Joint Transportation Research Program

JTRP

FHWA/IN/JTRP-97/9

Final Report

A COST-EFFECTIVENESS EVALUATION OF THE HOOSIER HELPER FREEWAY SERVICE PATROL

PHASE I

Steven P. Latoski
Raktim Pal
Kumares C. Sinha

February 1998

Indiana Department of Transportation

Purdue University

Final Report

Phase I

A Cost-Effectiveness Evaluation of the Hoosier Helper Freeway Service Patrol

by

Steven P. Latoski
and
Raktim Pal
Graduate Research Assistants

and

Kumares C. Sinha
Professor of Civil Engineering

School of Civil Engineering
Purdue University

Joint Transportation Research Program
Project No: C-36-71G
File No: 8-9-7

Prepared in Cooperation with the
Indiana Department of Transportation and the
U.S. Department of Transportation
Federal Highway Administration

Purdue University
West Lafayette, IN 47907
February 1998

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FHWA/IN/JTRP-97/9	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A Cost-Effectiveness Evaluation of the Hoosier Helper Freeway Service Patrol		5. Report Date February 1998
		6. Performing Organization Code
7. Author(s) Steven P. Latoski, Raktim Pal, and Kumares C. Sinha		8. Performing Organization Report No. FHWA/IN/JTRP-97/9
9. Performing Organization Name and Address Joint Transportation Research Program 1284 Civil Engineering Building Purdue University West Lafayette, Indiana 47907-1284		10. Work Unit No.
		11. Contract or Grant No. SPR-2126
12. Sponsoring Agency Name and Address Indiana Department of Transportation State Office Building 100 North Senate Avenue Indianapolis, IN 46204		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the Indiana Department of Transportation and Federal Highway Administration.

16. Abstract

This research provides a benefit-cost analysis for each of two distinct Hoosier Helper operating scenarios: daytime patrol and 24-hour patrol. The computation of agency cost involves an aggregation of equivalent annual investment cost, employee salaries and fringe benefit, overhead cost, and maintenance cost for Hoosier Helper. The following components comprise the estimation of Hoosier Helper benefits: non-recurrent congestion delay savings, secondary crash reduction, and vehicle operating cost savings. The results of an analysis of over two thousand evaluations from motorists assisted by Hoosier Helper are also presented.

17. Key Words freeway, service patrol, benefit-cost analysis, incident management, congestion, secondary crash.	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	95	

Form DOT F 1700.7 (8-69)

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance of each member of the study advisory committee: David Pluckebaum (initial months), Dan Shamo, John Nagle, Bill Flora, and Sedat Gulen from the Indiana Department of Transportation, as well as Larry Tucker and Don Johnson from the Federal Highway Administration.

This project was funded by the Joint Transportation Research Program of Purdue University in cooperation with INDOT and FHWA. We are very appreciative of their support and assistance.

IMPLEMENTATION REPORT

This study's findings will permit an economic comparison of the daytime and 24-hour patrol periods, thus assisting Indiana Department of Transportation (INDOT) officials in the re-evaluation and for future planning of various Hoosier Helper deployment strategies. The results show Hoosier Helper does, in fact, serve as a key component within the incident management framework for the Borman Expressway; moreover, they clearly support the program's operating strategy as it exists today. INDOT may utilize the findings stated in this report to justify, at least in part, the expansion of Hoosier Helper to other areas within Indiana. August, 1997 marks the start of Hoosier Helper operation in Indianapolis, and officials at INDOT's Greenfield district may find the results of this study useful in selecting the most cost-effective Hoosier Helper operation scenario for Indianapolis.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

1. INTRODUCTION

Highway congestion represents a daily problem for commuters and truckers in all major metropolitan areas, costing travelers more than $40 billion annually in our nation's 50 largest cities [1]. In particular, the Federal Highway Administration (FHWA) reported that non-recurrent congestion, or congestion caused by traffic incidents, accounts for 60 percent of congestion induced delay [2]. In the search for a lower-cost approach to combat the effect of traffic incidents on freeway operation, several states have made freeway service patrols an increasingly popular choice in larger urban areas. Freeway service patrols function as a "low-tech" incident management program, providing incident detection, response, and clearance; moreover, based on the findings of service patrol evaluations in the literature, these programs can serve as a key component within any comprehensive incident management framework. It is considered that an efficient freeway service patrol substantially reduces incident duration time which, in turn, alleviates the delay attributed to non-recurrent, incident-related congestion and lowers the chance of secondary crashes. Furthermore, these programs create a sense of security for motorists in addition to improving public relations for the service's sponsor [3].

1.1. Hoosier Helper Operation

The Hoosier Helper program in Northwest Indiana is a roving freeway service patrol program which started on August 30, 1991. The program, supported by the

Indiana Department of Transportation (INDOT), maintains a fleet of three pick-up trucks and three vans, and at least two vehicles are in service 24 hours a day, seven days a week. Hoosier Helper expanded to 24 hour operation on Memorial Day weekend 1996. Previous to that, the program provided motorist assistance between the hours of 6:00 AM and 8:30 PM. Hoosier Helper crews regularly patrol a 16 mile stretch of the six-lane Interstate 80-94 freeway near Gary, commonly known as the Borman Expressway, looking for and responding to incidents. The Borman Expressway runs from the Indiana-Illinois border to the Interstate 90 interchange. In addition, during peak travel periods, the program's crews cover an eight mile portion of the four-lane Interstate 65 freeway from U.S. Highway 30 in Merrillville to 15th Avenue in Gary, located one mile south of the Interstate 90 interchange. Figure 1.1 illustrates the discussed Hoosier Helper patrol area. Examples of motorist assists, provided free of charge by the program, include supplying fuel, changing flat tires, calling private tow truck operators, and furnishing support at crash sites. Hoosier Helper patrolmen maintain a daily activity log which documents all assists made. At the conclusion of an assist, a patrolman will record the following information regarding the incident: Hoosier Helper arrival time, road, direction of travel, mile marker, state and license plate number of vehicle assisted, type of vehicle assisted, lateral location of incident, services rendered, and Hoosier Helper departure time. INDOT compiles the daily activity logs continuously and appends them to the Hoosier Helper assist database, containing records of incidents since the start of the program. The database provides the incident data used in this study.

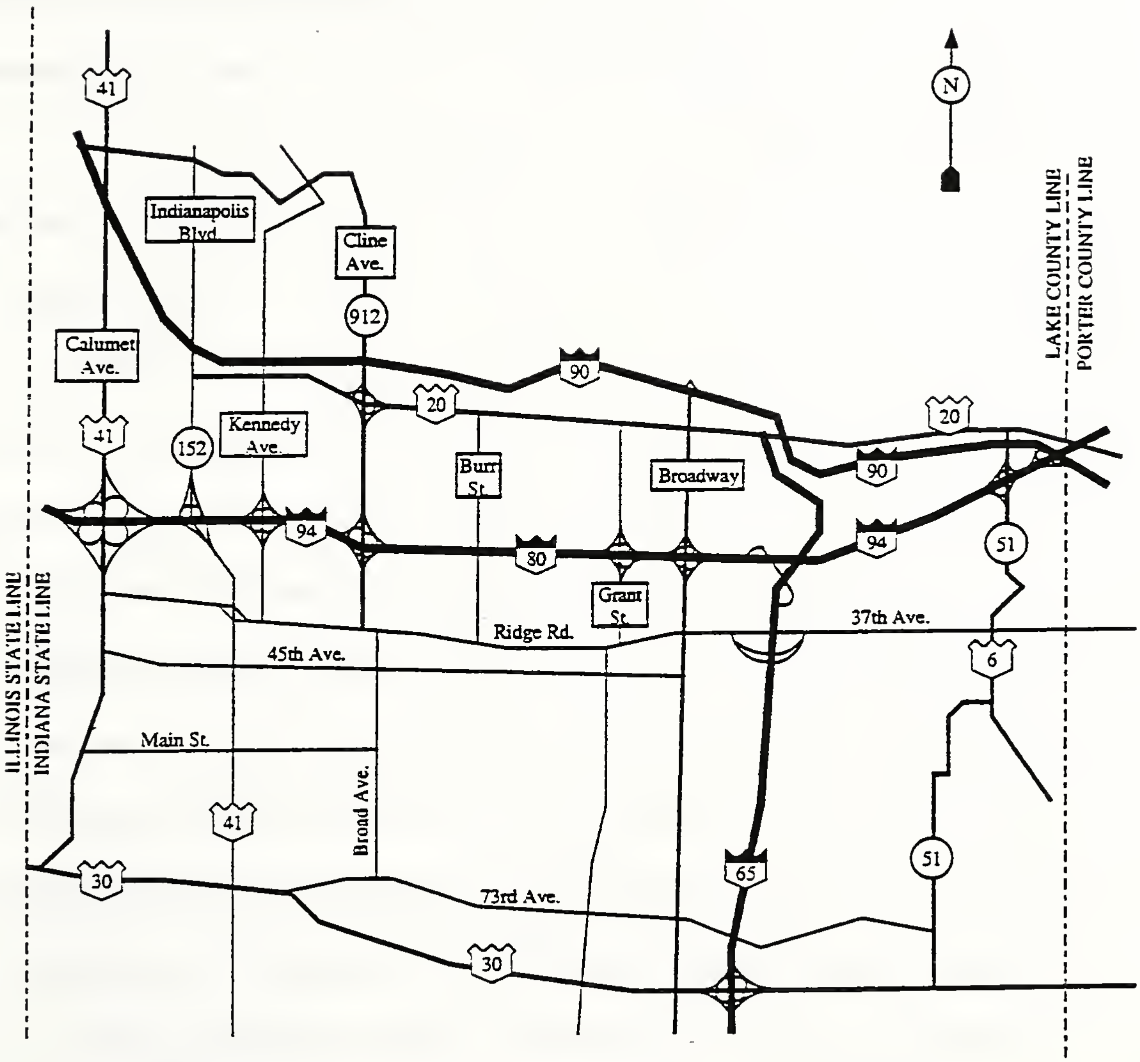

Figure 1.1 Map of the Study Network

1.2. Methodology

This report presents a detailed evaluation of the Hoosier Helper freeway service patrol. Specifically, the study results will include a benefit-cost analysis for each of two distinct Hoosier Helper operating scenarios: daytime patrol and 24 hour patrol. The year 1995 and a seven month period from June 1, 1996 to December 31, 1996 represent the time frames for the daytime and 24 hour evaluations, respectively.

Figure 1.2 displays the framework to be followed in the benefit-cost analysis. The computation of agency cost concerns an aggregation of equivalent annual investment cost, employee salaries and benefits, overhead cost, and maintenance cost for Hoosier Helper. An equivalent annual investment cost was computed from the present worth of all Hoosier Helper equipment purchases at the year marking the start of the program. The following components comprise the estimation of Hoosier Helper benefit: non-recurrent congestion delay savings, secondary crash reduction, and vehicle operating cost savings. The assessment of non-recurrent congestion delay savings necessitates the completion of three main tasks: incident generation, estimation of unit travel time value, and incident simulation. The computation of benefits resulting from secondary crash reduction includes the finding of additional delay savings and crash cost savings. The calculation of vehicle operating cost savings pertains to an estimation of fuel consumption reduction.

The study findings will permit an economic comparison, through the unit-less benefit-cost ratio, of the two stated patrol periods, thus assisting INDOT officials in the re-evaluation and/or future planning of various Hoosier Helper deployment strategies. In addition, the results of an analysis of over two thousand evaluations, representing the only

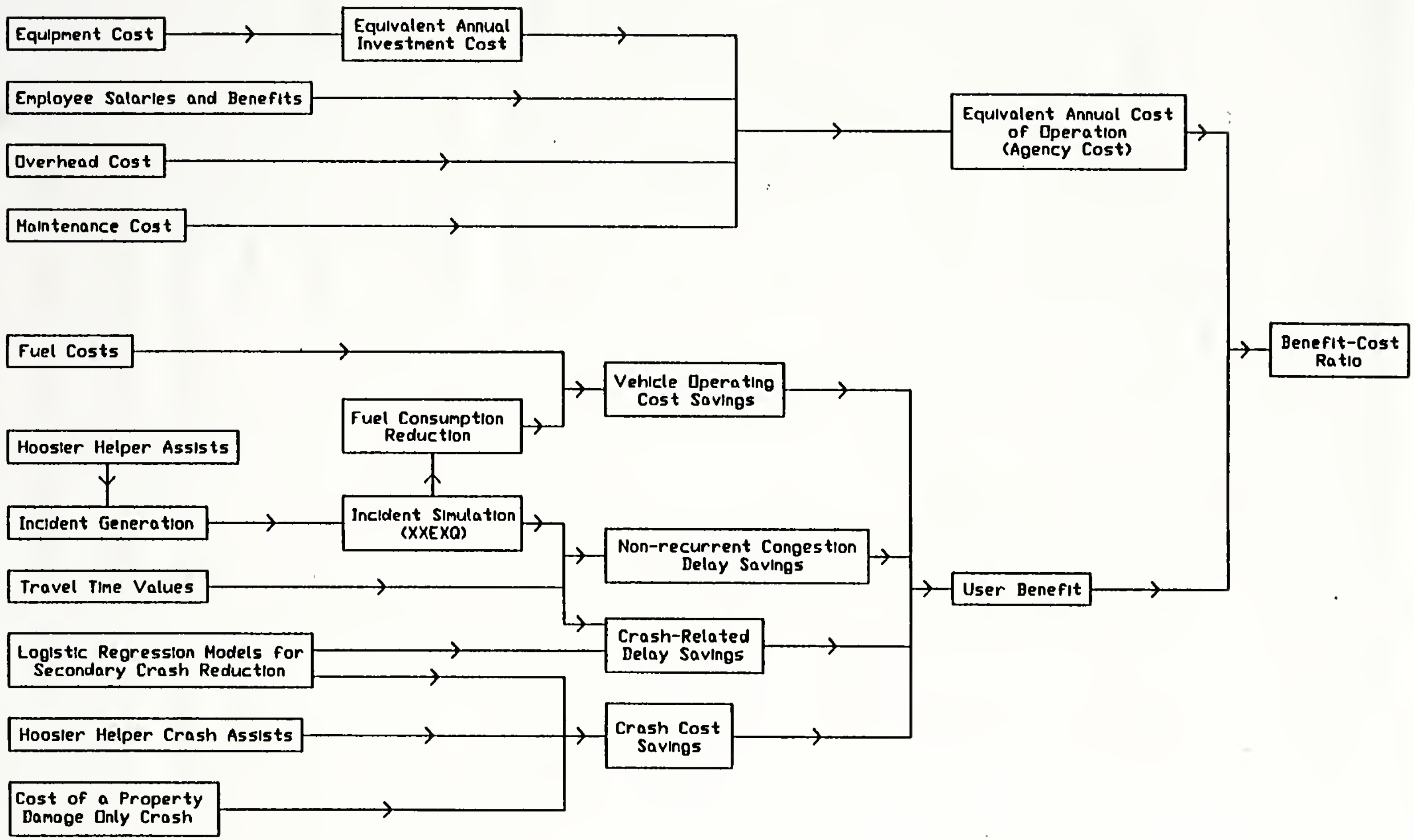

Figure 1.2 Framework for the Benefit-Cost Analysis

available performance evaluation of Hoosier Helper, from motorists assisted by the program are presented. No past freeway service patrol evaluation included a benefit estimation as comprehensive as that presented in this thesis.

1.3. Organization of the Report

This report consists of seven chapters. Chapter 2 offers a description of other United States service patrols in operation and a review of past service patrol evaluation studies, as documented in the literature. Chapter 3 presents an analysis of the incident data gathered for the daytime and 24 hour Hoosier Helper evaluations. A summary of the 1995 and June 1996 to December 1996 investment, overhead, and maintenance costs associated with Hoosier Helper daytime and 24 hour operation is provided in Chapter 4. Chapter 5 discusses the estimation of all Hoosier Helper benefit components. A report of findings from an analysis of response of the motorists assisted by Hoosier Helper is covered in Chapter 6, and Chapter 7 furnishes the benefit-cost ratio for each of the two Hoosier Helper evaluations and a discussion of results, complete with suggestions for future work.

2. LITERATURE REVIEW

An extensive literature review revealed that many of the major freeway service patrols in the United States have been subject to a benefit-cost analysis. Table 2.1 presents a detailed list of 23 freeway service patrols operating in 12 states today [1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17]. Each of the freeway service patrols listed in the table receive all funding from their respective state Department of Transportation (DOT), with the exception of the freeway service patrols located in Michigan and Texas. Those two programs obtained partial sponsorship from their respective DOT and local businesses. Although most state DOTs, including INDOT, provide their own force service, the California Department of Transportation, Colorado Department of Transportation, and Michigan Department of Transportation support freeway service patrols operated by outside contractors. Table 2.1 also contains the results of ten freeway service patrol studies yielding benefit-cost ratios ranging from 2:1 to 36:1. Table 2.2 provides an in-depth look at the benefit estimation approaches of eight freeway service patrol studies [1, 4, 7, 10, 13]. Because of the challenges associated with measuring such variables as incident detection and response time, roadway capacity reduction at an incident site, and travel time value, researchers in several studies, as shown in Table 2.2, assumed values for these key variables. For example, researchers assumed a motorist's time was valued at $10 per hour in the Chicago, Denver, Detroit, and New York studies.

Table 2.1 Freeway Service Patrol Programs in the United States

State	Location	Patrol Name (year started)	Ownership	Number of Vehicles	Hours of Operation	Benefit-Cost Ratio (year)
California	Los Angeles	Freeway Service Patrol (1991)	public	153 tow trucks	peak hours	11:1 (1994)
California	San Francisco Bay Area	Freeway Service Patrol (1992)	public	49 tow trucks	peak hours	N/A
California	Orange County	Freeway Service Patrol (1992)	public	12 tow trucks	peak hours	N/A
California	Sacramento	Freeway Service Patrol (1992)	public	6 tow trucks	peak hours	N/A
California	San Diego	Freeway Service Patrol (1993)	public	15 tow trucks	peak hours	N/A
Colorado	Denver	Mile-High Courtesy Patrol (1992)	public	4 tow trucks, 2 pick-up trucks	peak hours	10.5:1 to 16.9:1 (1993)
Georgia	Atlanta	Highway Emergency Response Operator (1996)	public	12 pick-up trucks	daytime hours	N/A
Illinois	Chicago	Emergency Traffic Patrol (1960)	public	3 heavy tow trucks, 36 tow trucks, 11 pick-up trucks	24 hours	17:1 (1990)
Maryland	Baltimore Area	Emergency Traffic Patrol (1989)	public	4 tow trucks	peak hours	N/A
Maryland	Washington Area	Emergency Traffic Patrol (1989)	public	4 tow trucks	peak hours	N/A
Michigan	Detroit	Courtesy Patrol Program (1994)	public / private	4 vans	peak hours	15:1 (1996)
Minnesota	Minneapolis	Highway Helper (1987)	public	7 pick-up trucks	daytime hours	2.3:1 (1994)
New Jersey	Morris, Essex, Bergen Counties	Emergency Service Patrol (1993)	public	8 vans	daytime hours	11:1 (N/A)
New York	New York Metropolitan Area	Highway Emergency Local Patrol (1994)	public	28 pick-up trucks	peak hours	26:1 (1996)
North Carolina	Charlotte, Winston-Salem, Greensboro, Haywood County	Motorist Assistance Patrol (1992)	public	8 pick-up trucks	daytime hours	7.6:1 (1993)
Texas	Houston	Motorist Assistance Program (1986)	public / private	2 pick-up trucks, 18 vans	daytime hours	7:1 to 36:1 (1991)
Texas	Houston	District 12 Service Patrol (1971)	public	1 pick-up truck	nighttime hours	2:1 (1976)
Texas	El Paso	Texas Courtesy Patrol (1993)	public	6 pick-up trucks	daytime hours	N/A
Texas	Dallas	Texas Courtesy Patrol (1987)	public	14 pick-up trucks	daytime hours	N/A
Texas	Fort Worth	Texas Courtesy Patrol (1973)	public	6 pick-up trucks	24 hours	N/A
Texas	San Antonio	Texas Courtesy Patrol (1978)	public	6 pick-up trucks	24 hours	N/A
Texas	Austin	Texas Courtesy Patrol (1997)	public	2 pick-up trucks	daytime hours	N/A
Washington	Seattle (2 floating bridges)	Incident Response Team (1990)	public	4 tow trucks	peak hours	N/A

Table 2.2 Freeway Service Patrol Benefit Estimation Approaches

Patrol Name and Location	Benefit-Cost Ratio (evaluation period)	Benefit Components	Simulation Model (analysis area)	Travel Time Value	Roadway Capacity Reduction at Incident Site (number of lanes in one direction)	Incident Duration Reduction Attributed to Freeway Service Patrol Operation
Mile-High Courtesy Patrol: Denver, Colorado	10.5:1 to 16.9:1 (August 28, 1992 to February 26, 1993)	Congestion delay savings	Deterministic queuing model (segment of the patrol route)	$10 per hour, based on an assumption (1993 dollars)	Assumed a fraction of lanes lost for all incident types: right or left shoulder, 0.7; left or right lane, 1.7; middle lane, 2.3; off-road, 0.3 (3 lanes)	Detection time assumed unchanged; Field data for response and clearance time reported 10.5 minutes for in-lane incidents and 8.6 minutes for shoulder incidents
Highway Helper: Minneapolis, Minnesota	2.3:1 (March 1993 to February 1994)	Congestion delay savings of incidents involving stalled vehicles	N/A	$5 per hour, based on an assumption (1994 dollars)	N/A	Field data for the duration of stalled vehicles reported 8 minutes for all lateral locations
Southwest Freeway Motorist Assistance Program: Houston, Texas	19:1 (August 1991 to July 1992)	Congestion delay savings and cost of service savings to assisted motorists	FREQ10PC, a deterministic and macroscopic model (patrol route)	$10.47 per hour, based on a previous Texas study (1992 dollars)	Field data (3 lanes) collected for the following incident types and locations: stall blocking shoulder, 29%; stall or crash blocking one lane, 52%. Field data (4 lanes) collected for stalls: 1 lane blocked, 43%; 3 lanes blocked, 82%. Assumed 12.5% for a stall blocking the shoulder (4 lanes)	Field data for the duration of all incidents reported 16.5 minutes for all lateral locations
Courtesy Patrol Program: Detroit, Michigan	15:1 (September 1994 to August 1995)	Congestion Delay Savings	Deterministic queuing model (N/A)	$10 per hour, based on an assumption (1995 dollars)	N/A	N/A
Highway Emergency Local Patrol: New York, New York	26:1 (September 1994 to August 1995)	Congestion Delay Savings	Deterministic queuing model (N/A)	$10 per hour, based on an assumption (1995 dollars)	N/A	N/A
Emergency Traffic Patrol: Chicago, Illinois	17:1 (N/A)	Congestion Delay Savings	N/A	$10 per hour, based on an assumption (1990 dollars)	N/A	N/A
Motorist Assistance Program: Houston, Texas	7:1 to 36:1 (N/A)	Congestion Delay Savings	N/A	$12 per hour, based on an assumption	N/A	Assumed a range of durations, from 5 minutes to 20 minutes, for all incidents and lateral locations
Motorist Assistance Patrol: Charlotte, North Carolina	7.6:1 (N/A)	Congestion Delay Savings	FREWAY3 (N/A)	N/A	N/A	N/A

This travel time value represented a reasonable assumption when comparing it to the $10.47 per hour travel time value, based on an actual study result, used in the Southwest Freeway Motorist Assistance Program (MAP) evaluation. Clearly, when considering the benefit components computed and the field data gathered, the Southwest Freeway MAP study yielded the most detailed benefit estimation of any evaluation listed in Table 2.2. This chapter concludes with a synopsis of three freeway service patrol evaluations.

Cuciti and Janson [7] conducted a benefit-cost analysis, covering six months of service patrol operation from August 1992 to February 1993, of the Mile-High Courtesy Patrol (MHCP) which operated on approximately 28 miles of Interstate 25 and a short section of Interstate 70 in Denver. The Colorado Department of Transportation sponsored program for motorist assistance during peak travel hours functioned under contracts with the American Automobile Association and the Colorado State Patrol, two organizations utilizing tow trucks and four-wheel-drive vehicles, respectively. During the study period, the MHCP attended to an average of 27.6 incidents per day. Cuciti and Janson made assumptions, in terms of number of lanes lost, concerning roadway capacity reduction at the following incident sites: right or left shoulder, 0.7; left or right lane, 1.7; middle lane, 2.3; off-road, 0.3. With regard to incident duration reduction by the MHCP, Cuciti and Janson assumed incident detection times remained unchanged before and after the program's inception; however, the researchers reported, based on actual observations, that the MHCP reduced incident response and clearance times by 10.5 minutes for in-lane incidents and 8.6 minutes for incidents occurring outside the traveled way. Cuciti and Janson used a deterministic queuing model and a $10 per hour (1993 dollars) travel time value assumption to estimate a six month delay savings ranging from $1.8 to $2 million. Given a range of MHCP contract costs, the researchers computed benefit-cost ratios varying from 10.5:1 to 16.9:1.

A Minnesota Department of Transportation (MnDOT) [10] report described the operation and evaluation of the Highway Helper program, a daytime service patrol which assisted 12,798 motorists in a one year period from March 1993 to February 1994 on Twin Cities metro area highways. MnDOT researchers based Highway Helper's benefit estimation on the savings in incident duration time when Highway Helper assists a stalled motorist during peak travel hours. Stalls accounted for 84 percent of all incidents attended to by the program. Previous MnDOT research, cited in the report, on the impact of stalled vehicles on Twin Cities highways concluded one minute of incident duration caused five vehicle-hours of total delay, and Highway Helper contributed to an eight minute reduction in the duration of a stall when the program assisted a motorist. MnDOT researchers assumed a conservative value of $5 per hour (1994 dollars) to estimate a motorist's cost of delay which, in turn, yielded a 2.3:1 benefit-cost ratio for Highway Helper.

Hawkins [13] completed a detailed evaluation of the Southwest Freeway MAP in Houston. The Texas Department of Transportation funded service patrol, assessed from August 1991 to July 1992, involved two vans operating during daytime hours in construction zones on U.S. Highway 59. In order to ensure a more accurate MAP benefit estimation, Hawkins obtained before and after MAP incident duration data and calculated an average incident duration reduction of 16.5 minutes. The researcher acquired the before MAP incident duration data through a previous Texas Transportation Institute (TTI) study of Southwest Freeway operations. Hawkins also measured the extent of roadway capacity reduction during incident occurrence through field studies at the site of MAP assists. Hawkins estimated, for a three lane freeway segment, a 29 percent reduction in roadway capacity for a stall located on the shoulder and a roadway capacity reduction of 52 percent for a stall or crash blocking one lane. Similarly, for a four lane freeway segment, Hawkins reported a 43 percent reduction in roadway capacity for a stall blocking one lane, a roadway capacity reduction of 82 percent for a stall blocking 3 lanes, and an assumed 12.5 percent decrease in roadway capacity for a stall blocking the shoulder. Through the use of the FREQ10PC macroscopic traffic simulation model and a previously estimated, by the TTI, travel time value of $10.47 per hour (1992 dollars), Hawkins computed a one year travel time savings benefit of $3,687,574. The MAP benefit estimate also included a $125,013 appraisal of the value of services provided, free of charge, to assisted motorists. This user benefit accounted for the cost of private assistance (e.g. wrecker services) to stranded motorists if the MAP did not exist. The Southwest Freeway MAP cost $196,500 to operate during the study period, resulting in a benefit-cost ratio of 19:1 for the program.

The benefit calculations reported in the literature only account for delay savings attributed to service patrol operation; however, secondary crash reduction may represent another significant benefit of freeway service patrols. These programs reduce primary incident duration which stands as a possible contributor of secondary crash occurrence. In addition, vehicle operating cost savings warrants consideration within the scope of total user benefit because fuel consumption stands as a clear additional cost to motorists in the presence of congestion, and freeway service patrols work to relieve the duration of non-recurrent congestion. The present study, when compared to freeway service patrol evaluations in the literature, is detailed in the sense that it accounts for secondary crash reduction benefit and vehicle operating cost savings, in addition to delay savings. Moreover, this study strives to produce a more accurate estimate of non-recurrent congestion delay savings by utilizing a network simulation approach, thus allowing travelers to divert around an incident occurring on the Hoosier Helper patrol route during computer simulation.

3. ANALYSIS OF INCIDENT DATA

An INDOT database containing Hoosier Helper motorist assists from August 30, 1991 to January 22, 1996 served as the source of incident information required to estimate the benefit of daytime Hoosier Helper operation in 1995. The benefit estimation of 24 hour Hoosier Helper operation was based on records of motorist assists from June 1, 1996 to December 31, 1996. Hoosier Helper completed 28,609 assists, or 17.8 assists per day, in the August 1991 to January 1996 period, and the program performed 8,986 assists, or 42 assists per day, in the stated period for 24 hour Hoosier Helper evaluation. The regular Hoosier Helper vehicle deployment strategy has remained constant from the start of the program to the present; therefore, the increase in incident rate between the two discussed time frames depended on the program's change in hours of operation and the average difference in additional vehicle deployment frequency when hazardous driving conditions exist. Based on the type of data, listed in Chapter 1, recorded by Hoosier Helper patrolmen after each motorist assist, the assist database provided such incident information as longitudinal and lateral location, type, clearance time, and an approximate indication of occurrence via Hoosier Helper arrival time. Disablements, abandoned vehicles, crashes, debris, and pedestrian assists represented the categories pertaining to incident type. Incidents marked as disablements involved one or more of the following Hoosier Helper services: supplying gas, changing tire, giving jump start, calling tow trucks, doing minor repair, extinguishing fire, removing vehicle from roadway, escorting a motorist, calling other, providing information, and waking a sleeping motorist. The following sections of this chapter present a detailed analysis of Hoosier Helper assisted incident frequency and clearance time during daytime and 24 hour program operation. The variance in the number of observations for different incident distributions was attributed to the absence of some complete records of motorist assists within the database.

3.1. Hoosier Helper Assisted Incidents, Daytime Operation

Figure 3.1 and Table 3.1 present a distribution of incident frequency and clearance time by incident type and lateral location of occurrence for the period from August 1991 to January 1996. An analysis of these incidents found that disablements, with a mean clearance time of 13.60 minutes, represented 67.8 percent of the total number of incidents, 28,461. Crashes had the largest mean clearance time, 26.76 minutes, of all incident types and comprised 5.3 percent of all incidents. The remainder of the incident frequency distribution consisted of 18.7 percent abandoned vehicles, 7.7 percent debris removal, and 0.5 percent pedestrian assists. For the purpose of comparison, a 1984 FHWA study reported that 80 percent of freeway incidents recorded by local authorities were disablements and abandoned vehicles, while crashes made up ten percent of reported incidents [2]. The above average clearance time of incidents blocking one lane (see Table 3.1), except those concerning debris because of the emphasis on fast removal, could have been attributed to a greater degree of incident severity.

Table 3.2 contains a distribution of daily incident rates and incident types by season and day of the week (weekday and weekend) for the Borman Expressway and

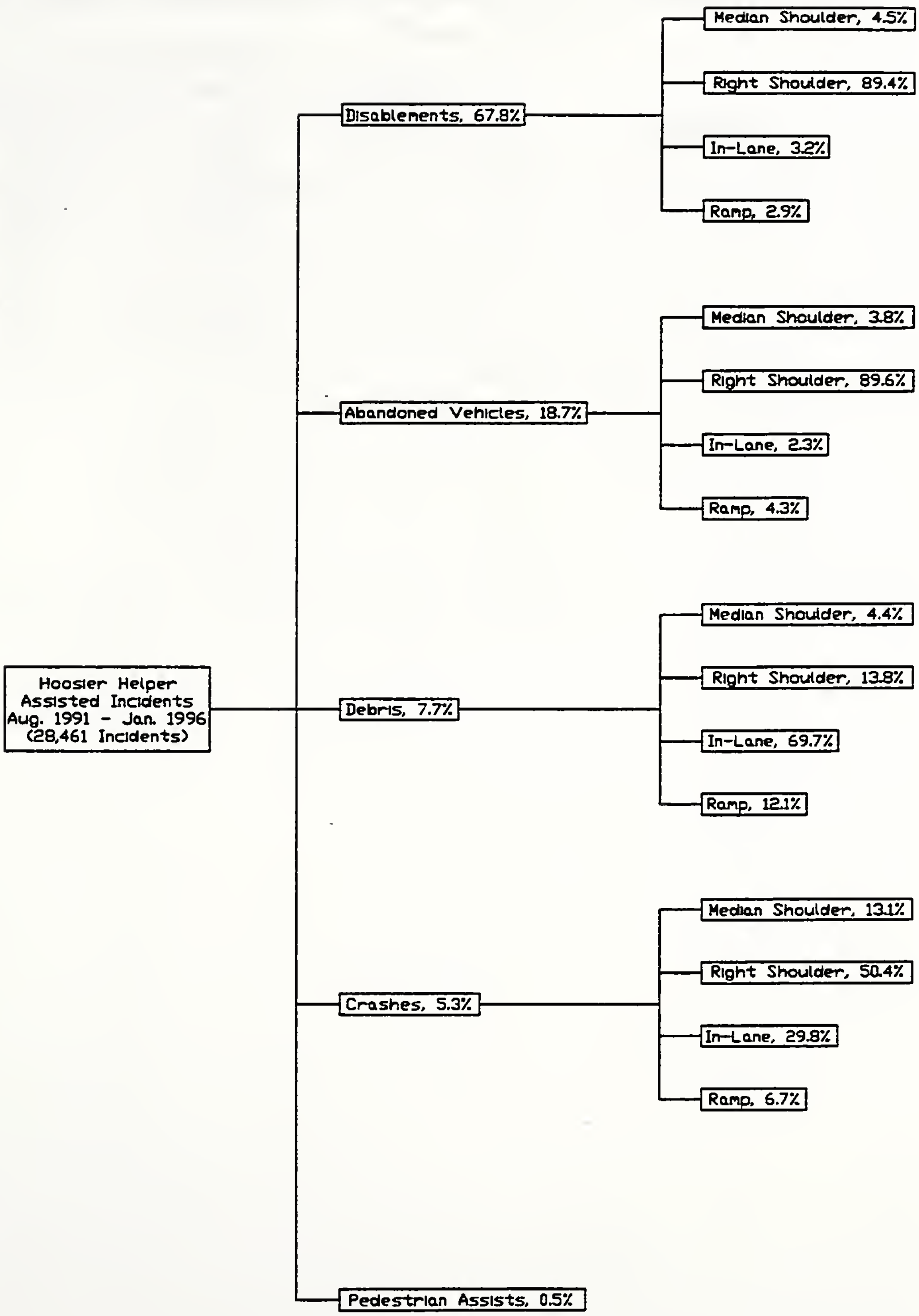

Figure 3.1 Distribution of Hoosier Helper Assisted Incidents by Type and Lateral Location, Daytime Operation

Table 3.1 Clearance Time of Hoosier Helper Assisted Incidents, Daytime Operation

	Incident Location					
	In-Lane		**Shoulder**		**Ramp**	
Incident Type	**Mean**	**STD**	**Mean**	**STD**	**Mean**	**STD**
Disablements	17.86 *(582)*	29.14	13.39 *(17585)*	16.05	15.85 *(543)*	17.36
Abandoned Vehicles	5.85 *(120)*	7.80	3.60 *(4820)*	7.75	4.45 *(222)*	9.96
Debris	4.99 *(1490)*	12.52	5.56 *(390)*	10.66	4.82 *(259)*	16.58
Crashes	32.69 *(430)*	29.93	23.89 *(911)*	26.20	27.38 *(95)*	22.99

Note: - All mean and standard deviation values are in minutes
- The number of observations per category are expressed in italics

Table 3.2 Distribution of Hoosier Helper Assisted Incidents by Time of Year, Daytime Operation

Location	Season / Day of Week	Average Number of Incidents Per Day	Percent Disablements	Percent Abandoned Vehicles	Percent Debris	Percent Crashes
Borman Expressway	Spring / Weekday	13.6	65.7	18.3	10.8	5.2
	Spring / Weekend	19.0	71.7	15.4	9.6	3.3
	Summer / Weekday	14.3	66.1	16.1	13.0	4.8
	Summer / Weekend	23.4	74.8	14.3	6.2	4.7
	Fall / Weekday	15.6	67.7	19.1	7.3	5.9
	Fall / Weekend	18.8	71.2	18.6	6.5	3.7
	Winter / Weekday	13.3	66.2	20.8	5.2	7.8
	Winter / Weekend	14.0	68.6	21.2	5.0	5.2
	Total	15.5	68.4	18.1	8.2	5.3
Interstate 65	Spring / Weekday	1.8	62.2	26.8	5.4	5.4
	Spring / Weekend	3.7	67.6	23.2	6.5	6.5
	Summer / Weekday	1.4	59.9	28.9	8.3	8.3
	Summer / Weekend	4.4	72.5	19.9	5.2	5.2
	Fall / Weekday	1.6	68.5	24.3	3.5	3.5
	Fall / Weekend	3.0	66.7	20.4	3.9	3.9
	Winter / Weekday	1.6	66.8	22.5	2.6	2.6
	Winter / Weekend	3.1	64.3	25.9	4.1	4.1
	Total	2.1	66.3	23.9	4.8	4.8

Note:
- Incident rate classification was based on 28,377 observations
- Incident type classification was based on 28,233 observations

Interstate 65. The season and day of the week categories selected for the incident breakdown by time of year correspond to those chosen as incident simulation scenarios for the estimation of Hoosier Helper benefits. The following seasons consisted of a three month period considered to have atmospheric conditions typically associated with the season that the months represent: spring in March, April, and May; summer in June, July, and August; fall in September, October, and November; winter in December, January, and February. The table shows that the daily incident rate increased in the summer months, especially with regard to summer weekends. The presence of roadway construction, where Hoosier Helper operators occasionally deploy an additional patrol vehicle during peak travel hours, and higher traffic volumes due to vacationers could have collectively contributed to the phenomena. The percentage of crashes on the Borman Expressway rose in winter, a fact most likely caused, in part, by weather conditions.

Table 3.3 lists incident rates for seven different time periods within a day. The greatest rate of incident occurrence, an overall average of 1.513 incidents per hour, took place during the afternoon peak travel hours of 3:00 PM and 6:00 PM. This period also contained the highest hourly traffic volumes for a typical day. As previously stated, Hoosier Helper maintained daytime operations from 6:00 AM to 8:30 PM; however, the table reveals the program completed, on average, over 20 percent of its motorist assists between the hours of 9:00 PM and 6:00 AM. This finding could have been attributed to the occasional expansion of Hoosier Helper patrol-hours during holiday weekends, overnight roadway construction, and other hazardous driving conditions.

Table 3.3 Distribution of Hoosier Helper Assisted Incidents by Time of Day, Daytime Operation

Season / Day of Week	Time of Day	Average Incident Rate on Borman Expressway (incidents per hour)	Average Incident Rate on Interstate 65 (incidents per hour)
Spring / Weekday	6 AM to 9 AM	0.292	0.035
	9 AM to 12 PM	0.278	0.034
	12 PM to 3 PM	0.918	0.079
	3 PM to 6 PM	1.318	0.256
	6 PM to 9 PM	0.569	0.113
	9 PM to 12 AM	0.155	0.041
	12 AM to 6 AM	0.504	0.016
Spring / Weekend	6 AM to 9 AM	0.711	0.051
	9 AM to 12 PM	0.746	0.108
	12 PM to 3 PM	1.470	0.305
	3 PM to 6 PM	1.267	0.327
	6 PM to 9 PM	0.806	0.225
	9 PM to 12 AM	0.346	0.114
	12 AM to 6 AM	0.490	0.051
Summer / Weekday	6 AM to 9 AM	0.625	0.044
	9 AM to 12 PM	0.475	0.036
	12 PM to 3 PM	0.755	0.087
	3 PM to 6 PM	1.143	0.111
	6 PM to 9 PM	0.590	0.084
	9 PM to 12 AM	0.147	0.016
	12 AM to 6 AM	0.513	0.046
Summer / Weekend	6 AM to 9 AM	0.902	0.162
	9 AM to 12 PM	1.016	0.140
	12 PM to 3 PM	1.517	0.305
	3 PM to 6 PM	1.333	0.381
	6 PM to 9 PM	1.089	0.206
	9 PM to 12 AM	0.413	0.044
	12 AM to 6 AM	0.763	0.144
Fall / Weekday	6 AM to 9 AM	0.503	0.043
	9 AM to 12 PM	0.443	0.054
	12 PM to 3 PM	0.986	0.075
	3 PM to 6 PM	1.492	0.156
	6 PM to 9 PM	0.941	0.117
	9 PM to 12 AM	0.257	0.038
	12 AM to 6 AM	0.297	0.025
Fall / Weekend	6 AM to 9 AM	0.367	0.064
	9 AM to 12 PM	0.538	0.087
	12 PM to 3 PM	1.444	0.279
	3 PM to 6 PM	1.638	0.256
	6 PM to 9 PM	1.213	0.179
	9 PM to 12 AM	0.574	0.087
	12 AM to 6 AM	0.236	0.017
Winter / Weekday	6 AM to 9 AM	0.434	0.024
	9 AM to 12 PM	0.412	0.020
	12 PM to 3 PM	0.814	0.066
	3 PM to 6 PM	1.056	0.259
	6 PM to 9 PM	0.672	0.110
	9 PM to 12 AM	0.246	0.040
	12 AM to 6 AM	0.393	0.009
Winter / Weekend	6 AM to 9 AM	0.453	0.039
	9 AM to 12 PM	0.436	0.056
	12 PM to 3 PM	1.031	0.233
	3 PM to 6 PM	1.058	0.344
	6 PM to 9 PM	0.811	0.222
	9 PM to 12 AM	0.325	0.081
	12 AM to 6 AM	0.276	0.025
Total	6 AM to 9 AM	0.501	0.048
	9 AM to 12 PM	0.480	0.054
	12 PM to 3 PM	1.012	0.134
	3 PM to 6 PM	1.281	0.232
	6 PM to 9 PM	0.786	0.135
	9 PM to 12 AM	0.267	0.048
	12 AM to 6 AM	0.421	0.031

Note: - Incident rate classification was based on 28,350 observations

Table 3.4 provides incident rates and directional distributions by longitudinal location on the Borman Expressway and Interstate 65. Figure 1.1 illustrates the specific location of the roadway links listed. The Burr Street to Grant Street link exhibited an above average incident rate, 1.246 incidents per day per mile, because it represented an area of overlap of two regular Hoosier Helper patrol routes. Interstate 65 yielded significantly lower incident rates compared to that of the Borman Expressway because, as discussed in Chapter 1, Hoosier Helper does not patrol the interstate on a regular basis.

3.2. Hoosier Helper Assisted Incidents, 24 Hour Operation

Figure 3.2 and Table 3.5 present incident frequency and clearance time, disaggregated by incident type and lateral location of occurrence, for the period from June 1996 to December 1996. An investigation of these incidents produced the following distribution regarding incident type: 69.6 percent disablements, 16.9 percent abandoned vehicles, 5.8 percent debris removal, 7.5 percent crashes, and 0.2 percent pedestrian assists. The percentage of crash and debris incidents blocking one lane increased significantly, by about 40 and 30 percent respectively, in comparison to findings stated in the previous section. As expected, crashes had the largest mean clearance time of all incident types, 30.12 minutes.

Tables 3.6, 3.7, and 3.8 contain a breakdown of incidents by time of year, time of day, and location, respectively. The results reported in these tables exhibit the same trends, discussed in the previous section, as those in corresponding tables for incidents occurring during daytime Hoosier Helper operation. However, a comparison of Tables 3.3 and 3.7 revealed that an unexpectedly large margin exists between daytime hour

Table 3.4 Distribution of Hoosier Helper Assisted Incidents by Location, Daytime Operation

Location	Link	Length of Link (miles)	Incident Rate (incidents/day/mile)	Percent on EB / NB Lanes	Percent on WB / SB Lanes
Borman Expressway (eastbound / westbound freeway)	Indiana-Illinois border to Calumet Ave.	0.87	0.589	47.9	52.1
	Calumet Ave. to Indianapolis Blvd.	1.51	1.425	49.9	50.1
	Indianapolis Blvd. to Kennedy Ave.	0.97	0.778	51.4	48.6
	Kennedy Ave. to Cline Ave.	1.56	0.435	50.0	50.0
	Cline Ave. to Burr St.	1.51	0.702	51.9	48.1
	Burr St. to Grant St.	2.47	1.246	51.7	48.3
	Grant. St. to Broadway	1.00	0.974	49.0	51.0
	Broadway to Interstate 65	1.86	0.805	54.4	45.6
	Interstate 65 to State Road 51	3.25	0.612	48.9	51.1
	State Road 51 to Interstate 90	0.51	1.302	51.1	48.9
	Total	15.51	0.861	50.8	49.2
Interstate 65 (northbound / southbound freeway)	U. S. Highway 30 to 61st St.	2.51	0.149	42.2	57.8
	61st St. to Ridge Road	3.10	0.169	45.7	54.3
	Ridge Road to Borman Expressway	1.39	0.297	46.6	53.4
	Borman Expressway to Interstate 90	2.21	0.093	57.5	42.5
	Total	9.21	0.165	46.7	53.3

Note: - Incident rate classification was based on 23,911 observations
- Directional distribution classification was based on 23,823 observations

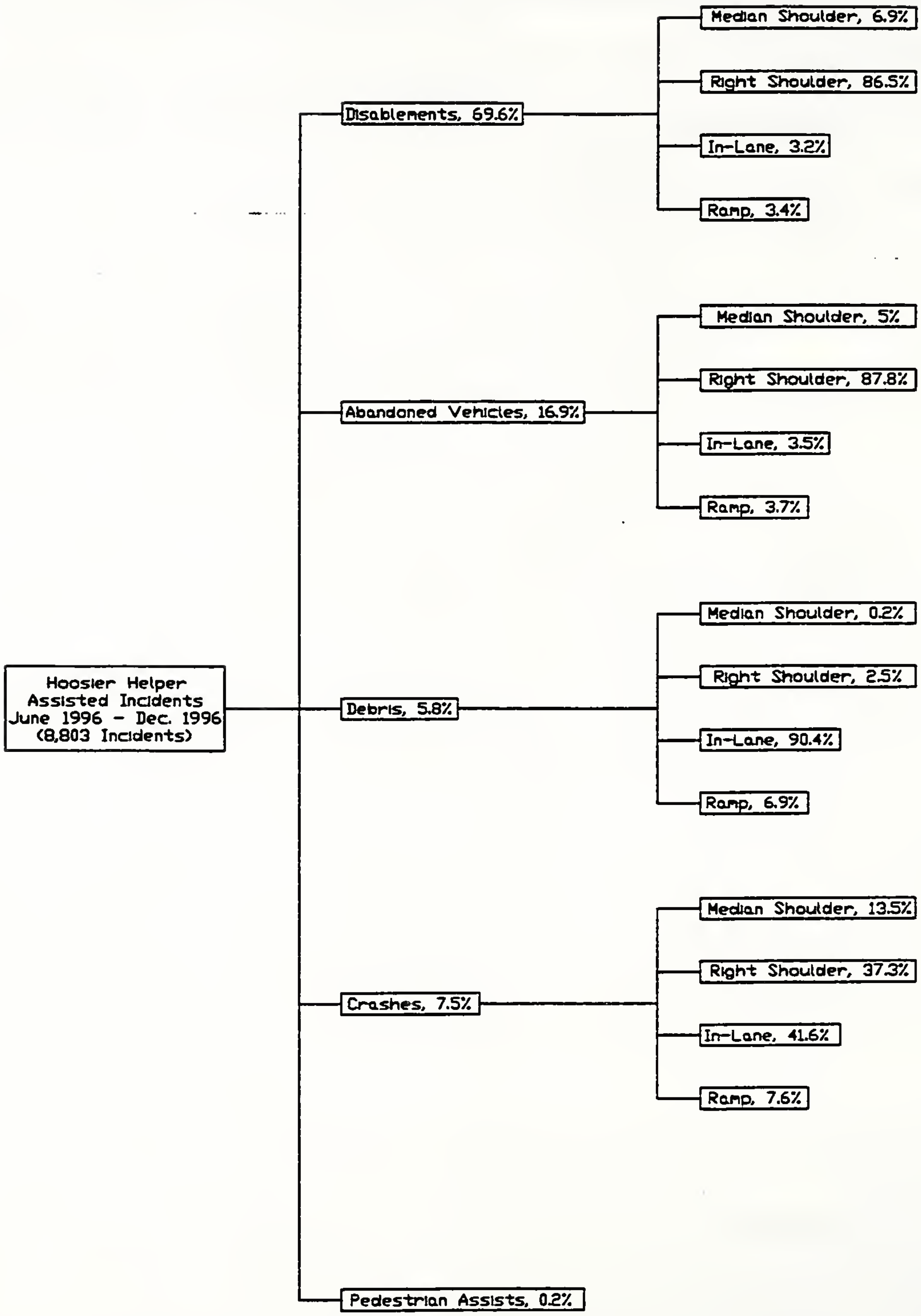

Figure 3.2 Distribution of Hoosier Helper Assisted Incidents by Type and Lateral Location, 24 Hour Operation

Table 3.5 Clearance Time of Hoosier Helper Assisted Incidents, 24 Hour Operation

	Incident Location					
	In-Lane		Shoulder		Ramp	
Incident Type	**Mean**	**STD**	**Mean**	**STD**	**Mean**	**STD**
Disablements	13.85 *(179)*	19.16	12.11 *(5523)*	15.75	13.97 *(195)*	18.51
Abandoned Vehicles	3.19 *(52)*	2.35	3.10 *(1339)*	4.53	5.07 *(52)*	9.20
Debris	4.35 *(446)*	9.09	6.22 *(12)*	16.43	4.56 (33)	13.30
Crashes	34.42 *(254)*	30.98	24.84 *(315)*	29.01	42.55 *(46)*	52.31

Note: - All mean and standard deviation values are in minutes
- The number of observations per category are expressed in italics

Table 3.6 Distribution of Hoosier Helper Assisted Incidents by Time of Year, 24 Hour Operation

Location	Season / Day of Week	Average Number of Incidents Per Day	Percent Disablements	Percent Abandoned Vehicles	Percent Debris	Percent Crashes
Borman Expressway	Summer / Weekday	42.2	70.7	14.4	7.8	7.1
	Summer / Weekend	31.2	75.2	13.7	3.7	7.4
	Fall / Weekday	37.1	66.0	19.8	6.5	7.7
	Fall / Weekend	33.9	73.2	18.1	4.9	3.8
	Winter / Weekday	32.4	68.4	18.4	4.0	9.2
	Winter / Weekend	34.1	65.0	14.9	4.6	15.5
	Total	36.9	69.6	16.8	6.1	7.5
Interstate 65	Summer / Weekday	6.9	70.8	16.9	4.0	8.3
	Summer / Weekend	3.8	66.3	22.8	4.0	6.9
	Fall / Weekday	4.1	67.8	20.2	2.6	9.4
	Fall / Weekend	2.9	74.7	13.3	0	12.0
	Winter / Weekday	4.1	66.7	20.0	0	13.3
	Winter / Weekend	3.6	68.7	18.8	3.1	9.4
	Total	4.7	69.4	18.4	3.0	9.2

Note: - Incident rate classification was based on 8,913 observations
- Incident type classification was based on 8,814 observations

Table 3.7 Distribution of Hoosier Helper Assisted Incidents by Time of Day, 24 Hour Operation

Season / Day of Week	Time of Day	Average Incident Rate on Borman Expressway (incidents per hour)	Average Incident Rate on Interstate 65 (incidents per hour)
Summer / Weekday	6 AM to 9 AM	2.482	0.303
	9 AM to 12 PM	2.431	0.308
	12 PM to 3 PM	2.118	0.287
	3 PM to 6 PM	2.579	0.687
	6 PM to 9 PM	1.990	0.374
	9 PM to 12 AM	1.051	0.154
	12 AM to 6 AM	0.615	0.082
Summer / Weekend	6 AM to 9 AM	0.914	0.111
	9 AM to 12 PM	1.444	0.062
	12 PM to 3 PM	2.049	0.198
	3 PM to 6 PM	2.580	0.358
	6 PM to 9 PM	1.605	0.235
	9 PM to 12 AM	0.753	0.185
	12 AM to 6 AM	0.457	0.049
Fall / Weekday	6 AM to 9 AM	2.072	0.174
	9 AM to 12 PM	2.000	0.195
	12 PM to 3 PM	1.687	0.179
	3 PM to 6 PM	2.395	0.256
	6 PM to 9 PM	1.836	0.195
	9 PM to 12 AM	0.985	0.154
	12 AM to 6 AM	0.641	0.064
Fall / Weekend	6 AM to 9 AM	1.282	0.038
	9 AM to 12 PM	1.603	0.103
	12 PM to 3 PM	1.346	0.141
	3 PM to 6 PM	2.282	0.282
	6 PM to 9 PM	1.833	0.154
	9 PM to 12 AM	0.987	0.064
	12 AM to 6 AM	0.855	0.077
Winter / Weekday	6 AM to 9 AM	1.848	0.030
	9 AM to 12 PM	1.258	0.106
	12 PM to 3 PM	1.606	0.197
	3 PM to 6 PM	2.152	0.394
	6 PM to 9 PM	1.364	0.212
	9 PM to 12 AM	1.121	0.318
	12 AM to 6 AM	0.682	0.053
Winter / Weekend	6 AM to 9 AM	1.963	0.222
	9 AM to 12 PM	1.556	0.111
	12 PM to 3 PM	1.556	0.074
	3 PM to 6 PM	2.259	0.296
	6 PM to 9 PM	1.296	0.222
	9 PM to 12 AM	1.148	0.222
	12 AM to 6 AM	0.722	0.019
Total	6 AM to 9 AM	1.927	0.176
	9 AM to 12 PM	1.917	0.188
	12 PM to 3 PM	1.808	0.207
	3 PM to 6 PM	2.430	0.419
	6 PM to 9 PM	1.782	0.252
	9 PM to 12 AM	0.997	0.167
	12 AM to 6 AM	0.647	0.066

Note: - Incident rate classification was based on 8,794 observations

Table 3.8 Distribution of Hoosier Helper Assisted Incidents by Location, 24 Hour Operation

Location	Link	Length of Link (miles)	Incident Rate (incidents/day/mile)	Percent on EB / NB Lanes	Percent on WB / SB Lanes
Borman Expressway (eastbound / westbound freeway)	Indiana-Illinois border to Calumet Ave.	0.87	1.133	53.6	46.4
	Calumet Ave. to Indianapolis Blvd.	1.51	3.970	46.8	53.2
	Indianapolis Blvd. to Kennedy Ave.	0.97	2.206	50.4	49.6
	Kennedy Ave. to Cline Ave.	1.56	0.689	63.0	57.0
	Cline Ave. to Burr St.	1.51	1.649	56.5	43.5
	Burr St. to Grant St.	2.47	3.046	50.0	50.0
	Grant. St. to Broadway	1.00	2.598	49.0	51.0
	Broadway to Interstate 65	1.86	2.213	52.5	47.5
	Interstate 65 to State Road 51	3.25	1.586	49.7	50.3
	State Road 51 to Interstate 90	0.51	2.263	56.1	43.9
	Total	15.51	2.143	50.9	49.1
Interstate 65 (northbound / southbound freeway)	U. S. Highway 30 to 61st St.	2.51	0.259	34.8	65.2
	61st St. to Ridge Road	3.10	0.404	42.7	57.3
	Ridge Road to Borman Expressway	1.39	0.854	47.6	52.4
	Borman Expressway to Interstate 90	2.21	0.311	59.4	40.6
	Total	9.21	0.410	45.9	54.1

Note: - Incident rate classification was based on 7,920 observations
- Directional distribution classification was based on 7,874 observations

incident rates for daytime and 24 hour program operation. Possible explanations for the increase in motorist assists for the June 1996 to December 1996 period include a more efficient Hoosier Helper operation, relative to the program's earlier years, and a greater frequency of additional Hoosier Helper vehicle deployment because of roadway construction, periods of heavy travel, or other hazardous driving conditions.

4. HOOSIER HELPER COSTS

This chapter presents a summary of the 1995 and June 1996 to December 1996 investment, overhead, and maintenance costs related to Hoosier Helper daytime and 24 hour operation. The cost data, obtained from INDOT, contained records of all Hoosier Helper equipment purchases from the start of the program in 1991 through 1996. The data also included a detailed summary of 1995 and 1996 overhead costs, maintenance costs, and employee salaries. The given cost information allowed for the finding of an equivalent annual investment cost, overhead cost, and maintenance cost for 1995 and the stated seven month period in 1996.

4.1. Estimation of Equivalent Annual Cost

Each investment item, purchased prior to 1996, was converted to 1995 dollars through a Consumer Price Index (CPI) which best represented the item purchased [18]. All unique Hoosier Helper capital items were assumed to serve as an integral part of the program's continuing operation; therefore, these items were considered as perpetual investments. The process of estimating an equivalent annual investment cost involved assigning a service life and, if necessary, a salvage value to each item of investment. Table 4.1 lists all of the information, relative to Hoosier Helper equipment purchases, required to estimate the program's 1995 and 1996 equivalent annual investment cost. Major

Table 4.1 Hoosier Helper Investment Items

Investment Item (purchase year)	Purchase Price (quantity)	Service Life (years)	Salvage Value (per item)	CPI Category[1]	Purchase Year CPI	1995 CPI	1996 CPI[2]
New one-ton, extended cab truck (1991)	$17,865.24 (2)	3	$1000	New trucks	127.0	145.9	152.3
Used 1989 Ford E-250 van (1993)	$3,583.22 (1)	2	$500	Used cars	133.9	156.5	163.6
Used 1989 Ford E-250 van (1995)	$1,357.30 (1)	2	$500	Used cars	156.5	156.5	163.6
Used 1990 Ford E-250 van (1994)	$1,256.90 (1)	2	$500	Used cars	141.7	156.5	163.6
New 1995 Ford F-350 truck (1995)	$17,865.24 (1)	3	$1000	New trucks	145.9	145.9	152.3
Fillrite 1210 petroleum pump (1992)	$264.50 (2)	10	-	Transportation	126.5	139.1	143.7
Car phone (1992)	$169 (5)	5	-	Appliances and electronic equipment	84.6	80.0	79.5
Tools (1992)	$636 (1)	10	-	Auto maintenance and repair	141.3	154.0	159.4
Dual purpose hitch for truck (1992)	$252 (2)	3	-	New trucks	130.9	145.9	152.3
12 Volt, 5000 lb., electric detachable winch (1992)	$602.43 (2)	10	-	Auto maintenance and repair	141.3	154.0	159.4
Push bumper for truck (1992)	$594.93 (2)	3	-	New trucks	130.9	145.9	152.3
Tools (1991)	$821.70 (1)	10	-	Auto maintenance and repair	136.0	154.0	159.4
Running boards for truck (1992)	$205.50 (2)	3	-	New trucks	130.9	145.9	152.3
Water bucket (1992)	$19.08 (2)	10	-	Transportation	126.5	139.1	143.7
Socket holder (1992)	$15 (4)	10	-	Auto maintenance and repair	141.3	154.0	159.4
Elastic shock cord (1992)	$21.64 (1)	10	-	Auto maintenance and repair	141.3	154.0	159.4
Hooks and holders (1992)	$141.34 (1)	10	-	Auto maintenance and repair	141.3	154.0	159.4
3 ton hydraulic floor jack (1992)	$149.58 (2)	10	-	Auto maintenance and repair	141.3	154.0	159.4
CB and accessories (1992)	$125.85 (2)	5	-	Appliances and electronic equipment	84.6	80.0	79.5
Tool set (1992)	$229.50 (2)	10	-	Auto maintenance and repair	141.3	154.0	159.4
Set of pliers (1992)	$36.14 (2)	10	-	Auto maintenance and repair	141.3	154.0	159.4
Electrical pliers (1992)	$18 (2)	10	-	Auto maintenance and repair	141.3	154.0	159.4
3 ton hydraulic floor jack (1991)	$127.58 (2)	10	-	Auto maintenance and repair	136.0	154.0	159.4
Lug wrench (1991)	$5.36 (2)	10	-	Auto maintenance and repair	136.0	154.0	159.4
Tools (1991)	$99.38 (1)	10	-	Auto maintenance and repair	136.0	154.0	159.4
CB and accessories (1991)	$125.85 (2)	5	-	Appliances and electronic equipment	86.0	80.0	79.5
Tools (1992)	$707.02 (1)	10	-	Auto maintenance and repair	141.3	154.0	159.4
Tools (1993)	$620.25 (1)	10	-	Auto maintenance and repair	145.9	154.0	159.4
Illuminated flashing traffic cone (1993)	$89 (13)	5	-	Transportation	130.4	139.1	143.7
Fillrite meter (1992)	$98.63 (1)	10	-	Auto maintenance and repair	141.3	154.0	159.4
120 gallon portable fuel tank (1992)	$229 (1)	10	-	Auto maintenance and repair	141.3	154.0	159.4
Tools (1992)	$101.18 (1)	10	-	Auto maintenance and repair	141.3	154.0	159.4
Booster cable (1993)	$59.87 (1)	10	-	Auto maintenance and repair	145.9	154.0	159.4
Truck hitch (1992)	$164.83 (2)	3	-	New trucks	130.9	145.9	152.3
Bottle and floor jacks (1993)	$407.50 (1)	10	-	Auto maintenance and repair	145.9	154.0	159.4
Reflective tape (1993)	$268.80 (1)	3	-	Transportation	130.4	139.1	143.7
Cellular phone accessory (1992)	$25 (1)	5	-	Appliances and electronic equipment	84.6	80.0	79.5
Reflective tape (1992)	$334 (1)	3	-	Transportation	126.5	139.1	143.7
Tools (1993)	$200.40 (1)	10	-	Auto maintenance and repair	145.9	154.0	159.4
3 ton hydraulic floor jack (1993)	$130.46 (3)	10	-	Auto maintenance and repair	145.9	154.0	159.4
Telescoping field mast[3] (1994)	$4165 (1)	10	-	Appliances and electronic equipment	82.3	80.0	79.5
Cellular phone (1994)	$199 (12)	5	-	Appliances and electronic equipment	82.3	80.0	79.5
486 laptop computer (1994)	$3284 (4)	5	$500	Appliances and electronic equipment	82.3	80.0	79.5
Power supply for a computer (1993)	$143.75 (4)	5	-	Appliances and electronic equipment	83.4	80.0	79.5
Traffic control items (1993)	$4664 (1)	5	-	Transportation	130.4	139.1	143.7
Plastic water can (1994)	$8.09 (3)	10	-	Transportation	134.3	139.1	143.7
Disposable blanket (1995)	$3.50 (10)	10	-	Transportation	139.1	139.1	143.7
Small tools and equipment (1995)	$166 (1)	10	-	Auto maintenance and repair	154.0	154.0	159.4
Building and plant equipment (1995)	$506 (1)	10	-	Auto maintenance and repair	154.0	154.0	159.4
Shop equipment (1995)	$2270 (1)	10	-	Auto maintenance and repair	154.0	154.0	159.4
Traffic maintenance equipment (1995)	$107,445 (1)	5	-	Transportation	139.1	139.1	143.7
Camera equipment (1996)	$203.70 (1)	5	-	Appliances and electronic equipment	79.5	-	79.5

[1] As stated in the U.S. Bureau of the Census *Statistical Abstract of the United States: 1996*

[2] 1996 CPI values represent projected values

[3] INDOT did not consider the telescoping field mast a perpetual investment

investments included service vehicles, tools, communication equipment, computers, and traffic control equipment.

Figure 4.1 illustrates, through an example involving a new truck purchase in 1991 (see Table 4.1), the procedure used in calculating Hoosier Helper's equivalent annual investment cost. First, the purchase price, service life, and salvage value of specific investment items was found. Second, each item's salvage value was moved to its purchase year and, subsequently, combined with the item's purchase price, yielding a value of net investment. Then, using the capital recovery factor for perpetual life, the study computed the capital cost of perpetual investment for each perpetual investment item at their respective first purchase years. Lastly, given the present worth of all investments at the start of the program (1991), an estimation of equivalent annual investment cost for Hoosier Helper was obtained. This result, when combined with 1995 salary and fringe benefit, overhead, and maintenance figures, produced the Hoosier Helper program's equivalent annual cost of operation for the year 1995. Table 4.2 presents an itemized inventory of 1995 Hoosier Helper overhead and maintenance costs in addition to employee salaries. The interest rate was assumed to be 5 percent.

Table 4.3 provides a distribution of 1995 Hoosier Helper costs. The program's total operating cost during a period marked by daytime operation was estimated at $411,200. The salary and fringe benefits of Hoosier Helper employees represented the greatest expense. A dollar estimate of employee fringe benefits was obtained by taking 65 percent, as suggested by INDOT, of employee base salaries. In 1995, Hoosier Helper consisted of a six member incident response crew, one mechanic, one clerk, and one

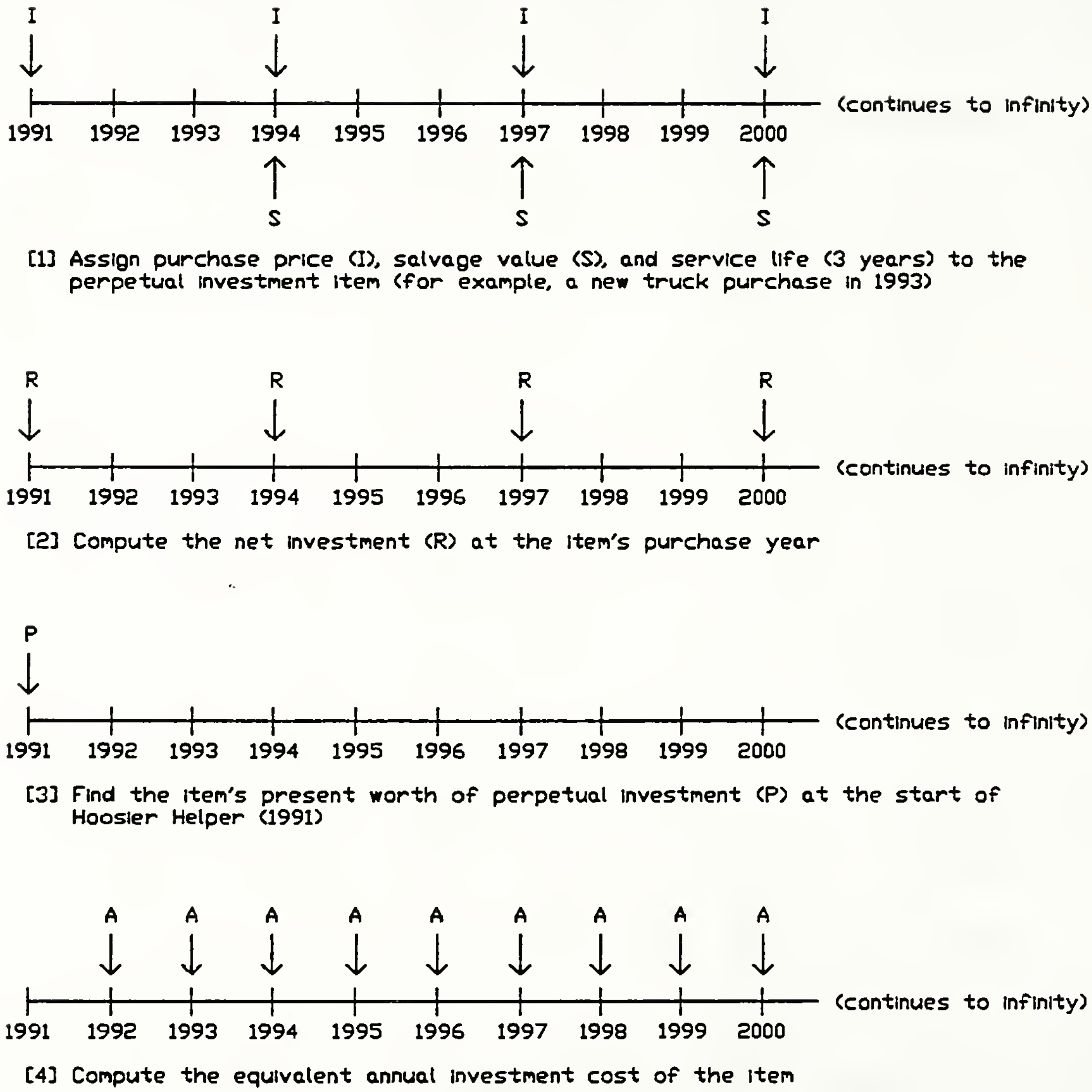

Figure 4.1 Procedure for Calculating Equivalent Annual Investment Cost

Table 4.2 Hoosier Helper Overhead Items, Maintenance Items, and Individual Employee Salaries; Daytime Operation

Cost Type	Item	1995 Cost
Overhead	Light, Heat, Water, and Power	$2,606.00
	Freight, Express, and Drayage	$84.00
	Beepers and Bellboys	$947.00
	Vehicular Telephone	$10,088.00
	Local Telephone	$4,443.00
	Long Distance Telephone and Telegraph	$2,311.00
	Rental of Office Copy Equipment	$1,896.00
	Janitorial Service and Trash Removal	-$960.00
	Film Processing	$7.00
	Agreements and Fees	-$300.00
	Security Alarms	$252.00
	Laundry and Cleaning Supplies	$180.00
	Automotive Fuel, Grease, and Oil	$461.00
	Household Supplies	$640.00
	Camera Supplies	$4.00
	Data Processing Supplies	$30.00
	Safety Supplies	$119.00
	Fuel for Hoosier Helper Vehicles	$16212.29
Maintenance	Maintenance of Equipment Rental	$20.00
	Rent or Maintenance of Telecommunications Equipment and Services	$840.00
	Auto Equipment Repairs	$14,519.00
	Office Equipment Repairs	$204.00
	Auto Parts and Supplies	$17,624.00
	Repair Parts and Supplies	$1,917.00
	Shop Machine Parts	$2.00
	Equipment Paint and Paint Supplies	$87.00
Employee Salary	Incident Response Technician II	$16,200 + $4,200 overtime
	Incident Response Technician II	$16,200 + $4,200 overtime
	Incident Response Technician III	$15,700 + $5,500 overtime
	Incident Response Technician III	$15,700 + $5,500 overtime
	Incident Response Technician III	$15,700 + $5,500 overtime
	Incident Response Technician III	$15,700 + $5,500 overtime
	Mechanic II	$13,300 + $3,000 overtime
	Clerk II	$13,500
	Operations Manager	$25,300 + $1,900 overtime

Table 4.3 1995 Hoosier Helper Costs, Daytime Operation

Item	Cost
Equivalent Annual Investment Cost	$58,700
Overhead Cost	$39,000
Maintenance Cost	$35,200
Employee Salaries and Fringe Benefits	$278,300
Equivalent Annual Cost of Operation	**$411,200**

operations manager. Major overhead and maintenance costs (see Table 4.2) included automobile parts and repairs, gasoline, and telephone charges.

Table 4.4 contains a breakdown of Hoosier Helper costs during the program's 24 hour evaluation period, June 1996 to December 1996. Calculation of the investment cost involved taking a 7/12 fraction of the 1996 equivalent annual investment cost for the stated seven month period. The study computed the investment cost using the procedure outlined for 1995 with individual investment items, including those purchased in 1996, expressed in 1996 dollars via CPI adjustment (see Table 4.1). Hoosier Helper's total operating cost was $413,900, an average increase of $808 a day over 1995 costs. The expansion of Hoosier Helper personnel, to accommodate the change to 24 hour operation, explained the rise in program expenses between the two evaluation periods. In June 1996, Hoosier Helper employed a ten member incident response crew, one mechanic, two clerks, a freeway management engineer, and a freeway management operations engineer. Table 4.5 provides a breakdown of individual employee salaries for the program's 24 hour evaluation period; moreover, the table lists all June 1996 to December 1996 overhead and maintenance cost items.

4.2. Hoosier Helper Cost per Motorist Assist

Hoosier Helper completed a total of 7,470 motorist assists in 1995. This figure, coupled with the program's 1995 operating costs, yielded an average cost per assist of $55. In addition, Hoosier Helper attended to 8,986 incidents from June 1996 to December 1996, resulting in a $46 average cost per assist. For the purpose of comparison, Highway Helper in Minneapolis operated at $46 per assist in 1994, and the

Table 4.4 June 1996 to December 1996 Hoosier Helper Costs, 24 Hour Operation

Item	**Cost**
Investment Cost	$35,600
Overhead Cost	$45,700
Maintenance Cost	$39,700
Employee Salaries and Fringe Benefits	$292,900
Total Operating Cost	**$413,900**

Table 4.5 Hoosier Helper Overhead Items, Maintenance Items, and Individual Employee Salaries; 24 Hour Operation

Cost Type	Item	June 1996 - December 1996 Cost
Overhead[1]	Light, Heat, Water, and Power	$1,828.84
	Freight, Express, and Drayage	$205.03
	Beepers and Bellboys	$1,012.67
	Vehicular Telephone	$5,969.04
	Local Telephone	$5,176.80
	Long Distance Telephone and Telegraph	$1,702.67
	Int. on Construction Contract or Agreement	$123.76
	Rental of Office Copy Equipment	$2,212.00
	Film Processing	$20.60
	Security Alarms	$49.00
	Stationery and Office Supplies	$99.14
	Laundry and Cleaning Supplies	$441.43
	Automotive Fuel, Grease, and Oil	$1,121.70
	Household Supplies	$293.06
	Data Processing Supplies	$15.28
	Acetylene and Oxygen	$20.67
	Alcohol and Anti-Freeze	$204.40
	Safety Supplies	$3,890.68
	Fuel for Hoosier Helper Vehicles	$21,345.33
Maintenance[1]	Rent or Maintenance of Telecommunications Equipment and Services	$2,016.00
	Auto Equipment Repairs	$13,446.02
	Shop Equipment Repairs	$56.00
	Maintenance Repairs and Inspection	$1,121.27
	Iron and Steel	$137.26
	Auto Parts and Supplies	$22,166.39
	Repair Parts and Supplies	$750.54
	Equipment Paint and Paint Supplies	$16.61
Employee Salary	Freeway Management Clerk	$9,720.27
	Freeway Management Engineer	$27,064.44
	Freeway Management Operations Engineer	$18,430.50 + $1,273.63 overtime
	Freeway Management Clerk	$11,618.62
	Hoosier Helper Patrolman[2]	$7,816.89 + $1,535.64 overtime
	Hoosier Helper Mechanic[2]	$2,589.64 + $51.33 overtime
	Hoosier Helper Patrolman[2]	$9,016.54 + $650.35 overtime
	Hoosier Helper Patrolman	$10,879.41 + $2,318.62 overtime
	Hoosier Helper Patrolman	$10,230.71 + $1,982.94 overtime
	Hoosier Helper Patrolman	$11,338.48 + $3,371.36 overtime
	Hoosier Helper Patrolman	$11,586.01 + $3,322.18 overtime
	Hoosier Helper Patrolman[2]	$4,628.46
	Hoosier Helper Patrolman	$8,858.61 + $3,683.00 overtime
	Hoosier Helper Patrolman	$9,374.46 + $1,027.87 overtime
	Hoosier Helper Patrolman	$11,354.81 + $2,239.24 overtime

[1] June 1996 cost data was unavailable; therefore, cost data for July 1996 to December 1996 was taken and multiplied by 7/6 in order to obtain a cost for the 24 hour Hoosier Helper evaluation period

[2] Hoosier Helper employee for only a part of the 24 hour program evaluation period

Motorist Assistance Program in Houston functioned at $51 per assist in 1993 [10, 13]. Although Hoosier Helper's cost per assist in either of the two evaluation periods may appear significant, the program must be judged on the basis of benefits provided to motorists using the Borman Expressway and Interstate 65 in addition to motorists' perception of the program.

5. HOOSIER HELPER BENEFITS

The estimation of Hoosier Helper benefit, for daytime and 24 hour program operation, involved computing a dollar savings value for each of the following three components, considered to represent a significant benefit of freeway service patrols: non-recurrent congestion delay savings, secondary crash reduction, and vehicle operating cost savings. The benefit resulting from secondary crash reduction included additional delay savings and crash cost savings. The calculation of vehicle operating cost savings pertained to estimating fuel consumption reduction. The next section presents a detailed discussion regarding the computation of non-recurrent congestion delay savings.

5.1. Non-recurrent Congestion Delay Savings

5.1.1. Incident Generation

The assessment of non-recurrent congestion delay savings required the completion of three main tasks: incident generation, estimation of unit travel time value, and incident simulation. Incidents occur as random events; therefore, the historical Hoosier Helper assist data could not serve as direct input to a traffic simulation model for estimating congestion delay. Instead, an incident generation model was developed on the basis of the Hoosier Helper assist data to produce, randomly, a set of incidents for any given season and day of the week (weekday or weekend). The model output included such incident descriptors as occurrence time, longitudinal and lateral location, type, and clearance time, thus satisfying the input requirements for incident simulation of the traffic simulation model, XXEXQ, used in the present study [19]. Section 5.1.3 contains a discussion regarding XXEXQ specifics. The incident generation model was calibrated separately for the daytime and 24 hour Hoosier Helper evaluations, and the model exhibited a good fit to the historical data for each evaluation scenario.

5.1.2. Estimation of Unit Travel Time Value

The calculation of unit travel time value represents an important part of the overall benefit estimation process because it influences the values of non-recurrent congestion delay savings and delay savings due to secondary crash reduction, collectively expected to account for a large portion of the benefit. Table 5.1 provides a step-by-step description of the unit travel time value estimation for weekdays and weekends in the year 1995, marking the period of Hoosier Helper's daytime evaluation. The Borman Expressway, as indicated in the table, serves a high percentage of truck traffic; therefore, the study recognized the need to not only consider the value of travel time for automobiles but also that of single unit and combination truck operators. In 1987, the American Automobile Association computed a travel time value of $6 per hour for automobiles [20]. In 1991, the Highway Economics Requirement System reported, in 1990 dollars, a $25.42 and $28.33 per hour value of travel time for single unit trucks and combination trucks, respectively [21]. The study used Consumer Price Indexes (CPI) to represent the travel time value of automobiles, $8.03 per hour, in 1995 dollars, while Producer Price Indexes (PPI) were utilized to denote the travel time value of single unit trucks, $27.26 per hour, and combination trucks, $30.38 per hour, in 1995 dollars [18]. Table 5.2 contains a list of the

Table 5.1 Estimation of Unit Travel Time Value, Daytime Operation

Item	Weekday	Weekend
Value of Time by Vehicle (1995 dollars)	Auto = $8.03 per hour, Single Unit Truck = $27.26 per hour, Combination Truck = $30.38 per hour	
Borman Expressway Vehicle Classification	Percent SU Trucks = 9.7% Percent Comb. Trucks = 24.0%	Percent SU Trucks = 7.8% Percent Comb. Trucks = 11.5%
Aggregated Value of Time for the Borman Expressway	8.03*0.663 + 27.26*0.097 + 30.38*0.24 = $15.26 per hour	8.03*0.807 + 27.26*0.078 + 30.38*0.115 = $12.10 per hour
Interstate 65 Vehicle Classification	Percent SU Trucks = 4.8% Percent Comb. Trucks = 11.2%	Percent SU Trucks = 3.9% Percent Comb. Trucks = 5.4%
Aggregated Value of Time for Interstate 65	8.03*0.84 + 27.26*0.048 + 30.38*0.112 = $11.46 per hour	8.03*0.907 + 27.26*0.054 + 30.38*0.039 = $9.94 per hour
Percent Hoosier Helper Assists by Road	Borman Expressway = 90% Interstate 65 = 10%	Borman Expressway = 84.3% Interstate 65 = 15.7%
Overall Value of Time (1995 dollars)	15.26*0.90 + 11.46*0.10 = **14.88 per hour**	12.10*0.843 + 9.94*0.157 = **11.76 per hour**

Note: - All vehicle classifications are 24 hour averages
- Interstate 65 weekend vehicle classifications represent an approximation

Table 5.2 Consumer Price Indexes (CPI) and Producer Price Indexes (PPI) used in the Estimation of Hoosier Helper Benefit

Index	Item	Index Category[1]	Base Year Index Value	1995 Index Value	1996 Index Value
CPI	Automobile travel time value	All items	113.9[2] (1987)	152.4	157.8[2]
PPI	Single unit truck travel time value	All commodities	116.3 (1990)	124.7	125.1[2]
PPI	Combination truck travel time value	All commodities	116.3 (1990)	124.7	125.1[2]
CPI	Cost of a property damage only crash	Automobile maintenance and repair	150.2 (1994)	154.0	159.4[2]
CPI	Unleaded and diesel fuel cost	Fuel and other utilities	123.7 (1995, from U.S. city average area)	112.8 (from Chicago-Gary-Lake County, IL-IN-WI area)	-

[1] As stated in the U.S. Bureau of the Census *Statistical Abstract of the United States: 1996*

[2] Projected values

CPI and PPI values used to estimate a dollar value for each Hoosier Helper benefit component. Table 5.1 shows the vehicle classification percentages, based on 24 hour averages measured in 1992 and 1995 for the Borman Expressway and Interstate 65 respectively, vary considerably by location (Borman Expressway and Interstate 65) and day of the week (weekday and weekend), thus warranting the calculation of four travel time values through a weighted average, by vehicle classification percentage, of individual vehicle type values of travel time. Since the study disaggregated the incident simulation scenarios, for finding non-recurrent congestion delay savings, by day of the week, these four travel time values were only, in turn, combined by location. This resulted in an overall 1995 unit travel time value estimate of $14.88 per hour for weekdays and $11.76 per hour for weekends.

Table 5.3 presents a summary of the 1996, within which lay the evaluation period for 24 hour Hoosier Helper operation, unit travel time value estimation for weekdays and weekends. The table shows that the study updated, when possible, all information for 1996 and repeated the 1995 estimation process, resulting in a total 1996 unit travel time value assessment of $15.02 per hour for weekdays and $12.14 per hour for weekends. A rise in the CPI and PPI from 1995 to 1996, producing greater travel time values for automobiles and trucks, represented the main reason for the increase in overall unit travel time value estimates between the two stated periods.

5.1.3. Incident Simulation

The XXEXQ traffic simulation model provided the means for computing non-recurrent congestion delay savings during the daytime and 24 hour Hoosier Helper

Table 5.3 Estimation of Unit Travel Time Value, 24 Hour Operation

Item	Weekday	Weekend
Value of Time by Vehicle (1996 dollars)	Auto = $8.31 per hour, Single Unit Truck = $27.34 per hour, Combination Truck = $30.47 per hour	
Borman Expressway Vehicle Classification	Percent SU Trucks = 9.7% Percent Comb. Trucks = 24.0%	Percent SU Trucks = 7.8% Percent Comb. Trucks = 11.5%
Aggregated Value of Time for the Borman Expressway	8.31*0.663 + 27.34*0.097 + 30.47*0.24 = $15.47 per hour	8.31*0.807 + 27.34*0.078 + 30.47*0.115 = $12.34 per hour
Interstate 65 Vehicle Classification	Percent SU Trucks = 4.8% Percent Comb. Trucks = 11.2%	Percent SU Trucks = 3.9% Percent Comb. Trucks = 5.4%
Aggregated Value of Time for Interstate 65	8.31*0.84 + 27.34*0.048 + 30.47*0.112 = $11.71 per hour	8.31*0.907 + 27.34*0.054 + 30.47*0.039 = $10.20 per hour
Percent Hoosier Helper Assists by Road	Borman Expressway = 87.9% Interstate 65 = 12.1%	Borman Expressway = 90.7% Interstate 65 = 9.3%
Overall Value of Time (1996 dollars)	15.47*0.879 + 11.71*0.121 = **15.02 per hour**	12.34*0.907 + 10.20*0.093 = **12.14 per hour**

Note: - All vehicle classifications are 24 hour averages
- Interstate 65 weekend vehicle classifications represent an approximation

evaluation periods. XXEXQ was selected over other traffic simulation models, including the microscopic INTEGRATION and INTRAS models, because it satisfied two study requirements: minimal data input and computational efficiency. The former requirement was necessary due to the problem of data availability, and the latter requirement proved essential because the study considered a large study network and long simulation periods.

XXEXQ represents a macroscopic model developed specifically for the study of incidents. The model accommodates freeways and arterial streets, thus allowing for route diversion in the event of an incident. XXEXQ performs user equilibrium traffic assignment, and it utilizes the Bureau of Public Roads function to monitor the performance of individual roadway links. The XXEXQ input files require the following traffic network data: link lengths, link capacities and speed limits, link ground counts for calibration, a one hour origin-destination matrix, a system-wide proportion of informed drivers, incident location and duration, and the percent roadway capacity remaining at an incident site. The model's output includes system vehicle-miles traveled (VMT) and system travel time in vehicle-hours [22].

The present study modified XXEXQ to perform traffic assignment sequentially in one minute time intervals within a total simulation duration period of ten days. This action permitted traffic flows and capacity restrictions to vary by minute. Given hour-by-hour ground counts, the study altered traffic flows on an hourly basis, through the specification of a system-wide traffic intensity ratio for changing the stated origin-destination matrix, to better reflect daily network operations.

Figure 5.1 illustrates the Hoosier Helper evaluation network which served as input to XXEXQ for the simulation of incident impacts during daytime and 24 hour Hoosier Helper operation. The network contained all of the local streets in the Gary-Hammond-East Chicago metropolitan area with potential for use by travelers attempting to divert around an incident occurring on the Borman Expressway or Interstate 65. Overall, the Hoosier Helper evaluation network consisted of 401 links (272 physical links and 129 zonal access links) and 170 nodes, 43 of which represented origin-destination nodes. Given a 1990 origin-destination study completed by Wilbur Smith and Associates for the Northwest Indiana region, the number of trips between the 43 zones was obtained through an adjustment of the origin-destination data for 1995 and, subsequently, for 1996 using INDOT traffic adjustment factors for expressways. INDOT furnished 48 hour ground counts, measured sometime between March 1995 and August 1995, and link lengths for most federal and state roads in the network. The link lengths of local roads and link speed limits were gathered by traveling through the network, and Highway Capacity Software Version 2.1d, based on the 1994 Highway Capacity Manual, computed all link capacities. As previously stated, the incident generation model provided incident location and clearance time information. Table 5.4 presents roadway capacity reduction estimates, assumed for this study due to the lack of field data for the Borman Expressway, for a variety of incident scenarios, based on 1982 and 1971 studies in Minneapolis and Houston, respectively [23]. The study did not simulate incidents occurring on ramps because they represented a small percentage of incidents within the Hoosier Helper assist database; moreover, a review of the literature revealed that no field data existed for ramp incidents

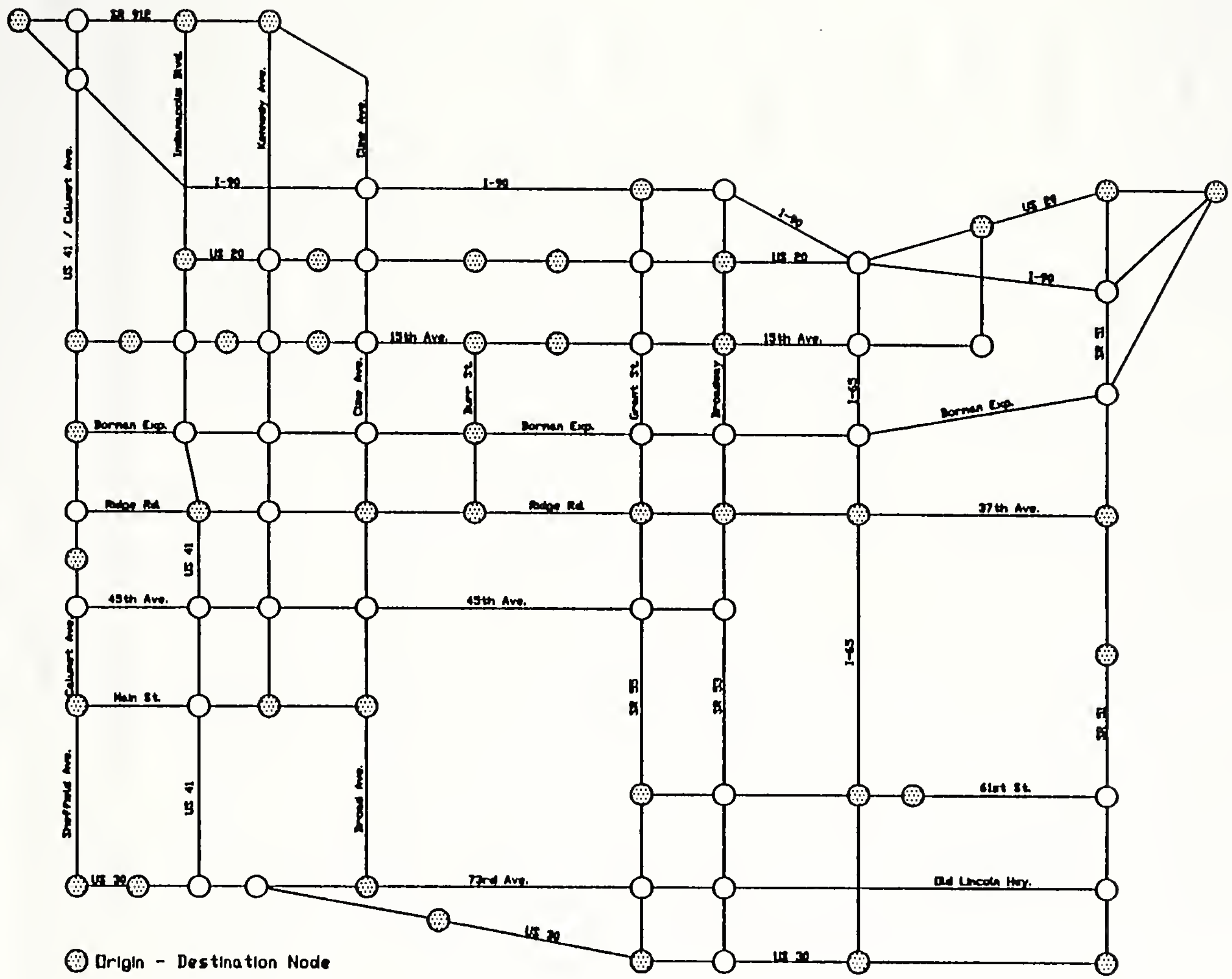

Figure 5.1 Hoosier Helper Evaluation Network

Table 5.4 Percent Roadway Capacity Remaining for Different Incident Characteristics

Incident Type	Lateral Location of Incident	Number of Lanes	
		2 (I-65)	3 (Borman Exp.)
Crashes and Debris	Shoulder	81	83
	1 Lane Blocked	39	53
All Other Incident Types	Shoulder	84	90
	1 Lane Blocked	42	57

concerning two key XXEXQ inputs: incident duration reduction resulting from freeway service patrol operation and percent roadway capacity remaining at an incident site.

The model calibration process involved making adjustments to the origin-destination matrix in order to closely match XXEXQ predicted traffic flows with actual traffic flows. The proportion of informed drivers, depicting those drivers with information of incident occurrence, was set at ten percent during model calibration to reflect the assumed low percentage of motorists with non-recurrent congestion information. Currently, periodic commercial radio reports, documenting only major incidents, stand as the sole source of non-recurrent congestion information for the Borman Expressway. For the afternoon peak hour, 4 PM to 5 PM, in the daytime Hoosier Helper evaluation period, all but one Hoosier Helper patrolled Borman Expressway and Interstate 65 link had predicted traffic volumes within ten percent of corresponding 1995 ground counts. Calibration of an origin-destination matrix for the program's 24 hour evaluation, when compared to 1995 ground counts adjusted to 1996 levels via INDOT traffic adjustment factors, yielded results within the stated accuracy concerning the origin-destination matrix for daytime Hoosier Helper evaluation.

After model calibration, the study utilized XXEXQ to examine eight different incident scenarios for the daytime Hoosier Helper evaluation and six different incident scenarios, excluding the spring season, for the 24 hour program evaluation. The scenarios varied by season and day of the week (weekday or weekend) to estimate more accurately the benefits of Hoosier Helper, and each season/day of the week scenario was simulated *twice* to evaluate the impacts of incidents *with and without Hoosier Helper in operation*, with the difference in the two system travel times, an output of each XXEXQ simulation, representing the non-recurrent congestion delay savings for the incident scenario in question. The two stated simulations within each incident scenario considered an assumed change in incident detection and response times for all inputted incidents because there was no available field data on these times for the Borman Expressway. The incident detection and response times represent two components of total incident duration, as shown in Equation 5.1.

$$T = T_1 + T_2 + T_3 + T_4 \quad (5.1)$$

where T stands for total incident duration time, T_1 (incident detection time) depicts the time between incident occurrence and reporting, T_2 (incident response time) denotes the time between reporting and response (e.g. Hoosier Helper) arrival, T_3 signifies the clearance time, and T_4 marks the queue dissipation time. The study obtained combined values of T_1 and T_2, taken to be fixed throughout the simulation of incident impacts, from a report by Sullivan [23]. The researcher reported that, on average, freeway service patrols reduce incident detection and response times by ten minutes for all crashes and in-lane incidents involving a patrol assist, and the patrols lower the incident duration component by 15 minutes for all other incidents attended to. Sullivan estimated the incident detection and response times from 1993 Orlando and San Francisco (Interstate 880) data, and Table 5.5 contains this information. For example, given a crash, the study would add a ten minute incident detection and response time to the incident's clearance time when simulating it with Hoosier Helper in operation. Then, while considering the same incident under the same season/day of the week scenario, the study would change

Table 5.5 Incident Detection and Response Times

Scenario	Crashes and All Other In-Lane Incidents	Other Incidents
Without Freeway Service Patrol	20 minutes	25 minutes
With Freeway Service Patrol	10 minutes	10 minutes

the incident's detection and response time to 20 minutes when simulating it without Hoosier Helper in operation. The previously discussed incident generation model provided, randomly, values of clearance time (T_3) which remained constant through both of the stated simulations within each incident scenario. XXEXQ inherently models queue dissipation following the completion of incident clearance, thus T_4 is determined within the framework of the traffic simulation model. The magnitude of queue dissipation time depends on the sum of T_1, T_2, and T_3 in addition to the level of traffic present throughout the total incident duration time.

The estimation of non-recurrent congestion delay savings required 16 XXEXQ simulations for the daytime Hoosier Helper evaluation and 12 simulations for the 24 hour program evaluation. Approximately 160 person-hours were needed in coding incidents, as received from the incident generation model, for all 28 simulations. Each XXEXQ simulation, executed on a UNIX mainframe, took about 24 hours to run.

5.1.4. Results

Table 5.6 presents Hoosier Helper's daytime benefit estimates, by season/day of the week incident scenario, for non-recurrent congestion delay savings. The magnitude of average daily non-recurrent congestion delay savings, based on ten days of simulation, mainly depended on the frequency, location, occurrence time, and duration of incidents involving crashes and debris within the incident scenario. Table 5.4 reveals these incidents stand as the severest of all incident types, based on their higher roadway capacity reduction values relative to incidents involving disablements and abandoned vehicles. For example, the average daily non-recurrent congestion delay savings for the fall/weekday

Table 5.6 Estimation of Non-recurrent Congestion Delay Savings, Daytime Operation

Season / Day of Week	Average Daily Congestion Delay (veh-hours)		Average Daily Non-recurrent Congestion Delay Savings (veh-hours)	Value of Travel Time (per hour)	Number of Days in 1995	Benefit (1995 $)
	Without HH	With HH				
Fall / Weekday	536.4	254.7	281.7	$14.88	65	$272,500
Fall / Weekend	548.9	294.4	254.5	$11.76	26	$77,800
Winter / Weekday	580.5	338.4	242.1	$14.88	63	$227,000
Winter / Weekend	434.0	212.1	221.9	$11.76	27	$70,500
Spring / Weekday	474.2	246.4	227.8	$14.88	66	$223,700
Spring / Weekend	528.0	258.6	269.4	$11.76	26	$82,400
Summer / Weekday	435.6	235.3	200.3	$14.88	66	$196,700
Summer / Weekend	588.2	291.6	296.6	$11.76	26	$90,700
Total					365	$1,241,300

and winter/weekday scenarios exceeded that of their corresponding weekend scenarios, in part, because the positive change in debris and crash incident percentage (see Table 3.2) offset the negative change in incident rate between the day of the week scenarios for each season. The fall/weekday scenario possessed the highest average daily non-recurrent congestion delay savings, 281.7 vehicle-hours, of any weekday scenario, partly because that scenario had the greatest afternoon peak travel, 3 PM to 6 PM, incident rate of all other weekday scenarios. Overall, XXEXQ estimated a $1,241,300 benefit, for the daytime Hoosier Helper evaluation period, as a result of non-recurrent congestion delay savings. This benefit measure exceeds the 1995 Hoosier Helper equivalent annual cost by a factor of three.

Table 5.7 contains the 24 hour Hoosier Helper benefit estimates regarding non-recurrent congestion delay savings for those season/day of the week scenarios included within the reported seven month evaluation period. XXEXQ computed a total non-recurrent congestion delay savings benefit of $3,708,100 for the program's 24 hour evaluation period, a figure surpassing the June 1996 to December 1996 Hoosier Helper operating cost by a factor of nine. The summer and fall seasons exhibited an average daily non-recurrent congestion delay savings for weekday scenarios which significantly exceeded that of corresponding weekend scenarios because the seasons' weekday incident rates (see Table 3.6) surpassed its weekend incident rates.

Table 5.7 Estimation of Non-recurrent Congestion Delay Savings, 24 Hour Operation

Season / Day of Week	Average Daily Congestion Delay (veh-hours)		Average Daily Non-recurrent Congestion Delay Savings (veh-hours)	Value of Travel Time (per hour)	Number of Days in 1996	Benefit (1996 $)
	Without HH	With HH				
Summer / Weekday	3560.2	1852.9	1707.3	$15.02	65	$1,666,800
Summer / Weekend	2437.1	1455.5	981.6	$12.14	27	$321,700
Fall / Weekday	3432.0	2320.6	1111.4	$15.02	65	$1,085,100
Fall / Weekend	1131.3	620.4	510.9	$12.14	26	$161,300
Winter / Weekday	3238.4	2092.1	1146.3	$15.02	22	$378,800
Winter / Weekend	2258.1	1393.8	864.3	$12.14	9	$94,400
Total					214	$3,708,100

5.2. Secondary Crash Reduction

5.2.1. Approach

Secondary crash reduction may stand as another significant benefit of Hoosier Helper because the program, as assumed through the data in Table 5.5, reduces incident duration, a possible contributor to increased secondary crash likelihood. Karlaftis et al. [24] fitted two logistic regression models to Hoosier Helper primary crash assist data, consisting of 741 observations, to determine the effects of several primary crash characteristics (clearance time, season, weekday vs. weekend, type of vehicle involved, lateral location) on the probability of secondary crash occurrence. A crash was considered secondary if it took place no more than three miles upstream and within the clearance time plus 15 minutes of a primary crash. The aforementioned study used logistic regression because the dependent variable, for primary crashes, was binary, taking a value of zero for primary crashes not linked to secondary crashes and one for primary crashes associated with secondary crashes. All of the explanatory variables, except for the continuous variable representing clearance time, included in the logistic regression models were coded as dummy variables.

Table 5.8 lists primary crash clearance time statistics for specific primary crash descriptors. The difference between the mean of a code one and code zero primary crash ranged from 3.88 minutes to 19.89 minutes for each classification. In fact, the variation between the two average clearance times exceeded ten minutes in nine of the 16 individual categories, and an overall comparison of code one and code zero primary crash means yielded an 11.27 minute difference.

Table 5.8 Borman Expressway Primary Crash Clearance Times

Category	Crash Code 0 Mean	Crash Code 0 STD	Crash Code 1 Mean	Crash Code 1 STD	Overall Mean	Overall STD
Fall	23.15	18.52	38.23	28.90	28.46	23.78
Winter	24.80	19.68	34.81	27.95	27.74	22.82
Spring	19.93	15.09	29.06	16.50	23.15	16.15
Summer	22.40	17.91	33.13	20.77	26.74	19.77
Weekday	23.00	18.37	33.87	22.94	26.97	20.80
Weekend	22.01	17.23	34.40	29.06	25.67	22.07
Car	22.69	17.68	32.66	21.85	26.35	19.88
Van	18.12	16.03	22.00	11.31	18.39	15.61
Truck	19.58	14.78	34.93	23.05	23.55	18.37
Semi	26.82	21.63	39.53	34.85	31.50	27.79
Median Shoulder	21.42	15.17	31.10	20.28	24.21	17.39
Right Shoulder	20.78	17.38	29.76	21.53	23.84	19.35
Left Lane	23.94	17.72	30.16	15.86	26.41	17.17
Center Lane	26.36	22.78	42.96	21.98	33.18	23.73
Right Lane	27.00	19.54	46.89	39.65	34.67	30.33
Ramp	26.88	18.32	37.53	19.24	30.14	19.06
Total Shoulder	20.93	16.86	30.02	21.30	23.93	18.91
Total In-lane	25.66	19.69	39.37	28.18	31.10	24.31
Overall	22.72	18.04	33.99	24.37	27.00	21.00

Note: - All mean and standard deviation values are in minutes

Table 5.9 contains the parameter estimates and resulting odds ratios for the two logistic regression models developed in the discussed study. Note that Model 2 provides more in-depth results regarding the influence of clearance time on the chance of a secondary crash.

5.2.2. Results

The odds ratios in Table 5.9 serve to quantify the effect of primary crash descriptors on the likelihood of secondary crash occurrence. By definition, an odds ratio measures the strength of association between a primary crash characteristic and the probability of secondary crash occurrence. For example, from Model 1, the chance of a secondary crash increases by a factor of 1.028 for every additional minute of primary crash clearance time or, in general, primary crash duration. According to assumptions drawn from Table 5.5, Hoosier Helper reduces crash duration, via faster detection and response, by ten minutes. Therefore, based on Model 2 results, the likelihood of a secondary crash increases by a factor of 1.185 ($e^{10*0.017}$) in winter and 1.363 ($e^{10*0.031}$) in all other seasons for a ten minute increase in crash duration. In other words, Hoosier Helper could reduce secondary crash probability by 18.5 percent in winter and 36.3 percent in all other seasons per crash assisted.

The Hoosier Helper accredited secondary crash reduction benefit for daytime and 24 hour program operation, each based on the discussed percent reductions in secondary crash likelihood per crash assisted, consisted of two components: crash-related delay savings and crash cost savings. Table 5.10 lists the benefits incurred as a result of crash-related delay savings for Hoosier Helper's daytime evaluation period. The study

Table 5.9 Logistic Regression Model Results

Variable	Model 1			Model 2		
	Coefficient Estimate	t-statistic (p-value)	Odds Ratio	Coefficient Estimate	t-statistic (p-value)	Odds Ratio
Constant	-2.32	-5.3 (less than 0.001)	–	-2.44	-5.61 (less than 0.001)	–
Clearance Time	0.027	6.72 (less than 0.001)	1.028	–	–	–
Clearance Time (winter)	–	–	–	0.017	3.26 (less than 0.001)	1.018
Clearance Time (spring, summer, fall)	–	–	–	0.031	6.69 (less than 0.001)	1.032
Car	0.966	2.36 (0.018)	2.62	0.964	2.34 (0.019)	2.62
Single Unit Truck	0.442	0.76 (0.45)	1.55	0.415	0.67 (0.506)	1.51
Combination Truck	0.762	1.71 (0.09)	2.14	0.731	1.67 (0.096)	2.07
Winter	-0.402	-2.11 (0.035)	0.66	–	–	–
Weekday	0.346	1.81 (0.074)	1.41	0.353	1.83 (0.071)	1.42
Ramp / Median	-0.264	-1.32 (0.19)	0.76	-0.248	-1.21 (0.232)	0.78

Rho-Squared of Model 1 = 0.39
Rho-Squared of Model 2 = 0.41

Table 5.10 Estimation of Crash-Related Delay Savings due to Secondary Crash Reduction, Daytime Operation

Season / Day of Week	Average Daily Non-recurrent Congestion Delay Savings (veh-hours)	Daily Delay Savings Attributed to Crashes (veh-hours)	Potential Daily Delay Saved Via Secondary Crash Reduction (veh-hours)	Value of Travel Time (per hour)	Number of Days in 1995	Benefit (1995 $)
Fall / Weekday	281.7	66.7	38.0	$14.88	65	$36,800
Fall / Weekend	254.5	7.8	4.4	$11.76	26	$1,300
Winter / Weekday	242.1	30.5	6.9	$14.88	63	$6,500
Winter / Weekend	221.9	98.7	22.4	$11.76	27	$7,100
Spring / Weekday	227.8	5.6	3.2	$14.88	66	$3,100
Spring / Weekend	269.4	4.4	2.5	$11.76	26	$800
Summer / Weekday	200.3	54.7	31.2	$14.88	66	$30,600
Summer / Weekend	296.6	76.4	43.5	$11.76	26	$13,300
Total					365	$99,500

calculated potential delay saved through secondary crash reduction by applying, to the value of delay attributed to crashes without Hoosier Helper in operation, the percent reductions in secondary crash likelihood resulting from a ten minute decrease in crash duration (18.5 percent in winter and 36.3 percent in all other seasons). The value of delay savings attributed to crashes represented a percentage of average daily non-recurrent congestion delay savings, a proportion determined, using XXEXQ, through a comparison of simulations concerning crashes and all incidents for each incident scenario. The total benefit, regarding daytime Hoosier Helper operation, for crash-related delay savings was $99,500.

Table 5.11 presents the benefit produced through crash cost savings for the daytime program evaluation period. Hoosier Helper assisted at 521 crashes in 1995. Given the previously stated percent reductions in secondary crash probability per crash assisted, applied to the number of crashes occurring without Hoosier Helper in operation, the program may have eliminated as many as 259 potential secondary crashes. A study of crashes within the Hoosier Helper assist database revealed one crash included an average of 1.48 vehicles; therefore, approximately 383 vehicles avoided involvement in and, at minimum, vehicle damage from a secondary crash. The National Highway Traffic Safety Administration (NHTSA) [25] reported a per vehicle cost of $1,353, CPI adjusted to 1995 dollars (see Table 5.2), for vehicle damages resulting from a property damage only (PDO) crash. This figure would have increased if the study accounted for other NHTSA stated PDO crash costs, including insurance administration costs, household productivity losses, workplace losses, and emergency service costs. The total benefit, concerning daytime

Table 5.11 Estimation of Crash Cost Savings due to Secondary Crash Reduction, Daytime Operation

Season	**1995 Hoosier Helper Crash Assists**	**Potential Secondary Crashes Reduced**	**Cost of Crash per Vehicle (1995 $)**	**Average Number of Vehicles in Crash**	**Benefit (1995 $)**
Winter	110	25	$1,353	1.48	$50,100
Spring, Summer, Fall	411	234	$1,353	1.48	$468,600
Total	521	259			$518,700

Hoosier Helper operation, for crash cost savings was $518,700. In fact, the benefit yielded by secondary crash reduction, $618,200, exceeded the 1995 Hoosier Helper program cost by a factor of 1.5.

Tables 5.12 and 5.13 contain the benefit produced through crash-related delay savings and crash cost savings, due to secondary crash reduction, for Hoosier Helper's 24 hour evaluation period. The total benefit for crash-related delay savings was $817,500. Using the discussed NHTSA reported PDO crash cost, CPI adjusted to a 1996 dollar value (see Table 5.2) of $1,401, the study estimated a total crash cost savings of $721,600. Overall, the benefit generated through secondary crash reduction, as a result of 24 hour Hoosier Helper operation, summed to $1,539,100, a figure surpassing the June 1996 to December 1996 program operating cost by a factor of 3.7. This result, together with the secondary crash reduction benefit-cost ratio for daytime Hoosier Helper operation, justifies the statement that secondary crash reduction indeed marks a significant benefit of freeway service patrols.

5.3. Vehicle Operating Cost Savings

5.3.1. Approach

The study based vehicle operating cost savings on an estimate of fuel consumption reduction. Equation 5.2, developed specifically for relating the effects of congestion to fuel consumption, was used to calculate this benefit component.

$$FC = (C_{vm} * VM) + (C_{cd} * CD) \quad (5.2)$$

where FC represents the change in fuel consumption in gallons, VM depicts the change in vehicle-miles traveled, CD stands for the change in congestion delay in vehicle-hours, C_{vm}

Table 5.12 Estimation of Crash-Related Delay Savings due to Secondary Crash Reduction, 24 Hour Operation

Season / Day of Week	Average Daily Non-recurrent Congestion Delay Savings (veh-hours)	Daily Delay Savings Attributed to Crashes (veh-hours)	Potential Daily Delay Saved Via Secondary Crash Reduction (veh-hours)	Value of Travel Time (per hour)	Number of Days in 1996	Benefit (1996 $)
Summer / Weekday	1707.3	629.5	358.7	$15.02	65	$350,200
Summer / Weekend	981.6	521.5	297.2	$12.14	27	$97,400
Fall / Weekday	1111.4	481.6	274.4	$15.02	65	$267,900
Fall / Weekend	510.9	220.9	125.9	$12.14	26	$39,700
Winter / Weekday	1146.3	646.4	146.7	$15.02	22	$48,500
Winter / Weekend	864.3	555.0	126.0	$12.14	9	$13,800
Total					214	$817,500

Table 5.13 Estimation of Crash Cost Savings due to Secondary Crash Reduction, 24 Hour Operation

Season	1996 Hoosier Helper Crash Assists	Potential Secondary Crashes Reduced	Cost of Crash per Vehicle (1996 $)	Average Number of Vehicles in Crash	Benefit (1996 $)
Winter	131	30	$1,401	1.48	$62,200
Summer and Fall	558	318	$1,401	1.48	$659,400
Total	689	348			$721,600

equals 0.04 for automobiles and 0.16 for heavy trucks, and C_{cd} equals 0.42 for automobiles and 1.87 for heavy trucks [21]. The coefficient values were based on urban fuel consumption rates reported in the Institute of Transportation Engineers *Transportation Planning Handbook* [26]. The traffic simulation model XXEXQ provided the input data for VM and CD, and fuel consumption reduction was found by entering the previously determined average daily system VMT savings and average daily system non-recurrent congestion delay savings into Equation 5.2. Total fuel consumption savings consisted of two vehicular components: automobiles and heavy trucks. The heavy truck constituent accounted for both single unit and combination trucks. The proportion of VM and CD attributed to these components was determined from a weighted average of vehicle classification percentages (see Table 5.1) which varied by location and day of the week. Heavy trucks accounted for 31.9 percent and 17.7 percent of the discussed fuel consumption equation input on weekdays and weekends, respectively.

5.3.2. Results

Table 5.14 presents the benefit estimate, by season/day of the week scenario, for fuel consumption reduction during Hoosier Helper's daytime evaluation period. International Energy Agency [27] reports furnished the 1995 unleaded and diesel fuel costs, CPI adjusted for the Chicago-Gary-Lake County region (see Table 5.2), shown in the table [18]. These costs included federal and Indiana imposed fuel taxes. In summary, the total benefits realized through fuel consumption reduction and attributed to vehicle operating cost savings was $78,300.

Table 5.14 Estimation of Vehicle Operating Cost Savings, Daytime Operation

Season / Day of Week	Average Daily VMT Savings	Average Daily Delay Savings (veh-hrs)	Average Daily Auto Fuel Savings (gallons)	Unleaded Fuel Cost per Gallon (1995 $)	Average Daily Heavy Truck Fuel Savings (gallons)	Diesel Fuel Cost per Gallon (1995 $)	Number of Days in 1995	Benefit (1995 $)
Fall / Weekday	120.4	281.7	83.9	$1.04	174.2	$1.02	65	$17,200
Fall / Weekend	100.8	254.5	91.3	$1.04	87.1	$1.02	26	$4,800
Winter / Weekday	112.8	242.1	72.3	$1.04	150.2	$1.02	63	$14,400
Winter / Weekend	100.4	221.9	80.0	$1.04	76.3	$1.02	27	$4,300
Spring / Weekday	95.2	227.8	67.7	$1.04	140.7	$1.02	66	$14,100
Spring / Weekend	107.6	269.4	96.7	$1.04	92.2	$1.02	26	$5,100
Summer / Weekday	114.0	200.3	60.4	$1.04	125.3	$1.02	66	$12,600
Summer / Weekend	260.4	296.6	111.1	$1.04	105.5	$1.02	26	$5,800
Total							365	$78,300

Table 5.15 lists the fuel consumption reduction benefit estimate, totaling $249,400, for the 24 hour Hoosier Helper evaluation period. The study utilized 1996 unleaded and diesel fuel costs, published by the International Energy Agency [27] and CPI adjusted for the Chicago-Gary-Lake County region (see Table 5.2), to calculate the stated fuel consumption reduction estimate [18]. Despite its magnitude relative to the other benefit components investigated in the study, the vehicle operating cost savings component warranted examination because fuel consumption stands as a clear additional cost to motorists in the presence of congestion.

Table 5.15 Estimation of Vehicle Operating Cost Savings, 24 Hour Operation

Season / Day of Week	Average Daily VMT Savings	Average Daily Delay Savings (veh-hrs)	Average Daily Auto Fuel Savings (gallons)	Unleaded Fuel Cost per Gallon (1996 $)	Average Daily Heavy Truck Fuel Savings (gallons)	Diesel Fuel Cost per Gallon (1996 $)	Number of Days in 1996	Benefit (1996 $)
Summer / Weekday	211.6	1707.3	494.1	$1.14	1029.3	$1.14	65	$112,900
Summer / Weekend	5.2	981.6	339.5	$1.14	325.0	$1.14	27	$20,500
Fall / Weekday	164.4	1111.4	322.4	$1.14	671.4	$1.14	65	$73,600
Fall / Weekend	49.6	510.9	178.2	$1.14	170.5	$1.14	26	$10,300
Winter / Weekday	343.6	1146.3	337.2	$1.14	701.3	$1.14	22	$26,000
Winter / Weekend	225.2	864.3	306.2	$1.14	292.5	$1.14	9	$6,100
Total							214	$249,400

6. ANALYSIS OF RESPONSE OF MOTORISTS ASSISTED BY HOOSIER HELPER

Hoosier Helper patrolmen give each assisted motorist an evaluation postcard, requesting the motorists' comments regarding the assistance he/she received. A study of the returned postcards represents the only available performance evaluation of the program. All responding motorists commended the patrolmen's efforts, thus indicating a high degree of satisfaction. The motorists' comments convey an important message because they originate from actual Borman Expressway users, many of whom are Indiana taxpayers. The Hoosier Helper program has, so far, been supported entirely by state funds.

Each Hoosier Helper evaluation postcard carries the capacity to yield the following information: motorist's home state and city, postmark date, and recommendations for improving Hoosier Helper. The study included 2,182 evaluations received by INDOT and 27,657 Hoosier Helper motorist assists from the start of the program through 1995. The evaluation and assist data existed as two separate databases, and each data set produced information regarding the number of evaluations and assists by year, by motorists' home state, and by Borman Expressway commuter.

6.1. Comparison of Hoosier Helper Evaluations and Assists

The Hoosier Helper postcard evaluation response rates were estimated on a yearly basis and for the entire range of evaluation postmark dates, 1991 through 1995. The year by year breakdown of response rates took into account 2,011 of the 2,182 total evaluations because the remaining evaluations did not have postmark dates. The results, provided in Figure 6.1, show approximately 7.9 percent of the motorists assisted by Hoosier Helper returned evaluations to INDOT. This was encouraging when considering that no incentive existed for submitting an evaluation, and motorists had to supply postage.

6.2. Hoosier Helper Evaluations and Assists by State

A total of 2,102 Hoosier Helper evaluations with return addresses and 25,959 Hoosier Helper assists with license plate listings were each divided by motorists' home state. The pie diagrams, as illustrated in Figures 6.2 and 6.3 for evaluations and assists respectively, reveal similar distributions by state. The graph of assists by state shows nearly 50 percent of motorists assisted by Hoosier Helper were from Indiana. This evidence is important with regard to financing the Hoosier Helper program with Indiana funds.

A comparison of results from the evaluation and assist databases, as presented in Figure 6.4, yields a close similarity between the percentage of Indiana motorist responses and the percentage of Indiana motorist assists. This observed correlation allows for the argument that the evaluation database serves as a representative sample of motorists assisted by Hoosier Helper.

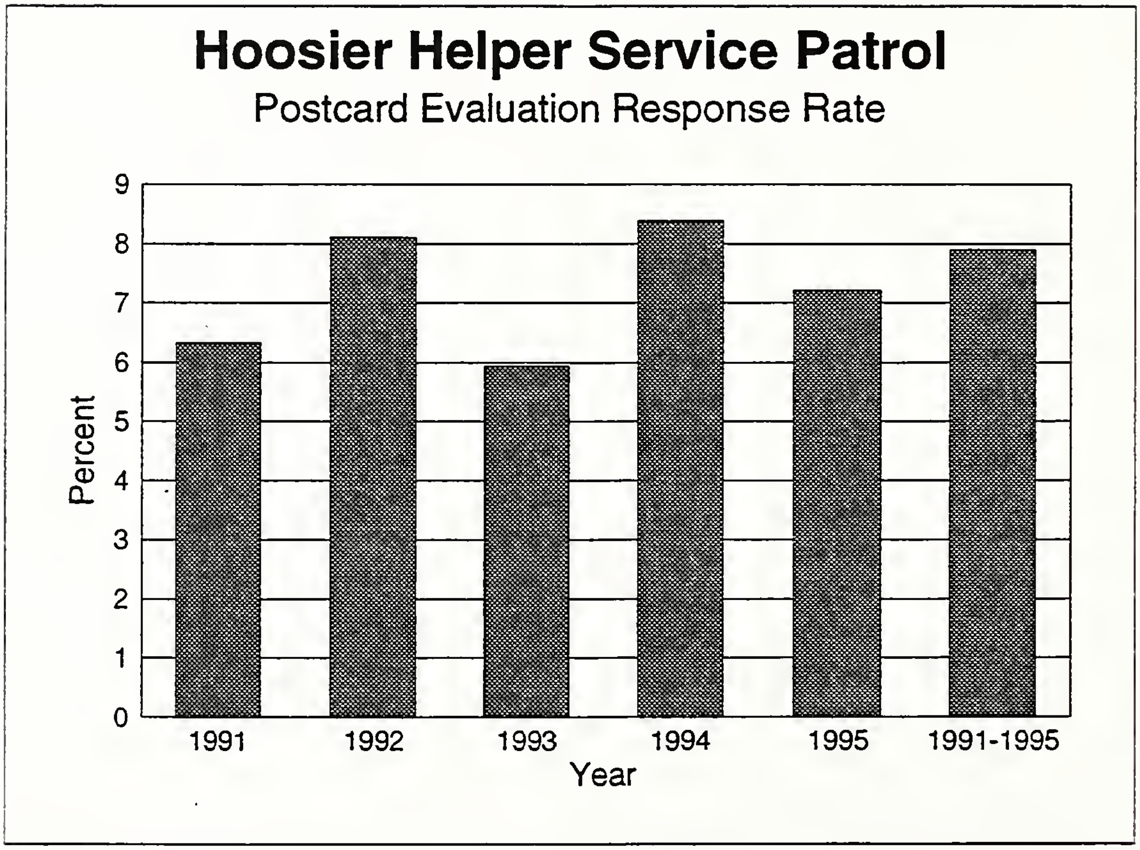

Figure 6.1 Hoosier Helper Postcard Evaluation Response Rate

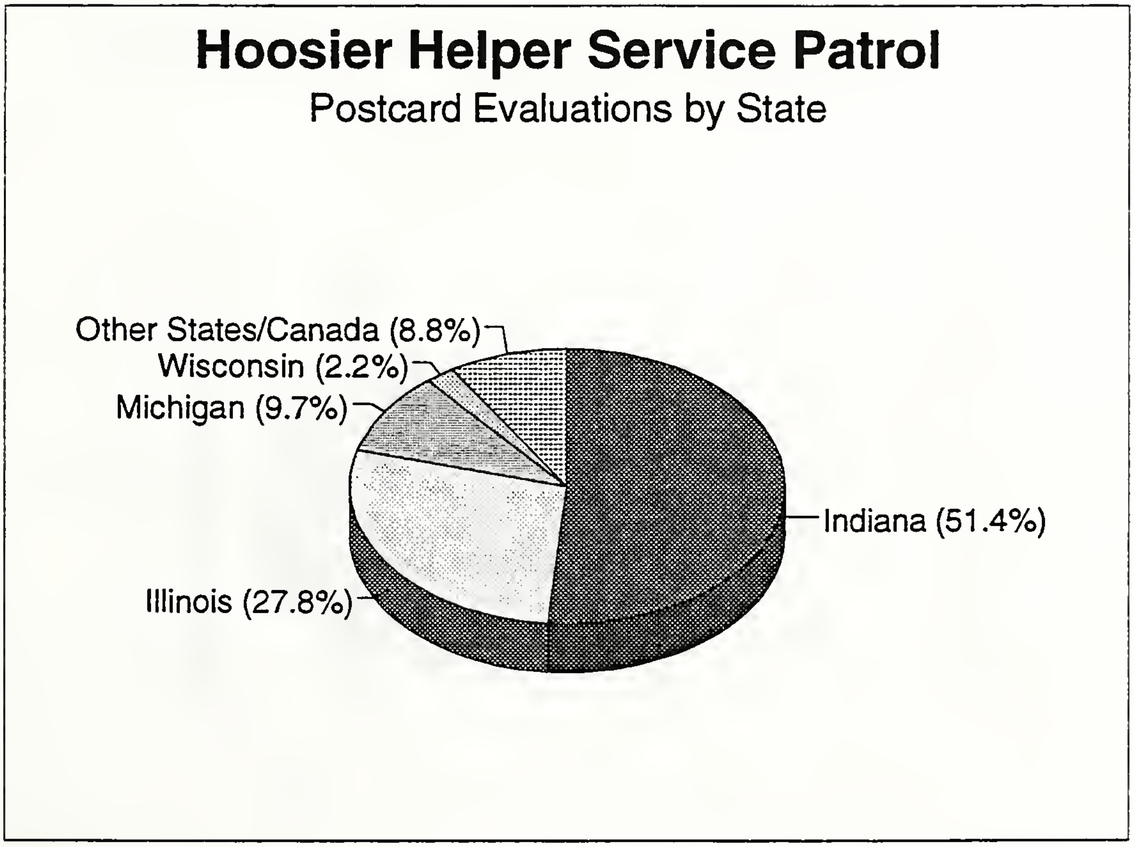

Figure 6.2 Hoosier Helper Evaluations by State

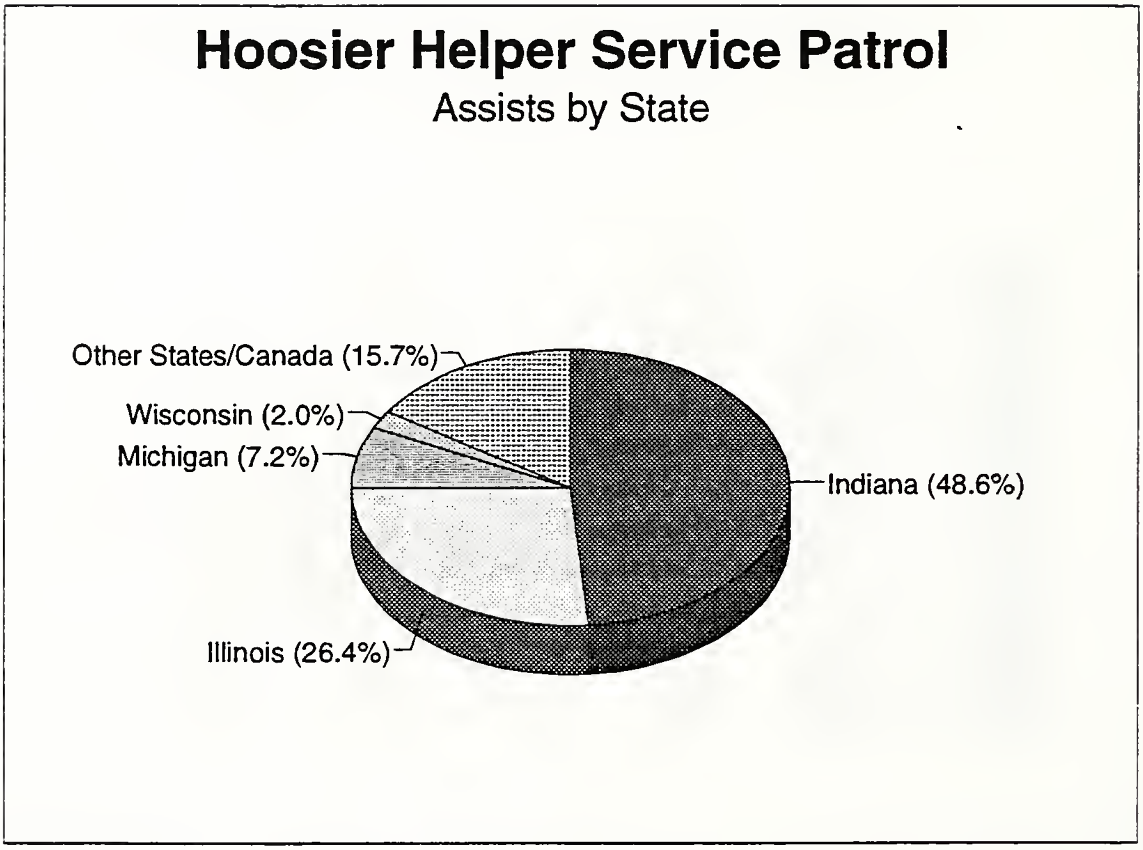

Figure 6.3 Hoosier Helper Assists by State

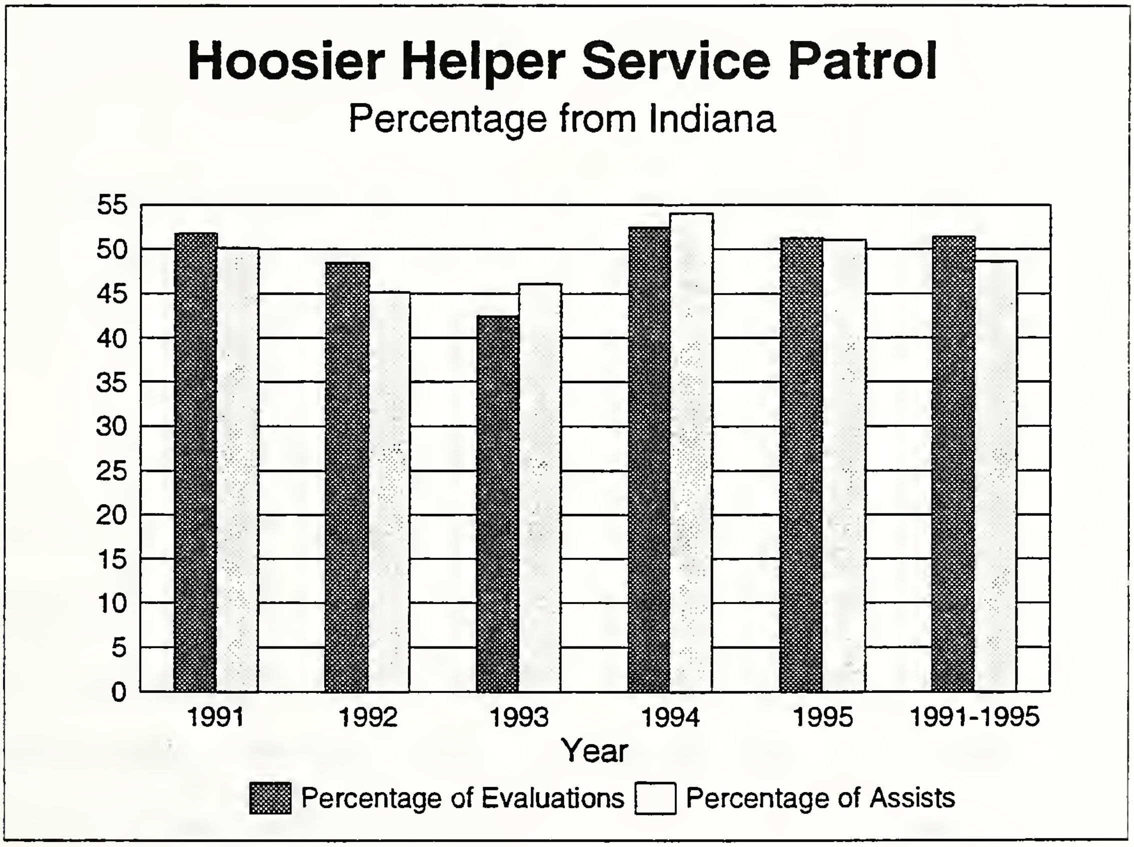

Figure 6.4 Percentage of Hoosier Helper Evaluations and Assists Concerning Indiana Motorists

6.3. Hoosier Helper Evaluations from Commuters

After excluding those Hoosier Helper evaluations without postmark dates and/or motorist home city, 1,949 evaluations were available to find the yearly distribution of commuters. It was assumed that the Borman Expressway commuters represented motorists from Chicago, Chicago's southern suburbs, and the Gary-Hammond-East Chicago metropolitan area. Table 6.1 provides a complete list of commuter home cities. Figure 6.5 illustrates the percentage of evaluations from Indiana and Illinois commuters. Because of the previously stated correlation between Indiana motorist evaluations and assists, the percentage of commuter evaluations function as a reasonable estimator of the percentage of commuter assists. Based on this argument, the results show three Indiana commuters received assistance for every Illinois commuter.

6.4. Motorist Recommendations for Hoosier Helper

From the 2,182 Hoosier Helper evaluations received by INDOT, 33 individual motorists contributed suggestions for further improving the services of Hoosier Helper. These motorists provided ideas pertaining to coverage and operation, information and equipment, and possible service fees. The low number of suggestions may have been attributed to the fact that the evaluation postcards did not specifically ask for Hoosier Helper improvement recommendations.

The most frequently suggested improvement for Hoosier Helper was that the program should operate 24 hours a day. Moreover, motorists advised that the program should be expanded to cover other parts of Indiana. INDOT has since responded to motorist concerns by upgrading Hoosier Helper to 24 hour operation in May 1996.

Table 6.1 Commuter Home Cities

Indiana Commuters	Illinois Commuters
Gary	Chicago
Portage	Thornton
Hobart	Burnham
Merrillville	Calumet City
Lake Station	Lansing
Schererville	Sauk Village
Griffith	Ford Heights
Highland	Chicago Heights
Munster	Glenwood
Dyer	Homewood
Hammond	South Holland
East Chicago	Harvey
Whiting	Dolton
	Phoenix

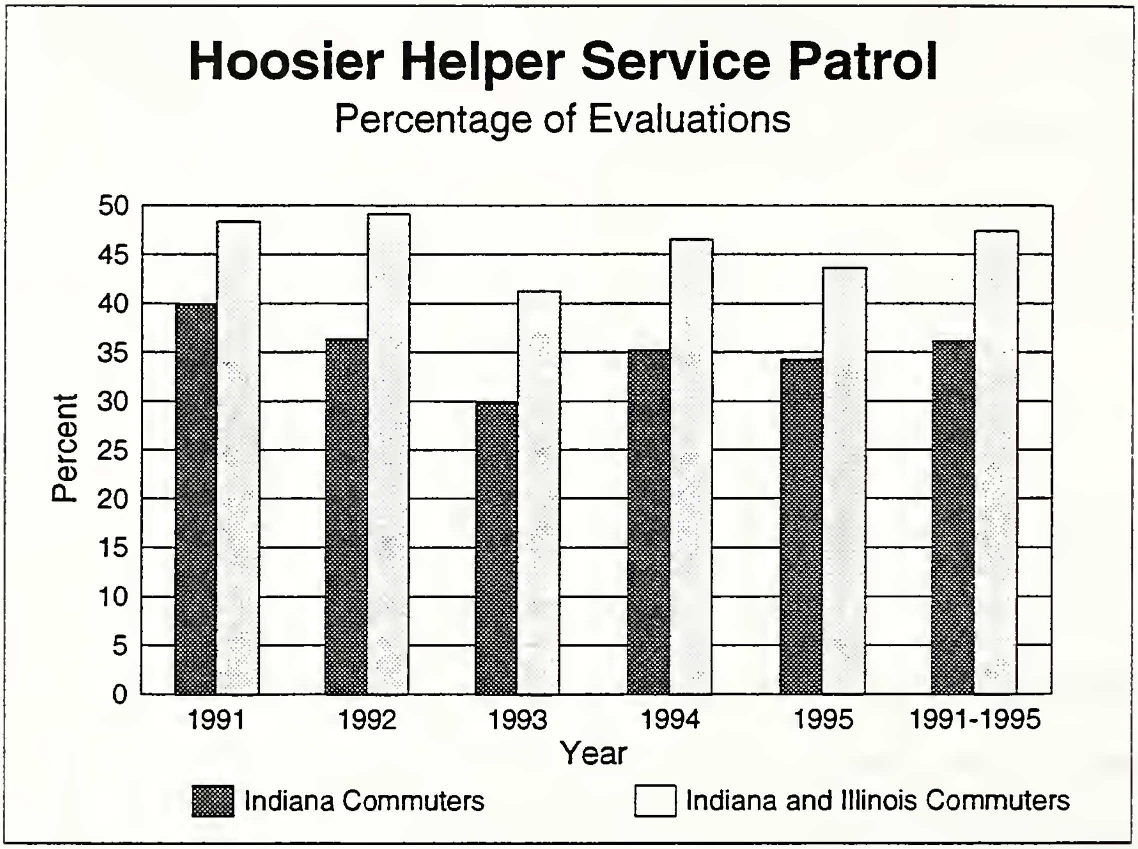

Figure 6.5 Percentage of Evaluations from Indiana and Illinois Commuters

INDOT has addressed many suggestions with regard to the need for specific tools and information. Motorists have requested that patrolmen carry a bolt cutter to remove padlocks, a variety of tools for repairing a flat tire, a list of AAA approved towing services, and a list of automobile repair shops. In addition, a motorist recommended that INDOT erect highway signs which display the telephone number of Hoosier Helper for drivers with cellular phones; however, INDOT has yet to accommodate that suggestion.

Motorist suggestions also included recommendations stating Hoosier Helper patrolmen should charge a service fee to assisted motorists and be allowed to accept gratuities. INDOT has never considered the idea of collecting money for services rendered; however, it may stand as a possible source for a part of Hoosier Helper operating revenues. Those motorists offering payment and gratuities for a free service genuinely reflect the public's desire for maintaining Indiana's Hoosier Helper program.

7. CONCLUSIONS

The study developed a benefit-cost evaluation methodology for freeway service patrol programs. Costs and benefits are identified in details. The methodology is based on easily available input data. As an example application of the proposed methodology, the case of Hoosier Helper service patrol in northern Indiana was used.

The total benefit estimation, $1,937,800, for Hoosier Helper's daytime evaluation period consisted of the following three components: non-recurrent congestion delay savings ($1,241,300), secondary crash reduction ($618,200), and vehicle operating cost savings ($78,300). Given the program's 1995 equivalent annual cost of $411,200, the study yielded a 4.71:1 benefit-cost ratio for daytime Hoosier Helper operation.

The study estimated a total Hoosier Helper benefit, for the period from June 1996 to December 1996, of $5,496,600. The following benefit components contributed to the overall program benefit estimation as indicated: non-recurrent congestion delay savings ($3,708,100), secondary crash reduction ($1,539,100), and vehicle operating cost savings ($249,400). Hoosier Helper's operating cost during the seven month study period amounted to $413,900, thus resulting in a benefit-cost ratio of 13.28:1 for 24 hour program operation.

7.1. Summary of the Methodology For Freeway Service Patrol Benefit-Cost Evaluation

There are a variety of ways that can be used to measure the benefit of freeway service patrol programs, both qualitatively and quantitatively. These include public perception, different operating statistics (cost per assist, cost per patrol-mile etc.), safety benefits, improved air quality, congestion delay savings, and benefit-cost ratios. The procedure based on benefit-cost ratio is adopted in this study as it is comprehensive and popular among practitioners.

7.1.1. Costs and Benefits

The total cost of a freeway service patrol can be classified into four major categories: investment cost, maintenance cost, overhead cost, and employee compensation. Investments include service vehicles, tools, communication equipment, computers, traffic control equipment, and traffic operation center. Maintenance costs mainly include parts and repair of vehicles, tools, and equipment. Major overhead costs include utility bills, telephone charges, gas and oil, and equipment and office supplies. The wages of the patrolmen and their supervisor, technician, mechanic, and clerk should be accounted for in employee compensation.

Reduction of non-recurrent incident induced congestion is one of the major benefits of a freeway service patrol program. Other benefits include secondary crash reduction and vehicle operating cost savings.

7.1.2. Data Types

The costs of investment items may be obtained from the purchase orders of the agency operating the service patrol. The agency usually maintains a record of expenditure. Various items such as costs of parts and repair of vehicles, tools and equipment, utilities, equipment and office supplies, gas, and telephone calls may be retrieved from the record. The wages and allowances of the employees may be obtained from the salary sheet.

Freeway service patrols usually keep daily activity logs describing the time, location and severity of incidents, type of assistance provided, patrol-miles covered, and special events if any. Such information is useful for evaluation of the patrol program. The information about roadway characteristics such as link length, capacity, and geometry; and traffic characteristics such as hourly traffic volume, directional distribution, and vehicular composition are also important, and may be obtained from the local and/or state transportation officials.

7.1.3. Estimation of Costs and Benefits

Investment items such as service vehicles, tools, communication equipment, computers, and traffic control equipment serve as an integral part of a service patrol and can be considered as perpetual investments i.e. they would be replaced with new ones at the end of service life. Each investment item, purchased in different years, needs to be converted to base year dollars through a price index which best represents the item purchased. The present worth of all investments in the starting year of the service patrol can be computed by first finding the purchase price, service life, and salvage value for specific investment items, and then adjusting through present worth factor. Finally, using capital recovery factor for perpetual life, an estimate of equivalent annual investment cost may be obtained.

Annual maintenance and overhead costs can be estimated from the records maintained by the agency responsible for service patrol operation. These costs also need to be converted to base year dollars through appropriate price indices. Annual salaries and benefits of the employees can be calculated from the salary sheet.

The assessment of non-recurrent congestion delay savings requires completion of three main tasks: incident generation, incident impact simulation, and estimation of unit travel time value. Incidents occur as random events, therefore, it would be necessary to develop a stochastic incident generation model based on the assist data obtained by the service patrol. Incidents generated from the model can serve as input to the traffic simulation software used for estimating congestion delay. Reduction in incident duration by the service patrol is also another important input, which may be obtained from a before-after study or from the current literature. Existing simulation software packages such as XXEXQ [19], INTRAS [28], INTEGRATION [29], and CORSIM [30] can be used to assess incident induced delay savings by the freeway patrol in the evaluation network, which should include the patrol area and the adjacent streets and arterials. On multiplication by unit travel time value, delay savings can be converted into dollars. In 1987, the American Automobile Association computed a travel time value of $6 per hour for automobiles [20]. In 1991, the Highway Economics Requirement System reported, in 1990 dollars, $25.42 and $28.33 per hour travel time value for single unit trucks and combination trucks, respectively [21]. Consumer Price Indices (CPI) and Producer Price Indices (PPI) can be used to convert the travel time values for automobiles and trucks, respectively into base year dollars.

Secondary crash reduction may account for a significant benefit of freeway service patrol program. A crash may be considered secondary if it takes place in the upstream vicinity and within close time interval of a primary crash. The effect of duration of a primary crash on the probability of secondary crash occurrence can be measured by odds ratio which may be obtained by fitting logistic regression model to the crash [24]. An odds ratio measures the strength of association between a primary crash characteristic and the probability of secondary crash occurrence. Thus the estimate of secondary crash reduction probability for a decrease in primary crash duration may be obtained. The corresponding delay savings may be estimated from the crash related delay savings which is obtained from incident impact simulation as discussed earlier. Unit crash costs can be obtained from the National Highway Traffic Safety Administration [25].

The vehicle operating cost savings can be estimated based on reduction in fuel consumption. The following equation relating the effects of congestion to fuel consumption can be used to estimate this benefit component :

$$FC = (C_{vm} * VM) + (C_{cd} * CD) \qquad (1)$$

where FC represents the change in fuel consumption in gallons, VM represents the change in vehicle-miles traveled, CD stands for the change in congestion delay in vehicle-hours, C_{vm} equals 0.04 for automobiles and 0.16 for heavy trucks, and C_{cd} equals 0.42 for automobiles and 1.87 for heavy trucks [21]. The coefficient values are based on urban fuel consumption rates reported in the Institute of Transportation Engineers Transportation Planning Handbook [26].

7.1.4. Risk and Uncertainty

There are uncertainties involved in estimation of costs and benefits of a freeway service patrol program. Among the cost items, maintenance and overhead costs especially vary from year to year. Benefit estimates also fluctuates depending on variation in unit cost of travel time, cost of crash, and fuel consumption rates. Moreover, estimate of non-recurrent incident induced delay varies considerably as incidents themselves are random events. Confidence intervals may be established to capture the fluctuation of estimates of costs and benefits. Hence, a range of benefit-cost ratio may be reported instead of a single estimated value.

7.2. Discussion of Results

A comparison of study results concerning the evaluations of Hoosier Helper daytime and 24 hour operation revealed the 24 hour benefit-cost ratio significantly exceeded the daytime benefit-cost ratio by a factor of 2.8. In other words, the benefit-cost ratios and the number of Hoosier Helper patrol-hours exhibited an economy of scale relationship. The large rise in incident rate from the daytime to 24 hour evaluation periods, particularly with respect to the daytime hours, represented the primary cause for the reported difference in benefit-cost ratios. As discussed in Chapter 3, the increased incident rate during daytime hours may have been attributed to greater Hoosier Helper operating efficiency and a higher frequency of additional vehicle deployment due to hazardous driving conditions within the 24 hour evaluation period. This phenomena, coupled with a rise in 1996 traffic volumes, resulted in XXEXQ yielding higher levels of average daily non-recurrent congestion delay savings and, in turn, additional benefit dollars for each 24 hour incident scenario (see Table 5.7) relative to that of corresponding daytime scenarios (see Table 5.6). Average daily non-recurrent congestion delay savings also served as a key input variable for computing benefits pertaining to crash-related delay savings due to secondary crash reduction and vehicle operating cost savings, thus explaining the large difference in benefit dollars, with regard to the daytime and 24 hour evaluations, for those two benefit components.

The frequency of severe incidents, specifically in-lane incidents, marked a secondary cause of the stated variance in benefit-cost ratios. A distribution of incidents for daytime and 24-hour Hoosier Helper evaluation, illustrated in Figures 3.1 and 3.2, showed the percentage of incidents blocking one lane increased by over 17 percent from the daytime to 24 hour evaluation data sets; therefore, incidents occurring within the 24 hour evaluation period further reduced roadway capacity, on average, than incidents happening within the daytime evaluation period. Moreover, the contrast in crash cost savings due to secondary crash reduction between the two Hoosier Helper evaluations was credited, in part, to a 42 percent increase in the proportion of crashes from the daytime to 24 hour evaluation data sets.

Despite an increase in the hourly Hoosier Helper operating cost among the two evaluation periods, $77.69 per hour for 1995 and $80.59 per hour for June 1996 to

December 1996, the benefit brought about by the program's change to 24 hour operation clearly supports Hoosier Helper's operating strategy as it exists today.

7.3. Shortcomings of the Study and Suggestions for Future Work

This study offered a wealth of information concerning a cost-effectiveness evaluation of the Hoosier Helper freeway service patrol, and it strived to present results containing the highest degree of accuracy possible. However, because of the lack of available information pertaining to the study area and time constraints, the study utilized the findings of some out-of-state research in order to obtain values for a select number of key variables required to estimate non-recurrent congestion delay savings. In particular, these variables included incident duration savings as a result of Hoosier Helper operation, capacity reduction at an incident site, and travel time value. The study based all necessary assumptions on the most recent research available, with measurements taken from study areas having similar characteristics to that of the Borman Expressway and Interstate 65. A comprehensive estimation of the stated variables would demand three individual studies. The following two paragraphs describe some methods for measuring the information assumed in this study.

The non-availability of total incident duration data, particularly incident detection and response times, before and after Hoosier Helper operation had perhaps the greatest impact on the accuracy of the study results because incident response and clearance procedures vary among police departments and freeway service patrols across the country; therefore, Sullivan's [23] findings, used in this study, marked solely an approximation of incident duration savings as a result of Hoosier Helper operation. Measurement of incident duration savings would necessitate a complete assessment of incidents from start to finish, a task requiring the use of video technology. As of February 1997, three video cameras for closed-circuit television were in place and functional on the Borman Expressway, and the number of cameras will increase to 12 by early 1998. While these cameras could capture total incident duration with Hoosier Helper in operation, video at other study areas, preferably future Hoosier Helper deployment sites, must be obtained to measure total incident duration without the services of Hoosier Helper. For example, a second Hoosier Helper program will begin operation, during peak travel hours, in August 1997 on a section of interstate highway northeast of Indianapolis, thus making it possible, when considering the program's hours, to record incidents with and without Hoosier Helper in operation using a video camera mounted on a nearby high-rise building or roadside mast.

An estimation of capacity reduction at an incident site and travel time value on the Borman Expressway and Interstate 65 would most likely yield different results, compared to previous studies, because of the high percentage of truck traffic encompassing the study area. Hawkins [13] collected capacity reduction data by filming traffic flow, from which traffic volume could be counted, at the location of incidents. The researcher's crew obtained satisfactory and safe vantage points for filming incidents through riding in freeway service patrol vehicles. With regard to examining travel time value, Hawkins reported that researchers at the Texas Transportation Institute developed a speed choice model which produced a value of time based on the assumption that a rational driver selects a speed with the intention of minimizing total driving cost.

Aside from the previously discussed assumptions, there were several shortcomings with respect to the simulation model used. Drawbacks of XXEXQ include the inability to model intersection delay and the absence of a link-specific traffic intensity ratio for changing the simulated traffic volumes throughout various time periods. The lack of a link-specific traffic intensity ratio posed a minimal impact on model calibration because the Borman Expressway exhibits high, steady traffic volumes in both directions throughout the day. Furthermore, the drawback regarding intersection delay was not considered to affect significantly the overall estimate of non-recurrent congestion delay savings, due to the fact that all incidents were simulated on freeways. In addition, traffic is assigned to travel no faster than the posted speed limit in XXEXQ, and in reality, vehicles on the local roads serving as diversion routes in the study area will typically travel at a free-flow speed which exceeds the speed limit, thus offsetting, at least partially, the absence of intersection delay.

As reported in Chapter 5, model calibration for the daytime and 24 hour Hoosier Helper evaluations demanded the availability of actual 1995 and 1996 ground counts for all links throughout the study network; however, INDOT only possessed records of 48 hour ground counts, for most network links, taken during weekdays in the spring and summer months of 1995. Therefore, the fall and winter simulation scenarios utilized an origin-destination matrix calibrated, for the purpose of matching simulated traffic volumes with actual ground counts, with spring and summer traffic data. In addition, because INDOT conducts traffic volume measurements every three years for a given location, the

1996 volumes represented an approximation of actual ground counts since they were arrived at through the use of INDOT traffic adjustment factors.

LIST OF REFERENCES

[1] U. Dutta, R. Tadi, D. Devadoss, M. Poola (1997), "Freeway Courtesy Patrol as a Roadside Assistance Program: Experience of Two Large Metropolitan Areas", Presented at the 76th Annual Meeting of the Transportation Research Board, Washington D.C., January 12-16.

[2] L. R. Grenzeback and C. E. Woodle (1992), "The True Costs of Highway Congestion", *ITE Journal*, Vol. 62, No. 3, pp. 6-10.

[3] R. L. Nowlin (1994), "Institutional Concerns Regarding the Implementation of State Managed Service Patrols", Texas A&M University, College Station, Texas.

[4] M. Morris and W. Lee (1994), "Survey of Efforts To Evaluate Freeway Service Patrols", *Transportation Research Record*, No. 1446, pp. 77-85.

[5] California Department of Transportation (1997), "Freeway Service Patrol", *www.dot.ca.gov/dist07/facts/fspfact.htm*, Internet.

[6] California Department of Transportation (1997), "San Diego Freeway Service Patrol", *www.dot.ca.gov/dist11/facts/fsp.html*, Internet.

[7] P. Cuciti and B. Janson (1995), "Incident Management via Courtesy Patrol: Evaluation of a Pilot Program in Colorado", *Transportation Research Record*, No. 1494, pp. 84-90.

[8] Maryland Department of Transportation (1997), "Emergency Traffic Patrol (ETP)", *www.inform.umd.edu/UMS+State/MD_Resources/MDOT/sha/chart/etp.htm*, Internet.

[9] Georgia Department of Transportation (1996), "Highway Emergency Response Operator", Pamphlet.

[10] Minnesota Department of Transportation (1994), *Highway Helper Summary Report: Twin Cities Metro Area*, Report No. TMC 07450-0394.

[11] New Jersey Department of Transportation (1996), "New Vehicles for Emergency Service Patrols", *www.state.nj.us/transportation/press/nov1996/espnew.htm*, Internet.

[12] Texas Department of Transportation (1997), "Texas Courtesy Patrol", Pamphlet.

[13] P. A. Hawkins (1993), "Evaluation of the Southwest Freeway Motorist Assistance Program in Houston", Report No. TX-94/1922-1F, Texas Transportation Institute, College Station, Texas.

[14] M. Welch, Texas Department of Transportation, Austin. Personal communication, February 1997.

[15] Texas Department of Transportation (1997), "TxDOT Launches Austin Courtesy Patrol Jan. 6", *www.dot.state.tx.us/insdtdot/geodist/aus/97-001.htm*, Internet.

[16] J. Althauser, Washington Department of Transportation, Seattle. Personal communication, February 1997.

[17] J. Cotton, Texas Department of Transportation, Austin. Personal communication, April 1997.

[18] U.S. Bureau of the Census (1996), *Statistical Abstract of the United States: 1996*, 116th edition, Washington, DC.

[19] F. Mannering, B. Jones, D. H. Garrison, B. Sebranke, and L. Janssen (1990), *Generation and Assessment of Incident Management Strategies, Vol. III*, Washington State Transportation Center, Report No. WA-RD 204.4, Seattle, WA.

[20] R. Reiss and W. Dunn (1991), *Freeway Incident Management Handbook*, Federal Highway Administration, Report No. FHWA-SA-91-056, Washington, DC.

[21] Federal Highway Administration (1995), *Estimating the Impacts of Transportation Alternatives*, Report No. FHWA-HI-94-053, Washington, DC.

[22] D. Garrison and F. Mannering (1990), "Assessing the Traffic Impacts of Freeway Incidents and Driver Information", *ITE Journal*, Vol. 60, Vol. 8, pp. 19-23.

[23] E. C. Sullivan (1996), "A New Model for Predicting Freeway Incidents and Incident Delays", Working paper, California State Polytechnic University, San Luis Obispo, CA.

[24] M. G. Karlaftis, N. J. Richards, S. P. Latoski, and K. C. Sinha (1997), "ITS Impacts on Safety: An Investigation of Secondary Crash Causes", Working paper, Joint Highway Research Project, Purdue University, West Lafayette, IN.

[25] L. J. Blincoe (1996), *The Economic Cost of Motor Vehicle Crashes 1994*, National Highway Traffic Safety Administration, Report No. DOT-HS-808-425, Washington, DC.

[26] Institute of Transportation Engineers (1992), *Transportation Planning Handbook*, Prentice-Hall, Englewood Cliffs, N.J.

[27] International Energy Agency (1996), *Energy Prices and Taxes: Third Quarter 1996*, Paris, France.

[28] Wicks, D. A. and Lieberman, E. B. (1980), *Development and Testing of INTRAS, A Microscopic Simulation Model, Vol. 1 : User's Manual*, Report No. FHWA-RD-80-107, Washington D.C.

[29] Van Aerde, M. (1990), *Modeling of Integrated Traffic Networks Using the INTEGRATION Simulation Model*, Report No. TDS-90-02, Ontario Ministry of Transportation.

[30] Halati, A.; Lieu, H. and Walker, S. (1997), "CORSIM - Corridor Traffic Simulation Model", Presented at the 76th Annual Meeting of the Transportation Research Board, Washington D.C., January 12-16.