation. Office of Traffic Engineering. January 1982.

22 Goolsby, M.E. Influence of Incidents on Freeway Quality of Service. Highway Research Record 339. Transportation Research Board. Washington DC. 1971.

I-495 Capital Beltway Incident Scenario

Situation: Single Lane Blocking Incident at 7:00 AM that Causes a
Single Lane Blocking Accident at 7:30 AM
Location: East of I-270 Spur (Primary), West of Wisconsin Ave (Secondary)
Pre-Incident Capacity: 6,600 vehicles per hour
Capacity During Incident: 3,762 vehicles per hour (57%)

I-495 Incident Scenario MOE's
AM Peak Period - Outer Loop East of I-270 Spur with
Secondary Accident West of Wisconsin Avenue

Measure of Effectiveness	Normal Recurring Congestion	Initial and Secondary Incident with No Incident Management	Initial and Secondary Incident with Freeway Service Patrols	Initial fncident with FSP and ATMS support
incident Duration (minutes)		40-55	30-45	25
Total Vehicle Hours of Delay	1921	3386	2990	2210
Change in Delay due to Incident	-	76%	56%	15%
Incident Vehicle Hours Delay	-	1465	1069	269
Change in Delay due to CHART	-		-27%	-80%
Average Travel Speed (mph)	37.1	29.2	31.0	35.3
Travel Time (minutes)	26.8	34.1	32.1	28.2
Fuel Consumption (gallons)	11546	11674	11615	11640
CO Emissions (kg)	1212	1390	1343	1256
HC Emissions (kg)	104	123	118	109
NOx Emissions (kg)	311	298	301	308
Total Emissions (kg)	1627	1811	1762	1673
Vehicle Miles Traveled	232,316	219,641	222,536	231,783
Vehicle Hours Traveled	6257	7522	7174	6567
Passenger Hours Traveled	7506	9026	6609	7880
Passenger/Fuel Costs	$89,513	$104,853	$100,609	$93,350
Cost Savings		-	$4,244	$11,503

Comment: For comparison purposes, a separate simulation run was made to determine the delay impact of the primary incident alone. The primary incident produced 680 vehicle hours of delay when compared to the normal recurring congestion pattern. In this scenario, the secondary incident occurred under the no-incident-management case and the FSP only case. When FSP's are combined with ATMS, delays are reduced to the point where the secondary incident was prevented (did not occur). The delay and cost savings associated with preventing a secondary incident are substantial when compared to partial mitigation of both incidents with FSP's. In this scenario, FSP's reduced incident delay by 12 percent while FSP's with ATMS support reduced incident delay by 35 percent.

5.2.2 I-695 (Baltimore Beltway)

I-695 Inner Loop - PM Peak Period (4:00 to 6:00 PM)
US 1 Washington Blvd. to I-795

I-695 - Current Recurring Congestion Patterns

The inner loop of the I-695 Baltimore Beltway experiences recurring congestion during the PM peak period between I-97 and I-70. The simulation model coverage included the I-695 inner loop from the Alt. US 1 on ramp to the I-795 on ramp.

I-695 Baltimore Beltway Incident Scenario

Situation: Single Lane Blocking Incident at 4:00 PM
Location: Between US 40 Loop Ramps
Pre-Incdent Capacity: 10,000 vehicles per hour
Capacity During Incident: 6,700 vehicles per hour (67%)

I-695 Incident Scenario MOE's
PM Peak Period - Inner Loop between US 40 Loop Ramps

Measure of Effectiveness	Normal Recurring Congestion	No Incident Management	With Freeway Service Patrols	With FSP and ATMS support
Incident Duration (minutes)	-	40	30	25
Total Vehicle Hours of Delay	1720	3516	3038	2795
Change in Delay due to Incident	-	+104.4%	+76.6%	+62.5%
Incident Vehicle Hours Delay		1796	1318	1075
Change in Delay due to CHART			-14%	-21%
Average Travel Speed (mph)	37.7	28.2	30.4	31.6
Travel Time (minutes)	25.6	34.2	31.8	30.6
Fuel Consumption (gallons)	11444	11446	11510	11526
CO Emissions (kg)	1124	1347	1299	1271
HC Emissions (kg)	101	124	119	116
NOx Emissions (kg)	296	275	281	285
Total Emissions (kg)	1521	1746	1699	1672
Vehicle Miles Traveled	235,377	217,887	223,775	226.339
Vehicle Hours Traveled	6241	7723	7323	7168
Passenger Hours Traveled	7490	9268	8788	8602
Passenger/Fuel Costs	589,205	$106,990	$102,266	$100,430
Cost Savings	-	-	54,722	$6,560

Comment.- This incident occurred between two mainline recurring congestion queues. Since this section of the Baltimore Beltway operates near capacity, the delay impacts of an incident of this magnitude were substantial. Despite this, FSP's and FSP's with ATMS support can still reduced delays by 14 and 21 percent, respectively, and produced meaningful user cost benefits.

5.2.3 (Capital Beltway)-Prince Georges County

I-95 Outer Loop - AM Peak Period (7:00 to 9:00 PM)
Woodrow Wilson Bridge to I-495 (College Park)

I-95 - Current Recurring Congestion Patterns

The outer loop of the I-95 Capital BeItway between the Woodrow Wilson Bridge and I-495 (College Park) does not experience recurring congestion during the AM peak period The three lanes crossing the Woodrow Wihon Bridge constrain the amount of traffic entering the southern-most section of the study section. On some days, recurring congestion on westbound I-495 in Montgomery County spills back past the I-95 interchange toward US 1 at the northern end of the study section. The highest-volume portion of the study section is between the MD 450 and BW Parkway interchanges. The simulation model coverage included the I-95 outer loop from the Woodrow WiIson Bridge to the I-495 interchange near College Park (26.69 miles).

I-95 Capital Beltwav Incident Scenario

Situation: Two Lane Blocking Accident at 7:00 AM
Location: North of MD 4 Interchange
Pre-Incident Capacity: 9,200 vehicles per hour
Capacity During Incident: 2,484 vehicles per hour (27%)

I-95 incident Scenario MOE's
AM Peak Period - Outer Loop North of MD 4 Interchange

Measure of Effectiveness	Normal Recurring Congestion	No Incident Management	with Freeway Service Patrols	With FSP and ATMS Support
Incident Duration (minutes)		55	45	35
Total Vehicle Hours of Delay	113	1978	1383	879
Change in Delay due to Incident		+1650%	+1106%	678%
Incident Vehicle Hours Delay		1885	1250	766
Change in Delay due to CHART			-31	-56%
Average Travel Speed (mph)	55.7	40.8	44.8	48.4
Travel Time (minutes)	28.8	39.2	35.7	33.1
Fuel Consumption (gallons)	18057	16045	15981	15939
CO Emissions (kg)	1509	1690	1631	1582
HC Emissions (kg)	112	135	127	121
NOx Emissions (kg)	589	545	556	565
Total Emissions (kg)	2210	2370	2314	2268
Vehicle Miles Taveled	318,664	302,721	306,319	309,593
Vehicle Hours Traveled	5718	7421	6843	6394
Passenger Hours Traveled	8862	8905	8212	7673
Passenger/Fuel Costs	$88,691	$109,106	$102,096	$96,654
Cost Savings	-	-	$7,010	$12,452

Comment: This scenario evaluated a major incident that occurred on a segment of the Capital Beltway carrying only moderate volumes. The total delay incurred was substantial, and the presence of FSP's or FSP's with ATMS support produced meaningful user cost saving.An unusual aspect of thisscenario was that once the full capacity of the freway was restored, the ensuing flood of traffic from the queue produced an additional bottleneck queue downstream of the incident site. Therefore, the incident effectively wasted downstream capacity while the incident was present, then overloaded downstream sections after the incident was removed.

5.3 Findings and Conclusions

The most significant finding of the corridor-level evaluation was that there appear to be more delay reduction benefits from serving incidents past the location of recurring congestion bottlenecks than serving the same incidents located prior to the location of recurring congestion. The benefits of serving incidents located prior to recurring congestion can be limited, since the incident-rated delay sometimes offsets or mitigates the delay caused by the recurring, congestion.

Another Ending was thatafter an incident has been removed, the ensuing “flood” of traffic released from the queue may cause unexpected congestion on downstream freeway sections. Also, the delay impacts of a secondary incident may at least partially offset the delay impacts of the primary incident that caused that secondary incident, as the secondary incident “meters” the flow of traffic approaching the primary incident.

Service patrol operators should be alerted to give priority to serving incidents past the location of recurring congestion rather than those located prior to the location of recurring congestion, if their resources are limited

The benefits of reducing the time of a primary incident can be significatn, not only in terms of delay and fuel savings to the affected motorists, but also in terms of causing a secondary incident to never occur.

6. SITE-SPECIFIC EVALUATION

6.1 Description of Site-specific Evaluation Process

The site-specific evaluation assessed the portion of capacity lost due to the presence of real incidents recorded by the CHART video surveillance cameras. Three specific incidents were studied. Observations are summarized in Tables 6-l & 6-2.

Table 6-1
Measured Capacity vs. National Data

Incident Location - Closure Condition	Observed Percent of Freeway Capacity Remaining	Percent of Capacity Remaining Based on National Models
Northbound I-695 at I-70 - One of Three Lanes Blocked	45%	53%
Northbound I-95 at US 50 Two of Four Lanes Blocked	31%	27%
Northbound I-95 at Wilson Bridge - Right Shoulder Blocked	83%	83%

Table 6-2
Impact of Truck Traffic on Capacity

	Left Lane (Lane 1 of 3)	Middle Lane (Lane 2 of 3)
Truck Volume	102	192
Volume of Other Vehicles	1,132	671
Total Volume	1,234	863

6.2 Findings and Conclusions

The key findings resulting from the site-specific analysis are as follows:

- capacity of freeway sections passing incidents in Maryland is consistent with national data
- high concentrations of truck traffic reduce the volume of other traffic carried by a lane substantially
- truck traffic impacts on congested flow are likely to be substantially greater than similar impacts under uncongested conditions

7. FUTURE EVALUATION RECOMMENDATIONS

Several recommendations are made regarding further data collection and monitoring. They are as follows:

- develop a simplified incident recording form for use by CHART service patrols, Maryland State police, and private sector support units
- issue a motorist mail-in survey to those served by freeway service patrols to determine the opinions of the systems users
- use CHART assets and resources *to* monitor other aspects of transportation efficiency, e.g. vehicle occupancy, demand management, operational improvements, and concept development.

Finally, a number of recommendations for further evaluation of the CHART program from the users' perspective are made for future consideration by SHA staff as follows:

- evaluate the impact of increasing the number of service patrols and/or the service patrol coverage area
- improve the efficiency of incident response by prioritizing the use of available assets in dealing with the four phases of incident response; detection, response, management, and recovery
- refine the system-wide benefits estimation procedure to incorporate;
    - truck traffic
    - surveillance and detection coverage
    - recurring congestion
    - the congounding effect of recurring congestion on non-recurring congestion
- evaluate other CHART components as they are implemented and/or enhanced as to their effect on the system users, including;
    - traffic surveillance
    - traveler information
    - traffic management
- monitor commercial traffic reports as a means of quantifying the effects of incidents on the duration of congestion and/or the length of queues generated.
- continue to refine the evaluation procedures by replacing data from national sources with Maryland data. An example would be response and management times for incidents.