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SAMUEL GINN
COLLEGE OF ENGINEERING

AN EVALUATION OF THE BENEFITS OF THE ALABAMA SERVICE AND ASSISTANCE PATROL

FINAL REPORT
Project 930-635

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Sponsored by
Alabama Department of Transportation
Montgomery, Alabama

December 2009

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Auburn, Alabama 36849

www.eng.auburn.edu/research/centers/hrc.html

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EXECUTIVE SUMMARY

The Alabama Service and Assistance Patrol (A.S.A.P.) is a freeway service patrol operated by the Alabama Department of Transportation (ALDOT) in the Birmingham region of Alabama. This patrol of service vehicles travels continuously on approximately 112 miles of freeway on weekdays and responds to incidents such as crashes, and vehicle breakdowns, rendering assistance from basic services to motorists to temporary traffic control. The A.S.A.P. program therefore provides benefits to the public through reductions of travel time delay, vehicle emissions, and secondary or follow-on crashes. Additionally, the A.S.A.P. program provides basic services to motorists such as fuel, air, and emergency starting. The economic value of these benefits can be estimated in order to conduct an evaluation of the economic effectiveness of the program. This study is the first comprehensive study across all categories of benefits since the program began in 1997. This study focuses on program operations in 2004 and 2005.

Analyses of the benefits of freeway service patrol programs dates back to the early 1970s. Over the last thirty-plus years, the methodologies used to estimate benefits, as well as the range of benefits considered, has broadened substantially. While most of these studies focus on particular type of benefits (such as travel time delay reduction), few have taken a comprehensive approach to such an analysis. Generally, four categories of benefits have been identified:

- Mobility (reduction in travel time delay due to more rapid clearance of incidents)
- Safety (reduction in secondary or follow-on crashes)
- Environmental (reduction of emissions and fuel consumption)
- Customer service (value of services provided to motorists)

Mobility benefits tend to be the most commonly studied category. Travel time delay may be more apparent to travelers than safety or environmental issues associated with incidents. Additionally, studies have shown that a substantial percentage of traffic congestion and resulting delay are due to non-recurring congestion – incidents – rather than typical daily congestion associated with volume and capacity relationships. Therefore, a detailed and thorough approach was developed to estimate the mobility benefits of the A.S.A.P. program. Analysis of benefits related to emissions reduction warranted a high level of detail due to the original motivation and funding for the A.S.A.P. program. The program was originally supported through the Congestion Mitigation and Air Quality (CMAQ) federal funding category. The focus of CMAQ funds was to support projects and programs that improve air quality. Quantification of safety

benefits in prior studies has been relatively limited and predicated on many assumptions. Attempts to relate incident durations and clearances to actual changes in rates or occurrences of secondary crashes have been coarse. Accordingly, the analysis of reduction in secondary crashes associated with the A.S.A.P. program was handled similarly. Finally, customer service benefits were valued economically through the use of values provided in several studies of other programs. These values were then adjusted across time and location to the study period for the current effort (2004-2005).

An additional guiding principle in the analyses was the use of range-based rather than deterministic results. In all of the analyses, selection of some of the values involved assumptions and subjective valuation. For example, determination of an appropriate value of travelers' time was informed by several prior studies, each of which used different values and assumptions. It can be argued that to some extent, the value should be determined individually for each traveler, but this approach is obviously impractical. Therefore, the estimated benefits in each category are presented as a range of values, along with a "most likely" value.

The range of economic benefits, as well as most likely values, were estimated in each of the four categories described above. The ratio of benefits to program costs during the study period, for each category, is shown Table ES-1. The overall benefit-cost ratio was found to be between 3.5:1 and 33:1, with a most likely value of approximately 15:1. This demonstrates that the benefits of the A.S.A.P. program greatly exceed the investment in the program.

Table ES-1: Summary of Benefit-Cost Ratios

Benefits Category	High Estimate	Low Estimate	Most Likely
Mobility	23.4	1.7	9.2
Safety	7.8	1.0	4.3
Environmental	0.1	0.1	0.1
Customer Service	1.7	0.9	1.3

As traffic volumes increase, consideration may be given to expanding the program service area. Factors to consider in selecting areas for program expansion include freeway segments with high volumes (considered to be 1500 vehicles per hour per lane based on previous studies). Freeway segments on which the average speed drops substantially from free-flow speeds (and therefore travel time increases) are likely candidates. Finally, safety indicators, particularly crash rate per freeway segment length and per vehicle-miles of travel, can also serve as criteria for program expansion.

ACKNOWLEDGMENTS

The authors wish to thank many people who assisted with the research documented in this report and who provided guidance along the way. Lionel Harbin of the Alabama Department of Transportation (ALDOT) provided the assist data and costs for the program from its inception in 1997 through June 2005 and provided comments on drafts of this report. Charles Turney of ALDOT provided critical traffic data. Luke Dixon and Andrew Heath, of Auburn University, assisted the mobility benefits portion of the analysis. Apurva Andurlekar, of the University of Alabama, assisted with the environmental impacts portion of the analysis. Elliott DeVore, of Auburn University, assisted with the customer service benefits portion of the analysis.

CHAPTER 1: INTRODUCTION

1.1 Background

As current highway infrastructure ages and traffic volumes continually increase, traffic congestion is becoming a serious problem for major metropolitan areas within the United States. According to a report produced by the Texas Transportation Institute on U.S. urban mobility, in the decade between 1993 and 2003; peak periods have increased in length by seven percent, delay has grown from an annual average of 40 hours of travel up to 47 hours per person, and the percent of freeway mileage affected by congestion has grown from 51 to 60 percent. Essentially, congestion now affects more time of the day, more of the system, and creates extra time penalties (Schrank et al., 2005). This congestion takes the form of both recurrent and non-recurrent delay. Recurrent congestion consists of the typical delay seen through high traffic volumes during the morning and afternoon peak hours. Conversely, non-recurrent congestion is often the result of more severe phenomena such as traffic incidents, special events, or construction.

To combat this increasing congestion, many state transportation agencies have deployed Freeway Service Patrols (FSP), also known as courtesy patrols, service patrols, and safety patrols. FSP deployments provide incident management within the transportation infrastructure to help manage traffic flow, reduce congestion, enhance productivity, and save time and money. Freeway service patrols have been cited as “the single-most effective element of an incident management program for reducing incident detection time and incident duration.” (Fenno et al., 1998). Many metropolitan areas have turned to using an FSP to help counter the effects of severe non-recurring congestion on the highway network. The first FSP service was developed in 1960 as the Chicago Emergency Traffic Patrol. By 1997, over 50 FSP deployments had emerged across the United States (Fenno et al., 1998). The primary goals of a freeway service patrol are to decrease detection time of incidents, decrease the duration of incidents, and reduce the risk of secondary accidents to motorists.

Freeway service patrols consist of a fleet of vehicles that roam the freeway network and help to combat non-recurring congestion through responsive incident clearance. These vehicles often target the high volume and high incident locations of the network served. FSP deployments have been shown to provide large benefits through enhanced mobility, emissions reductions, secondary crash reductions, and direct customer services. As stated, these deployments create these benefits through decreasing incident detection time and decreasing incident duration lengths. The onset of cellular devices and other forms of rapid communication have also enhanced the ability of FSP deployments within these roles.

Service patrol units improve mobility of the network through quick and efficient incident clearance. Patrol units are equipped with the necessary equipment to clear minor incidents from the highway. These units are not equipped to deal with large tractor-trailer incidents; however, the service patrol can provide a secondary role at the scene through efficient traffic control. The service patrol units are also often prepared with equipment designed for direct customer services. These items include gasoline, car jacks, booster cables, and first aid kits among others. Many studies have been performed on various FSP agencies to determine the economic benefit provided by these deployments compared to the inherent costs of the program. FSP deployments have initial costs due to purchasing new vehicles and equipment in addition to many annual costs incurred through operations, maintenance, and wage rates for employees. A benefit-cost evaluation is a useful tool as a benefit-cost ratio is an easily understood benchmark that details the cost-effectiveness of a program.

Translating the mobility, emissions, and customer savings to monetary amounts presents a complex analysis due to natural variability within traffic patterns and the existence of socioeconomic variables within the analysis. With regards to mobility, benefits are calculated with respect to the value of delay savings for motorists. This value is directly influenced by changeable inputs such as the location of the incident, time of the incident, incident duration reduction, the value of travel time, and average vehicle occupancy. To illustrate this variability, a range of benefit/cost ratios ranging from 2:1 to 36:1 for a variety of performed studies across the U.S. has been reported (Fenno et al., 1998). Due to this reason, a range of benefit/cost ratios that encompasses the range of reasonable values for these assumptions presents a more appropriate measure of effectiveness for the FSP as opposed to one single number. A benefit/cost range is derived through the consideration of selected input variables to the analysis as having a range of feasible values, rather than treating each one as a single, deterministic value. This approach addresses possible uncertainties in assigning values to key inputs such as the value of travel time, and the variable nature of some key inputs such as reduction in total incident duration that can be attributed to the service patrol.

This study is being performed to evaluate the benefits provided by the Alabama Service and Assistance Patrol (A.S.A.P.) located in Birmingham, Alabama. This particular program was formed in June of 1997 by the Alabama Department of Transportation and has grown to cover over 100 miles of Alabama highways. The program was initially organized and funded through the Congestion Mitigation and Air Quality category of the Intermodal Surface Transportation Efficiency Act of 1991. A.S.A.P. service runs Monday through Friday from 6 a.m. to 10 p.m. and as needed during special events. The program conducted 17,090 assists in from July 1, 2004 through June 30, 2005. This amount corresponds to an average of approximately 66 assists per weekday. The recorded cost of providing these services is $592,243 from July 1, 2004 through June 30, 2005. The cost information, provided by the Third Division office of ALDOT, includes capital costs, such as new equipment, as well as operations and maintenance costs, such as personnel salaries and associated benefits. This value forms the basis for the benefit-cost ratios developed in this study.

1.2 Objectives and Scope

The key objective of this study was to evaluate and demonstrate the economic benefits of the A.S.A.P. program to travelers in the Birmingham region. These benefits include those associated directly with the motorist assistance rendered as a part of A.S.A.P., as well as indirect benefits associated with reduced delay, improved safety, and reduced environmental impacts. Most of the effort in this study supported this objective. Through a review of the literature, four key categories of benefits of service patrols can be identified, described herein as mobility, environmental, safety, and customer service benefits. The most-often cited benefits are those associated with *mobility*, specifically, reduction in the delay incurred by travelers attributable to the presence of the service patrol's ability to respond quickly, clear minor incidents, and assist with traffic control in major incidents. *Environmental* benefits can also be quantified by estimating the reduction in emissions and fuel consumption associated with service patrol response to incidents. The improved air quality associated with reduced emissions, along with the mobility benefit of congestion mitigation, were key factors in the establishment of the A.S.A.P. program. *Safety* benefits can be realized through a reduction in secondary crashes that can occur in the congestion upstream of an incident that has already occurred. Finally, there are direct and tangible benefits to motorists assisted by the service patrol. Examples of these *customer service* benefits include the money saved by drivers not having to call for a tow truck in the event of a disabled vehicle and not needing to pay for assistance with a tire change, fuel delivery, or other minor issues.

This study had an additional objective to identify possible improvements and expansion areas for the program through a review of the literature and state-of-the-practice. By reviewing documented evaluations of freeway service patrols and ascertaining best practices, approaches to providing motorist assistance found successful in other regions but not yet applied in Alabama can be identified. Guidelines for evaluating candidate corridors and regions for expansion of the program can also be identified. Basic guidelines are given in this report, while further research can refine a specific model for service area expansion.

CHAPTER 2: LITERATURE REVIEW

A review of prior studies on the effectiveness and benefits of freeway service patrols can provide a context for developing a framework to evaluate the A.S.A.P. program. Documenting the value of these programs established in other areas can also inform the current analysis and provide perspective on the results. The review of published literature is divided into six areas of focus: the overall economic evaluation framework (typically consisting of benefit-cost analyses), mobility benefits, safety benefits, environmental benefits, customer service benefits, and analyses of service areas and program operations. The reduction in incident duration associated with FSPs can be translated into economic benefits based upon mobility, reductions in emissions, reductions in secondary crash reductions, and the value of direct customer services rendered. Conversely, these services create program operating costs that can offset these benefits to some extent, spurring a benefit-cost analysis as the typical evaluation tool.

2.1 Benefit-Cost Ratios

One of the first benefit-cost analyses conducted on freeway service patrols was performed in the Houston, TX region. This particular analysis found a benefit-cost ratio of 2:1 for the Houston FSP in 1973 (Fambro et al., 1976). This initial study set a high standard by examining benefits found through reduced delay, direct customer services, and safety enhancements. Delay reductions were calculated through customer questionnaires and estimated average stopped times and monetary savings were calculated through assumptions of values of travel time. This study was updated by the Texas Transportation Institute in 1993 with an evaluation of the South West Freeway Motorist Assistance Program. A much greater benefit-cost figure of 19:1 was discovered for the Houston FSP in this later effort by using updated computer simulations (Hawkins, 1993). This study utilized the computer simulation program FREQ10PC to simulate incidents on the freeway network and examine the impact of the FSP on delay. Similarly, a value of travel time was assumed to calculate monetary savings. An examination of the Los Angeles County Metro FSP was determined to have a benefit-cost ratio of greater than 5:1 for its services along an 8-mile section of I-10 (Skabardonis et al., 1998). For this study, incident delay reductions were estimated through collection of field data with loops and probe vehicles. The benefit-cost ratios were established through consideration of delay reductions and fuel savings. A study conducted by Khattak and Rouphail in 2003 on the Incident Management Assistance

Patrols in North Carolina calculated benefit-cost figures of 3.5:1 in Asheville, NC and 4.3:1 in Raleigh, NC. The study conducted incident simulations with the traffic software FREEVAL. Similar to the Houston study, these incident simulations were examined to determine the impact of FSP assistance on delay. An evaluation of the Freeway Incident Response Safety Team (FIRST) program in Minneapolis, MN found a higher benefit-cost ratio of 15.8:1 (MnDOT, 2004). This study also used a traffic simulation program, PARAMICS, to examine the impact of the FSP. Fuel savings and delay were considered in calculating monetary savings. A study performed in 2006 discovered a benefit-cost ratio of 4.4:1 for the Georgia Navigator program in Atlanta (GDOT, 2006). This study developed volume/time relationships to determine the impact of incidents on the freeway network. These relationships were applied to estimate the delay savings due to the FSP assistance. Finally, an analysis of Northern Virginia's safety service patrol revealed a benefit-cost ratio of 6.2:1 (Dougald et al., 2006). This study also used a microscopic simulation program to simulate incidents and evaluate the impact of the FSP.

Examination of these previously conducted studies revealed a common theme of estimating delay savings for calculating mobility benefits. The prevalent method for calculating delay savings was to apply specific incident durations for both with and without FSP assistance. Also, evaluation of these scenarios was often performed with a traffic simulation program. In addition, it is common practice to apply an assumed value of travel time to translate delay savings into monetary benefits. These common methodologies provide confidence in the similar proposed methodology for this study.

Using similar methods allows for comparisons to be made to the previously conducted studies. Table 2-1 depicts these calculated figures found through this review in addition to the location and publishing date of the studies.

Table 2-1: Reviewed Benefit-Cost Ratios

FSP Region	Benefit-Cost Ratio	Reference
Asheville NC	3.5	Khattak et al., 2005
Atlanta GA	4.4	Georgia DOT, 2006
Boston MA	19	Stamatiadis et al., 1997
Denver CO	10.4 to 16.9	Cuciti et al., 1995
Florida	2.0 to 41.5	Hagen et al., 2005
Gary IN	4.7 to 13.3	Latoski et al., 1999
Houston TX	2	Fambro et al., 1976
Houston TX	19	Hawkins, 1993
Hudson Valley NY	4.4 to 9.8	Haghani et al., 2006
Los Angeles CA	3.7 to 5.5	Skabardonis et al., 1998
Minneapolis MN	15.8	Minnesota DOT, 2004
Northern Virginia	6.2	Dougald et al., 2006
Raleigh NC	4.3	Khattak et al., 2005

This table reveals that, uniformly, all of these programs reviewed created greater economic benefits than their respective costs indicating that the FSP element of incident management is cost-effective. However, the benefit-cost ratios calculated also reveal a very large amount of variability. This variability is expected as each FSP analysis incorporated different inputs within the benefit calculations. Service area, fleet size, program hours, travel time values, incident times, and service location will all affect the analysis results. In the same way, some of these studies incorporate various combinations of the potential benefits in the categories previously mentioned (mobility, safety, environment, and customer service) while others only look at one or some of these areas.

Examination of these previously conducted studies revealed a common theme of investigating delay savings for calculating mobility benefits. The most prevalent method for calculating delay savings was to apply specific incident durations for both with and without FSP assistance. Other benefits are sometimes considered, such as emissions reduction, safety benefits of secondary crash reduction, and customer service benefits, but the category that is most commonly considered is that of travel time delay reduction (mobility).

Regarding selection of input values for key variables such as incident duration reduction and value of travel time, the more common practice in prior studies has been to apply single values for each of the inputs to translate delay savings into monetary benefits. While many studies report a single value of benefits (and resulting benefit-cost ratios), a few report a range.

For example, in the study of the Hudson Valley program, four different values were used for the incident duration reduction attributable to the service patrol, thus resulting in a range of benefit-cost ratio values. The idea behind using a range of inputs is to incorporate the situation-specific variability inherent in these benefits, and recognition that some of the inputs may be better treated as informed estimates rather than measured values.

As shown in Table 2-1, a few other studies determined a range of benefit-cost numbers depending upon a variability of inputs. For example, an evaluation of the Hoosier Helper program of Gary, IN calculated a range in ratios from 4.7:1 to 13.3:1 (Latoski et al., 1999). Likewise, a study of the Road Ranger Program in Florida calculated benefit-cost figures ranging from 2:1 to 41.5:1 (Hagen et al., 2005). A study performed on the Hudson Valley Highway Emergency Local Patrol (H.E.L.P.) program calculated benefit-cost numbers ranging from 4.4:1 to 9.8:1 (Haghani et al., 2006). These studies reveal the potential variability of benefit/cost ratios that can be found for a particular FSP. The Hoosier Helper study understood the importance of examining the program throughout the entirety of its service period as the 4.71:1 ratio was calculated for daytime operation only and the 13.28:1 ratio was calculated for the entire 24-hour service (Latoski et al., 1999). The study on the Highway Emergency Local Patrol of the Hudson Valley region examined the impact of varying incident durations on calculating benefit/cost ratios of the service patrol. This analysis was performed upon the idea that incident duration reductions will naturally vary on a case by case basis (Haghani et al., 2006). Finally, the study concerning the Road Ranger program in Florida recognized the importance of analyzing the patrol over a variety of locations throughout its entire network. This study reinforced the notion that service patrols will have significantly different impacts upon the highway network as dependant upon the location of assistance due to varying roadway geometries and traffic volumes (Hagen et al., 2005).

These research efforts clearly reveal that the calculated benefits of a service patrol can vary dramatically when considering different locations, times, and incident durations within the analysis. The concept of representing key inputs as occurring across a range of values rather than deterministically discussed here can serve as a guiding principle in the approach taken to evaluate the benefits of the A.S.A.P. program. This approach is described in detail in the next chapter of this report. This principle is consistent with the range of values for key inputs across the literature, as will be shown in the remainder of this chapter.

2.2 Mobility Benefits

Mobility benefits, i.e. the value of travel time saved by motorists passing through an area in which a service patrol is operating, are likely the most exhaustively studied and estimated benefit. To compute a value, however, requires decisions be made on several inputs. These inputs, as seen in previous studies and utilized in the present study, include the value of travel time, average vehicle occupancy, reduction in duration of incidents, and incident locations in time and space. Benefit-cost analyses of service patrols typically simulate incidents using traffic analysis software to determine total delay in travel times on the regional network; this requires a decision on the number of incidents to be simulated as well as the their distribution by time-of-day and day-of-week (temporally) and geographically (spatially).

2.2.1 Values of Travel Time

Within mobility studies, a key focus has been to quantify the value of travel time for both passenger cars and trucks. This input serves as a direct multiplier in benefit calculations of the service patrol. Based upon this characteristic, the assumed value of travel time can easily be responsible for a wide variability of results. A realistic range of values for quantifying travel time must be established to conduct an appropriate analysis and to achieve reasonable results from the analysis. Within the literature, the most popular resources for obtaining a travel time value appear to be studies by either the Texas Transportation Institute (TTI) or the American Automobile Association (AAA). To calculate a travel time value, TTI looked at both delay costs and fuel costs associated with both trucks and passenger cars. Studies conducted in Florida (Hagen et al., 2005) and Virginia (Dougald et al., 2006) used these figures as the basis for their analyses. TTI provides estimates of the value of travel time for both passenger cars and commercial trucks. This information is released as part of its annual urban mobility study. It should be noted that, within the TTI study, the value for travel time was derived from the individual's perspective and not from the wage rate. The commercial cost value only includes the truck operating time and not the value of the commodities within. These nationwide average values were obtained based upon information collected from over 50 metropolitan areas across the country. In 2003, the urban mobility study released values of $13.75/hr for passenger cars and \$72.65/hr for commercial trucks. The TTI numbers used in the Virginia study were slightly outdated at \$13.45/hr and \$71.05/hr.

In 1987, AAA produced a figure of \$6/hr for passenger car. Unfortunately, a description of how this number was generated could not be found within the literature. Both the Hoosier Helper program in Indiana (Latoski et al., 1999) and the H.E.L.P. program in New York (Haghani et al., 2006) utilized this figure and adjusted it to the respective current year based on the consumer price index (CPI) as determine by the U.S. Bureau of Labor Statistics. This adjustment yielded a value of \$8.03/hr in 1995 for the Hoosier Helper study. In conjunction with these passenger car values, the same studies both utilized truck travel time values of \$25.42/hr for single-unit truck and \$28.33/hr for combination truck. These figures were obtained from the Highway Economics Requirement System. Generated in 1990, these values were derived as a function of truck driver wage rate, from the Bureau of Labor Statistics, and an estimated average value for cargo. Similarly, these two studies transformed the 1990 values into corresponding present numbers through the use of a consumer price index. The Hoosier Helper study calculated values of \$8.03/hr and \$30.38/hr through the consumer price adjustments. The Hudson Valley study combined both the passenger car and truck values into a total combination value of \$15/hr. The CPI adjustment uses a historical base year value and an annual growth rate to determine the equivalent value in a future year.

The evaluation of the FIRST program in Minnesota used a travel time value of \$10.04/hr for passenger cars and \$18.61 for trucks. These figures were generated as a function of local wages (MnDOT, 2004). Similarly, an FSP study in North Carolina used a travel time value of \$10/hr but did not provide reference information on the figure (Khattak et al., 2005). A study of the Georgia Navigator program in Atlanta utilized values of \$19.14/hr for passenger car and \$32.15/hr for truck. These numbers were directly obtained from the Bureau of Labor Statistics (GDOT, 2006). Finally, a study conducted in the Puget Sound region of Washington state utilized \$12.40 per person-hour (Nee et al., 2001). Consideration of all of these previously utilized numbers provided guidance in selecting an appropriate range of travel time values to conduct an effective analysis for this input. Table 2-2 summarizes these values found in this literature review.

Table 2-2: Reviewed Values of Travel Time

FSP Region	Value of Passenger Travel Time	Value of Freight Travel Time	Reference
Atlanta GA	$19.14/hr	$32.15/hr	Georgia DOT, 2006
Florida	$13.75/hr	$72.65/hr	Hagen et al., 2005
Gary IN	$8.03/hr	$30.38/hr	Latoski et al., 1999
Hudson Valley NY	$15/hr	$15/hr	Haghani et al., 2006
Minneapolis MN	$10.04/hr	$18.61/hr	Minnesota DOT, 2004
North Carolina	$10/hr	$10/hr	Khattak et al., 2005
Northern Virginia	$13.45/hr	$71.05/hr	Dougald et al., 2006
Puget Sound WA	$12.40/hr	$12.40/hr	Nee et al., 2001

2.2.2 Average Vehicle Occupancy

The average vehicle occupancy figures utilized in benefit-cost analyses can significantly alter results within mobility and delay studies. Assumed vehicle occupancy essentially acts as a multiplier in estimations of benefits. Similar to travel time values, an appropriate range of average vehicle occupancy figures must be established to avoid underestimating or overestimating the impact of service patrol involvement. In consulting the literature, a limited number of studies were found that contained specific information regarding average vehicle occupancy used in their analyses. A study of the FSP in the Puget Sound Region assumed an average number of 1.2 passengers per vehicle (Nee et al., 2001). The evaluation of the FIRST program in Minneapolis, MN also used an average number of 1.2 passengers per vehicle (MnDOT, 2004). Justification for using these numbers was unable to found within these studies. The study of the Georgia Navigator Program in the Atlanta region utilized an average occupancy of 1.16 passengers per vehicle (GDOT, 2006).

In the Birmingham area, two counts were collected in 2006 by the Regional Planning Commission of Greater Birmingham. An occupancy count in Fultondale, Alabama found an average of 1.07 passengers per vehicle. This count was performed along I-65 southbound from 7AM to 8AM. Similarly, a count in Pelham, Alabama found an average of 1.09 passengers per vehicle. This count was performed along I-65 northbound between 7AM and 8AM (He, 2007). Table 2-3 summarizes the average vehicle occupancy values found in the literature review.

Table 2-3: Reviewed Values of Average Vehicle Occupancy

FSP Region	Average Vehicle Occupancy	Reference
Birmingham (Fultondale)	1.07	He, 2007
Birmingham (Pelham)	1.09	He, 2007
Atlanta GA	1.16	Georgia DOT, 2006
Minneapolis MN	1.2	Minnesota DOT, 2004
Puget Sound WA	1.2	Nee et al., 2001

2.2.3 Average Incident Durations With and Without Assistance

It is well documented that a key component of the benefits found through freeway service patrol and incident management programs is generated by restoring capacity as quickly as possible with the onset of non-recurring congestion. Based upon this fact, a large amount of information available in the literature is devoted towards quantifying average incident duration. Specifically, researchers have been interested in examining the impact of service patrols on the differences between incident durations with and without FSP assistance. An entire incident duration is comprised of three critical components. These include detection and verification, response, and clearance. The majority of the studies considered found substantial reductions in total incident durations with the implementation of an FSP with respect to quicker detection and response times. As freeway service patrol units are typically not equipped for clearing severe incidents; clearance time reductions were not as significant as the other two periods. Comparisons were often made through recorded differences between unassisted incident durations and assisted incident durations in FSP time logs. Service patrols commonly record incident assists with regards to time of arrival, time of clearance, and time of departure within these logs. Naturally, these logs are a valuable asset in analyzing the impact of service patrols on duration lengths. The ASAP program similarly uses such recordkeeping practices.

An evaluation of the FSP in Los Angeles County found that non-assisted incidents had longer durations as compared to those where a patrol unit was present. On average, the incident duration reductions within this network ranged from 7-20 minutes when the FSP was present. The FSP was found to reduce response times by up to 15 minutes whereas any remaining reduction was attributed to quicker detection times. The study presents specific examples along I-880 in which incident durations were reduced from an average of 37.6 minutes to 21.1 minutes (Skabardonis et al., 1998). The evaluation also cites studies of the Boston motorist assistance program and the Chicago emergency traffic patrols. These two programs were found to reduce average incident durations by 15 minutes and 20 minutes, respectively (Skarbardonis et al., 1998). Other studies found similar incident duration reductions. An analysis of the Georgia Navigator program in Atlanta discovered a 23 minute reduction in average incident duration with the assistance of a patrol unit (GDOT, 2006). Similarly, the analysis of the FIRST program in Minnesota found reductions of up to 8 minutes (MnDOT, 2004). Additionally, an evaluation of the South West Freeway Motorist Assistance Program in Houston found an average incident reduction of 16.5 minutes, from an average of 46.5 minutes without assistance to 30 minutes with assistance (Hawkins, 1993). An analysis of the freeway courtesy patrols in Houston in 1973 revealed that incident duration fell from an average of 49 minutes down to 27 minutes with the help of the patrol (Fambro et al., 1976). Focusing solely on response times, a study of the Puget Sound freeway service patrol found response time reductions between 44 and 77 percent. This percentage reduction corresponds to actual response times falling from between 5 and 10 minutes to less than 5 minutes (Nee et al., 2001). Similarly, the Hoosier Helper program in Indiana found 10 minute duration reductions in-lane incidents and 15 minute duration reductions for other less severe incidents with the presence of the service patrol (Latoski et al., 1999). Finally, a performance analysis of Virginia’s service patrols calculated a 17 percent average reduction in incident durations with assistance from the FSP. This reduction corresponds to an 11 minute reduction for shoulder incidents and a 9.5 minute reduction for in-lane incidents (Dougald et al., 2006). These studies revealed a range of reductions of incident durations from 5 minutes up to 25 minutes due to the assistance of freeway service patrols. These values are summarized in Table 2-4.

Table 2-4: Reviewed Values of Incident Duration Reduction

FSP Region	**Average Reduction**	**Reference**
Atlanta GA	23 minutes	GDOT, 2006
Boston MA	15 minutes	Skabardonis et al., 1998
Chicago IL	20 minutes	Skabardonis et al., 1998
Gary IN	10-15 minutes	Latoski et al., 1999
Houston TX	22 minutes	Fambro et al., 1976
Houston TX	16 minutes	Hawkins, 1993
Los Angeles CA	7-20 minutes	Skabardonis et al., 1998
Northern Virginia	11 minutes	Dougald et al., 2006
Puget Sound WA	5-10 minutes	Nee et al., 2001

2.2.4 Staging Incidents at Different Locations

The majority of the studies considered in this literature review went through extensive research to determine the locations of highest incidents, highest volumes, etc. that were served by the freeway service patrol in question. Some studies considered incidents only at peak volume locations; although this worst-case scenario reveals the potential benefits of an FSP to its highest extent, it is not representative of an entire service area and can lead to an overstatement of the program's benefits. However, a few notable examples do stray from the norm in attempting to consider the entirety of the network in question when quantifying the impact of the FSP. The examination of the Road Ranger program does try to account for the entire service area by varying the location of considered incidents over all 5 districts served (Hagen et al., 2005). Similarly, a study of the FIRST program in Minnesota stated that incidents were varied over a series of locations to encompass the entire service area. Unfortunately, no specifics were found as to the details of the locations considered for that study (MnDOT, 2004). Neither of these two studies limited the scope of their respective projects to portions of the roadway network served but rather considered the entire service area to appropriately evaluate the potential impacts of a service patrol.

2.2.5 Staging Incidents at Different Times

The worst-case scenario for freeway incidents often occurs during peak period conditions within major metropolitan areas. These conditions are normally represented by at-capacity or near-capacity situations on the highway network. Naturally, these high traffic volumes can lead to high rates of incident occurrences. It is in these conditions that the maximum potential benefits from the service patrol can be realized. Based upon this reasoning, most FSP evaluations found in the literature review examine or simulate incidents solely during weekday peak periods. For example, the evaluation of the Los Angeles program examined the effectiveness of the service patrol during weekday AM and PM peaks (Skabardonis et al., 1998). Reducing the scope of the analysis to the peak periods may ignore the performance of the service patrol during the rest of the day or allow for benefits found during peak traffic periods to be inappropriately extrapolated to other times. However, a few examples do take a broader view in varying incident time. The evaluation of the Hoosier Helper program in Indiana considered model simulations for both weekday periods and weekend periods (Latoski et al., 1999). More extensively, the study of the North Carolina FSP created average annual daily traffic profiles for each day of the week within the service area. Based upon these numbers, 8 hourly categories were created for model simulation. These categories were reduced to 5 urban models and 3 rural models that each represented a different period of the day (Khattak et al., 2005).

2.3 Safety Benefits

Another important benefit of freeway service patrols is that, by reducing the duration of incidents, the exposure of traffic to queuing and congestion is also reduced. The reduction in duration and therefore exposure results in a reduction in secondary crashes. This positive effect of service patrol programs has not been as widely studied as mobility benefits, and the issues in selecting values are also less clear; however, a few attempts have been made to quantify these benefits. In these attempts, a variety of approaches has been taken to estimate crash reduction benefits, ranging from identifying patterns in the incident logs maintained by service patrols to statistical and simulation modeling. The definition of what constitutes a secondary crash has also varied among the studies reviewed. For these reasons, a wide range of crash reduction extents have been reported.

In a study of the Hoosier Helper program in Indiana, Latoski et al. report on an approach taken by Karlaftis et al. to estimate the reduction in secondary crashes. The approach involved development of logistic regression to estimate secondary crash reduction as a function of several possible contributing factors: clearance time, season, weekday versus weekend, type of vehicle involved, lateral location in the roadway. The study found that "…Hoosier Helper could reduce secondary crash probability by 18.5% in winter and 36.3% in all other seasons per crash assisted." In this study, a secondary crash was defined as having occurred within 3 miles and 15 minutes upstream of the primary crash; crashes were the only incident type for which secondary crashes were considered (Latoski et al., 1999).

A methodology was developed to estimate secondary accident rates on Los Angeles freeways by Moore et al. (Moore et al., 2004) Based on the existence of favorable conditions (within a queue formation or at the boundary determined by the shock wave) secondary incidents are identified using a stratified search procedure. While the primary incident data consisted of more than 80 thousand records, their filtering procedure identified 177 potential secondary accidents which resulted in a secondary accident rate of 0.015 to 0.030 specifically associated with crashes, 0.007 to 0.013 for each reported incident (all incident types). In other words, on average, there is a 0.7% to 1.3% chance that a secondary crash will occur after an incident.

A study of secondary crash reductions associated with the Gateway Patrol program operated in southeastern Wisconsin found a secondary crash rate of 9.36% in 1997 and 6.19% in 1998. The reduction over the two-year span was attributed to the construction of pull-off crash investigation sites. A prior study in the Minneapolis area estimated "…that around 15% of crashes are the result of an earlier incident (MnDOT, 2004).

A review of the HELP Program in New York defined secondary crashes "…by scanning an incident database, crashes that could be possibly be considered as secondary to an existing incident were identified." Application of queueing theory and traffic flow theory shockwave analyses were then used to evaluate the likelihood that the identified crashes were truly associated with the congestion upstream of the primary incident. The researchers then took an approach to estimate secondary crash reduction as a function of incident duration reduction and lane occupancy values (Haghani et al., 2006). In terms of secondary incident reduction across all scenarios, the presence of the service patrol was estimated to eliminate approximately 12% for a 5-minute reduction in total incident time, 25% for a 10-minute reduction in total incident time, 43% for a 15-minute reduction in total incident time and 50% for a 20-minute reduction in total incident time. This study notes in previous studies of the service patrols in the Chicago and Milwaukee areas, 60% and 46% of the primary incidents which were suspected to have contributed to secondary crashes were actually crashes (Haghani et al., 2006).

The body of research addressing both the occurrence of secondary crashes and the potential reduction that could be attributed to a service patrol is more limited than that addressing mobility benefits, and a lack of consensus exists both on how to identify secondary crashes as well as the potential reduction in these crashes due to service patrol programs. Among the studies reviewed, secondary crashes were considered as a possible result of crashes only, all types of incidents, or as a function of a distribution based on traffic flow theory parameters. A disparity also exists as to the potential extent of reduction in secondary crashes; in the studies cited herein, these values range from 12% to 50% based on incident duration reduction and seasonal variation. The variability in definition of secondary crashes and potential reduction in such crashes create sufficient uncertainty such that a range-based approach to analyzing potential reduction can be justified.

2.4 Environmental Benefits

Another category of benefits sometimes attributed to the operations of a freeway service patrol is reduction in fuel consumption and in vehicle emissions associated with the reduction in time spent by vehicles in the congestion and queuing upstream of an incident. Vehicle emissions impacts appear to have been more widely studied. There are four vehicle emission species regulated by the EPA: carbon monoxide (CO), byproducts of hydrocarbons (HC), nitrogen oxides (NO_x) and particulate matter (PM). Ozone (O_3) is a pollutant associated with vehicle emissions as it is a byproduct of chemical reactions involving NO_x and HC, and carbon dioxide (CO_2). The amount and rate of emissions from motor vehicles is dependent on the characteristics of how a particular vehicle is driven. The emission rates of motor vehicles are primarily a function of the vehicle's physical characteristics, (e.g. vehicle weight, engine size, engine design, emission controls, gear ratios, tire size and pressure, etc.), environmental conditions (e.g. ambient air temperature), and driving conditions (e.g. stop and go traffic, constant speed, hilly terrain, etc.) (Hellinga, 1998).

2.4.1 Vehicle Emission Modeling

Variables and parameters that influence emissions can be grouped into the following categories: vehicle technology specifications, vehicle status, vehicle operating conditions, and external environment conditions (Heywood, 1988).

- Vehicle technology specifications include general vehicle design characteristics (weight, aerodynamic efficiency, etc.), propulsion characteristics (Otto or Diesel cycle), type of fuel, emission control devices (i.e. catalyst converter), and engine power.
- Vehicle status includes mileage, age, and mechanical status.
- Vehicle operating conditions include engine dynamics (engine speed, power demand, etc.), air-to-fuel mass ratio, vehicle kinematics variables (speed and acceleration), and temperature of the catalyst. These variables can in turn depend on variation in individual driver behavior.

- External environment conditions include air conditions (ambient temperature, atmospheric pressure, relative air humidity), and road characteristics (longitudinal grade, curves, and pavement quality).

Given the strong influence of vehicle technology specifications and status on emissions generation process, emission models are usually calibrated separately for every vehicle make and model, or for homogeneous vehicle categories. Vehicle operating conditions are generally the principal input to the models while external environment conditions can be introduced as secondary inputs.

There are a variety of approaches for vehicle emissions modeling, each with its strengths, its weaknesses and its limitations. There are technology-based engineering models that are very detailed and are normally developed for a specific vehicle or engine. These models are needed for technology development, calibration and regulation purposes (Heywood, 1988). However, integrated traffic emissions modeling requires a simpler and more general approach that takes account of vehicle diversity, grouping vehicles in homogeneous categories. Emission models are usually calibrated using chassis (or engine) dynamometer measurements. During a dynamometer test, emissions can be measured as the total generated during the cycle or during single sample bag or continuously, i.e., typically second-by-second. The following paragraphs describe the two basic approaches used for vehicle emission modeling.

The average speed approach assumes that the average emissions over a trip vary according to the average speed of the trip. The general shape of a speed-emission curve shows high emissions at slow average speeds when the vehicle “stops and goes” frequently, and a tendency to high emissions at high speed when a high engine power demand is present. These results have been obtained from measurements performed on a chassis dynamometer, while the test vehicle was operated over a certain driving cycle while its emissions were collected and analyzed. The relationship with average speed is determined by combining results from tests using cycles with different average speeds. This method has been utilized to develop models following the average speed approach.

The average speed approach is the commonly used method to estimate emissions from road traffic; this approach is based on aggregated emission information for various driving patterns, whereby the driving patterns are represented by their average speeds alone. All this information is collected according to vehicle technology, capacity class and model year, and a speed-dependent emission function is derived (Barkawi, 1997). This means that in addition to vehicle type, the average speed of the vehicle is the only decisive parameter used to estimate its emission rates. This restricts the approach to regional and national emission estimates.

The modal approach uses another variable in addition to speed, the acceleration rate, to describe in more detail the vehicle's operations. This type of model assigns an emission rate to each instantaneous combination of the two chosen variables (the timescale is usually every second). Data for the instantaneous models are derived from continuous measurements of speed and emissions. Emission rates corresponding with operating conditions in certain bands are combined to provide a two-dimensional matrix of emission factors, classified by the two operational variables. This second approach has been used to develop the instantaneous emission models.

The instantaneous models are also named modal models because the emissions are measured continuously at the exhaust during chassis dynamometer tests and stored at a particular time interval (usually every second). The operational condition of the vehicle is recorded simultaneously with the emission rate. In this way it is possible to generate emission functions by assigning exactly-defined emission values to particular operational conditions. The emission function for each pollutant can be defined as a two-dimensional matrix as defined above. All instantaneous emission data are put into one cell of the emission matrix, according to the velocity and acceleration of the measured vehicle at that time. The emission function is the arithmetic mean of all emission quantities in each cell of the emission matrix. Once such an emission matrix exists for a vehicle, it should be possible to calculate the emission amounts for any driving pattern that is defined as series of modal value-pairs of speed and acceleration (Pronello et al., 2000).

These approaches/methods are generally classified into three categories: Macroscopic, Mesoscopic, and Microscopic (Hellinga, 1998). Approaches classified as macroscopic typically handle emissions on the basis of aggregate traffic measures, such as vehicle miles travelled. An average emission rate per mile is used to transform the traffic measure into an estimate of total emissions. This approach is only able to distinguish between those incident management strategies that influence the vehicle miles travelled. They are insensitive to any changes in the level of congestion experienced.

Mesoscopic approaches typically utilize traffic measures that reflect, in at least a limited manner, the characteristics of the trip. Typically, average speed, roadway type and average trip length are used in conjunction with average emission rates (which are functions of roadway type and average speed) to estimate emission quantities. While mesoscopic approaches provide some additional capability to distinguish between the impacts of different incident management strategies, their benefits are limited by the difficulty in accurately estimating the average speed expected to result from the implementation of a given incident management strategy. Furthermore, the assumption that there exists a sufficiently strong correlation between emissions and average speed has been shown to be untrue for certain pollutants, including CO.

Microscopic methods typically rely on the development of relationships that are functions of vehicle type, instantaneous speed, instantaneous acceleration, engine temperature, ambient air temperature, etc. These relationships are applied on the basis of the second-by-second performance of the vehicle to estimated emissions. Microscopic approaches are the most accurate type in reflecting the impact of an incident management strategy on emissions. However, these methods are also computationally intensive, and require the provision of a significant quantity of input data (Hellinga, 1998).

2.4.2 Previous Studies of Vehicle Emission Estimation and Modeling

This section describes the various emission models as a background for comparing the models. As mentioned earlier these models are categorized as macroscopic and microscopic models. Macroscopic models use average aggregate network parameters to estimate networkwide energy consumption and emission rates. Alternatively, microscopic models estimate instantaneous vehicle fuel consumption and emission rates that are aggregated to estimate network-wide measures of effectiveness.

A considerable amount of research has been done to estimate impacts of different incident management strategies on the vehicle emissions. Different approaches have been proposed to evaluate impacts on vehicle emission. Some studies showed that a traffic simulation model integrated with an emission factor model can be used to evaluate the emissions effects of incident management strategies by comparing the before deployment scenario with the after deployment scenario. The practice of using traffic simulation models with emission model generally follows the following steps:

- Quantifying emission-producing vehicle activities (e.g. VMT, number of trips, idling delay, operating speeds) through a traffic simulation model
- Providing data on vehicle, fuel, operating and environmental characteristics to the emission factor model
- Running the emission factor model to predict activity-specific emission rates for the given vehicle, fuel, operating, and environmental characteristics;
- Multiplying each activity estimate by its appropriate activity-specific emission rate; and,
- Summing the estimated emission for all the activities.

In this approach, emission-producing vehicle activities need to be developed using either microscopic models such as TRAF-NETSIM or CORSIM, or macroscopic models like FREFLO and TRANSYT-7F. Newer simulation models like INTEGRATION, DYNAMIT, and DYNASMART are better suited for simulating various incident management scenarios. Scenarios representing before/after incident management deployment conditions need to be considered. As mentioned in the previous literature review of traffic simulation models, there are some microscopic simulation models available which have built-in emission models which can be used to calculate vehicle emission estimates, e.g. CORSIM.

Hellinga (1998) studied the use of a traffic network simulation model to quantify the impact of traffic management strategies on network traffic conditions by comparing network level measures of performance between the 'base scenario' and the 'ATMS scenario'. He presented an approach which provides a mechanism to quantify the impact of different incident management strategies on air quality, when selecting the desired strategy. The microscopic simulation model INTEGRATION was used**.** It was capable of estimating spatially and temporally correlated pollutant emissions on the basis of a drive mode elemental emissions sub-model. The evaluation of a single potential incident management strategy within this study indicates that the impact on air quality can vary significantly spatially and temporally.

Lee (2000) studied the impacts of traffic flow control on CO_2 emissions from passenger cars. The PARAMlCS microscopic traffic simulator was used for dynamic traffic modeling, and an emission model was integrated with PARAMICS using an Application Programming Interface (API). This integration model used a simple algorithm based on vehicle type and vehicle operating condition to calculate the level of pollution emitted from every vehicle during each simulation time-step. This study found that the provision of routing information to drivers generally reduces the total CO_2 emissions by decreasing total travel time and fuel consumption. It indicates that the deployment of ITS strategies possibly reduces the CO_2 emissions as a secondary effect of reduction in traffic congestion. The integrated model estimates the total emission based on the individual vehicles' second-by-second emissions rather than the link emissions calculated from average link flow. Therefore, the model provides a more valid functional relationship between traffic flow and emissions compared to conventional macro-scale models.

Saka, Agboh, Ndiritu, and Glassco (2000) used the microscopic simulation model Westa and the emission model MOBILE 5b to find the mobile emission reduction from an Electronic Toll Collection in the Baltimore metropolitan area. Westa was used for modeling the critical peak traffic flow patterns and MOBILE 5b used the output data from Westa for two different scenarios (pre–M-Tag and current M-Tag market penetration) to estimate emissions. They found the changes in estimated mobile emissions ranged form an 11% decrease for NO_x to more than 40% decrease for HC and CO for the two scenarios considered.

A study by El-Fadel, Sbayti and Kaysi (2001) investigates the effect of three levels of roadway network aggregation, macro-scale (overall network basis), meso-scale (roadway functional class basis) and micro-scale (link-by-link basis) on emission inventories. The traffic model EMME/2 and the MOBILE5b model were integrated to determine total emissions in the future Beirut Central District area for these three modeling approaches. Three levels of detail were used to estimate the total emissions, at the macro-, meso- and micro-scales. At the macro-scale, the average network speed was used to calculate an average emission factor for the whole network. Total emissions were estimated by multiplying total vehicle miles traveled by the average emission factor. For the meso-scale approach, an average emission factor for every roadway functional class was determined. The contribution of each roadway functional class to pollutant emissions was aggregated to yield total emissions. In the micro-scale method, link speeds were used to obtain emission factors for every link. Link VMT was multiplied by the corresponding link emission factors and summed over all links to obtain total emissions.

Stathopoulos et al. (2003) studied whether induced travel (in particular the generation of new trips) diminishes or off-sets the reduction in emissions from flow improvements. This work used micro-simulation techniques and a modal emissions model to develop a simple scenario that examines the effect of improving traffic flows on vehicle emissions. They used the VISSIM micro-simulation model and the CMEM database to evaluate this issue. This involved feeding micro-simulation output into the software provided with the CMEM database. They analyzed an arterial merge and a coordinated traffic signal and found that emissions of CO, NO_x and HC were initially reduced, but any initial emissions reductions are quickly overtaken by increased trips.

Kaysi, Chazbek, and El-Fadel (2004) developed a framework for assessing the potential of ITS in alleviating non-recurring traffic congestion and for estimating the resulting implications for vehicle-induced emissions in a congested city in a developing country using DYNASMART and MVEI/EMFAC (EMission FActor Model). Scenarios of three information techniques (no-information, pre-trip information, in-vehicle information) were simulated to estimate its effects on network performance and resulting emissions (CO, NO_x, and TOC). Average network travel time and stopped time were considered to calculate one hour emissions for the above mentioned scenarios. The study found that total emissions decreased as network performance improved (measured by decreases in travel and stop times). NO_x emissions increased as the travel time decreased with the implementation of an Incident Management program since the NO_x idle emission factor is very low compared to the NO_x mobile source emission factor. CO emissions and TOC emissions were found to be much more prevalent in the immediate vicinity than at the network level.

A study by Dodder (2004) presented a systems framework for assessing air quality impacts of ITS for Mexico City. The main purpose of this study was to present a framework that enables transportation analysts and planners to map and better understand the interactions between multiple ITS deployments and their possible impacts on air quality. Eight ITS-air quality mechanisms were used to track how these systems interact to improve air quality or fail to interact, and to avoid focusing too much on certain parameters that affect emissions. The focus on key system interactions can help avoid unforeseen outcomes in actual deployments and guide more comprehensive evaluations of ITS.

A study by Nesamani, Chu, McNally and Jayakrishnan (2006) proposed a methodology to estimate vehicle emission by capturing traffic variation. It uses an intermediate model component that can better estimate link speed by considering a set of emission specific characteristics for each link. MOBILE6 was used to estimate the emission factors by using improved link speed data as input. The intermediate model component was developed using multiple linear regression and was calibrated, validated and evaluated using the microscopic simulation model PARAMICS. The evaluation results of this study concluded that the proposed emission estimation method is capable of estimating time-dependent emissions if traffic sensor data are available as model input.

Stamatiadis et al. (1997) used traffic the simulation model FREQ11 to estimate emission reduction benefits in the evaluation of Massachusetts Motorist Assistance Program (MAP). Emissions reduction estimates were based on AM and PM peak hour operation. Incident scenarios were modeled using different characteristics such as type, time of occurrence, location, and type of response to the incident. For each incident scenario two cases were considered, one with the help of MAP and another without the help of MAP. Emissions were determined at a link level basis, i.e. for selected representative routes and then extrapolated for all similar routes. The study found that the MAP is beneficial for reducing vehicle emissions and these benefits were included in the estimation of overall benefits of the program.

Akihira (2004) studied the direct effects of changes in driving behavior on vehicle miles traveled and the indirect effects on the total fuel consumption and emissions. For this purpose the researcher used microscopic traffic simulation models CORSIM (which has built-in emission look-up table/model) and VISSIM, and emission models CMEM (Comprehensive Modal Emission Model) and MOBILE6. Comparison of the results obtained from the different models indicated that for HC emissions, the CORSIM built-in model seems to predict significantly lower results than other models. Other models predict generally consistent values with CMEM and slightly higher than MOBILE. For CO emissions, CMEM predicts significantly higher values than CORSIM and VISSIM. The other three models predict consistent values.

2.5 Customer Service Benefits

Another key category of benefits associated with service patrols are those directly received by travelers assisted by the program. The services rendered to motorists have quantifiable economic value since they would have to pay a private towing company or similar entity for services such as delivery of fuel, towing, etc. While mobility benefits appear to be the category most commonly addressed in the literature, there are a few cases where customer service benefits were quantified economically.

The Houston Motorist Assistance Program (MAP) was developed originally to assist while construction was performed on the U.S. 59 Freeway. This study was performed from July 1991 to September 1992. The cost benefit analysis for the MAP program was calculated from the average time a motorist saved driving and the out-of-pocket cost saved by motorists needing assistance verses the cost of the program. For the cost data for each motorist assist, the study used values from the Houston Wrecker Association. The values range from $0.25 for a phone call to $57 for gas and minor engine repair. To arrive at the savings to motorists, the cost per service as multiplied by the number of services performed in the time span for the study. The approximate savings was $125,000, although the average value per assist was not reported (Hawkins, 1993).

A study of the Hoosier Helper program in northwestern Indiana attempted to quantify several aspects of its benefits. One of these was the value of assists provided. This study took the approach of determining the values of assist by the cost to the program associated with the assists. In separate phases, the daytime operations of the program were evaluated for 1995, and later, 24-hour operation for six months during 1996. The daytime operations evaluation found a cost of $55 per assist, and the round-the-clock operations the following year resulted in a cost of $46 per assist (Latoski et al., 1999).

The Georgia DOT established a call box system to assist stranded motorists on major roadways. In a case where the motorist needed assistance, they would place a call to the 911 operator from the call box. The data for the study was collected for a 6-month period from June 1999 through November 1999, along Interstate 185. The benefit values for motorist assistance from the call boxes were mostly estimated or assumed values by the researchers. The factors that influenced these values were time saved by the motorist, speed of service, secondary accidents reduced, and burden placed on the 911 operator. Benefit values range from $2 for directions to $2000 for a medical emergency. The total benefit was calculated by multiplying the benefit value by the frequency of the type of assist. The total benefits came to $40,320 from the call boxes (Kolb et al., 2000). With 920 assists rendered during the study period as a result of calls placed, this corresponds to an average value of $43.83 per assist.

A more recent study of the Georgia Department of Transportation ITS program entitled “Georgia NaviGAtor” evaluated a variety of benefits of their program, including the “Highway Emergency Response Operators” (HERO) service patrol (Georgia DOT, 2006). A section of the report entitled “Savings Due to Motorist Assistance” briefly addressed the value of services directly rendered to travelers. Values of each type of service provided were assigned based on a survey of travelers assisted. The average value of services assisted was found to be $60.25 (Georgia DOT, 2006).

2.6 Operational Areas

A key decision in the development and periodic evaluation of a service patrol program is determination of the area, or freeway segments, to be served. Typical practice in service patrols is to serve the most heavily traveled and most incident prone areas, but the extent to which freeways with lower volumes is served varies widely. Among the studies cited in this literature review, little documentation was found regarding the decision making behind determination of the service area. It is suspected that DOT personnel in the affected areas, particularly traffic engineers, are quite familiar with their geographic areas and make recommendations based on this background.

A study conducted at the University of Maryland of the service patrol program in the Hudson Valley region of New York State examined benefit-cost ratios are related them to hourly traffic volumes. In this study, future expansions of the program were recommended only on freeway segments where volumes exceeded 1500 vehicles per hour per lane (Haghani et al., 2006).

In a study performed for the North Carolina Department of Transportation, a methodology for identifying and evaluating candidate roadway segments for expansion of their service patrol, the Incident Management and Assistance Patrol (IMAP). The researchers selected three indicators of high traffic and high crash rates to quantify candidate segments: AADT per lane, crashes per mile per year, and crashes per 100 million vehicle miles. These statistics were generated for freeways in North Carolina not already covered by IMAP, and the 85th percentile value for each was selected as a threshold to identify potential high impact sites. The researchers noted that the “index values for contiguous facilities can vary substantially. In addition, for very short segments, the crashes per mile per year and crashes per 100 million vehicle miles values are inflated because the formulas divide by facility length.” (Khattak et al., 2005). This implies that while the three variables used to identify candidate segments may be reasonable, caution must be used when calculating them for segments considered for program expansion so that potential impact on very short segments is not overstated, and that several contiguous segments should be considered together to smooth variability among the calculated values for individual segments. This study did not conclude that a particular traffic volume threshold be used to identify service patrol expansion areas, but that traffic volumes and two measures of crash frequency be used. Candidate areas would first be identified and these statistics generated for each and then compared to regional or statewide averages. Candidate segments whose statistics were very high (e.g., 85th percentile or greater) relative to their comparators would be highest priority for service patrol expansion. In summary, there is no consensus as to the methodology used to evaluate potential service patrol program expansions; this appears to be done on a case-by-case basis.

CHAPTER 3: ANALYSIS APPROACH

The approach taken in this study to evaluate the economic effectiveness of the A.S.A.P. program was developed based on a review of approaches found in the literature and a desire to quantify all major categories of benefits (mobility, safety, environmental, safety, and customer service). Benefits were to be estimated for each category, then summed and divided by the program's costs to provide a benefit-cost ratio for the study period. The level of effort employed to estimate benefits varied somewhat among the categories and studies noted in the literature review. Modeling of incidents and resultant traffic impacts has typically been completed using traffic simulation software to model mobility and environmental benefits. Safety benefits, when estimated, are often done in a less intensive manner by estimating the reduction in secondary crashes and then applying that reduction to economic data for crashes. Customer service benefits are those associated with the value of the service provided by the service patrol to the motorist assisted. When found in the literature, customer service benefits typically have seen the least sophisticated approach. A value is assigned to each potential benefit, either by calculating the costs associated with providing the assistance or surveying motorists or commercial service providers to estimate associated values.

3.1 Methodology

A key principle developed early in this study was the merit of viewing the potential benefit in each category as a range of possible values rather than a single value. Although data obtained from the A.S.A.P. program form the basis of the data analyses undertaken in each of these categories, many assumptions need to be made to arrive at some of the other values required to complete the analyses. Due to the lack of complete certainty associated with assumptions, a range of values, rather than a single value, seems appropriate. This concept is reflected in some of the studies found in the literature. While many studies of other programs produce a single benefit-cost ratio, some of the more complex and comprehensive studies take a range-based approach to quantifying the economic effectiveness of the programs studied. For example, the study of the Hudson Valley H.E.L.P. program, noted several times in the literature review, addressed three of the four categories of benefits identified in the current study, which more comprehensive than most studies found. One of the key inputs in benefits calculations is the extent to which incident durations are reduced by the activities of the service patrols; the

H.E.L.P. program study evaluated benefits across a range of values for incident duration reduction. The actual reduction of incident duration cannot be measured (since incidents responded to by the service patrol are not replayed without the assistance and results compared), a series of assumptions and simulations are typically used to develop values for this critical input, thereby lending support to the range-based approach. The other key reason to adopt a range-based approach is that assumed values for some of the inputs may have some degree of subjectivity or found to vary among studies conducted of other service patrol programs. For example, travel time values used in prior studies vary widely. The monetary value of motorists travel time can be based on a survey of travelers or developed through a thorough economic modeling process. Some degree of subjectivity may come into play. Therefore, a range of dollar values for travel time is used in the current analysis.

An analysis methodology was developed for each of the four categories of benefits to be included. For each category, a range of estimated benefits, as well as a most likely or average value is developed and then translated into monetary values. To arrive at a benefit-cost ratio to quantify the economic effectiveness of the A.S.A.P. program, these benefit ranges are summed across the categories and then divided by the program's costs. Therefore, a range of benefit-cost ratios and an average value is the result.

A traffic simulation model, using the widely used program CORSIM, was developed for the modeling effort. This model, described later in this chapter, is at the core of the analysis of mobility and environmental benefits. However, estimation of safety benefits based on the traffic simulation model would have required additional assumptions beyond those used in model development. Consistent with typical procedures found in the literature, safety benefits are estimated in a less-detailed but more straightforward procedure. Since a record of these assists has been maintained by the A.S.A.P. program, the value of associated benefits is calculated directly from these data rather than outputs of the traffic simulation model.

3.2 Data Collection

Data on assistance rendered and on program costs were obtained from the Third Division office of the Alabama Department of Transportation. Specifically, the incident log created by the A.S.A.P. program for the period July 1, 2004 through June 30, 2005 was used to identify the number, type, location, and time of day of assists provided. Program cost data were obtained for the same period.

Records from the A.S.A.P. program indicate that a total of 17,090 assists were rendered during the 12-month period on which this analysis is based. The distribution of these incidents by highway and by extent of blockage (shoulder only or number of lanes) is shown in Table 3-1. Upon examination of the individual records in the assist database, 200 records were excluded from the analysis; these records were those for which "no assist" was the category selected or other information was missing. The distribution of the remaining 16,890 incidents, along with the number of incidents for which dispatch time was recorded, is shown in Table 3-2. The dispatch time information was used in the modeling of incident duration, explained in the next section of this report.

Table 3-1: Incident Distribution and Sample Size

Interstate	Total Per Interstate	Shoulder	1 Lane	2 Lane	3+ Lane
I-20	620	546	50	17	7
I-59	7383	6496	593	206	88
I-65	6652	5852	534	186	79
I-459	2435	2143	196	68	29

Table 3-2: Incidents Based on 2004-2005 ASAP Log, with Outliers Removed

Incident Type	Distribution (%)	All incidents (with outliers and no assists removed)	Incidents with Dispatch Times
Shoulder	87.92	14850	805
1 lane blocked	8.02	1355	67
2 lanes blocked	2.80	472	29
≥ 3 lanes blocked	1.26	213	8

Cost data for A.S.A.P. were provided by ALDOT for this study. A freeway service patrol deployment has inherent costs associated with its operation. These costs are incurred through operations and maintenance of the program along with wages and benefits for employees. Cost data for the A.S.A.P. program, including recurring expenses (e.g., labor, benefits) and payments toward capital expenses (e.g., equipment) were obtained from ALDOT. For the analysis period of July 2004 – June 2005, the total program cost was $593,242.

3.3 Traffic Simulation Model

The microscopic traffic simulation model program CORSIM was chosen to analyze the potential impact of the A.S.A.P. vehicles on mobility through its estimation of vehicle-hours of total delay and on the environment through emissions reduction modeling. The simulation analysis was supported by traffic volume data and logbooks from the A.S.A.P. program obtained from ALDOT.

A fully-constructed network model detailing the entire ASAP freeway coverage area was developed. This analysis approach is designed to vary the staging time of incidents throughout the day; therefore, 16 unique models were constructed for each hour of the ASAP service period (6AM – 10PM). This was done to ensure that any simulation of an incident did not affect traffic conditions in the simulation of other incidents. Capacity restraints and engineering judgment were both applied to this process in an effort to produce accurate models. The primary motivation of these methods was to arrive at numbers that were realistic and appropriate. Each model utilized hourly volumes collected in 2004 and obtained from ALDOT and other derived hourly volumes as needed when data were unavailable.

To capture the variability found among incidents, 30 unique scenarios were randomly chosen, each with a different location and time. Thirty scenarios were chosen as this amount corresponds to a reasonably “large” data set as shown through the Central Limit Theorem. This characteristic is important in attempting to encompass the entire range of possible ASAP benefits.

Incident severity, with respect to lane blockages, was taken into account through analysis of ASAP logbooks covering the period of July 1, 2004 to July 1, 2005. The reported distribution of incident severity was applied to all 30 scenarios in a random manner. Applying this distribution created 24 shoulder incident scenarios, 4 one-lane blocked scenarios and 2 two-lane blocked scenarios. Figure 3-1 presents the entire ASAP coverage area and illustrates the spatial distribution of the 30 scenarios. Each incident location is designated as a circle. The temporal distribution of these scenarios was based on the distribution of traffic volume during the ASAP service period. This distribution can be seen in Table 3-3. Within CORSIM, incidents were simulated as capacity reductions and the appropriate number of lanes blocked. The appropriate capacity reduction factors were obtained from Exhibit 22-6 of the Highway Capacity Manual (TRB, 2000).

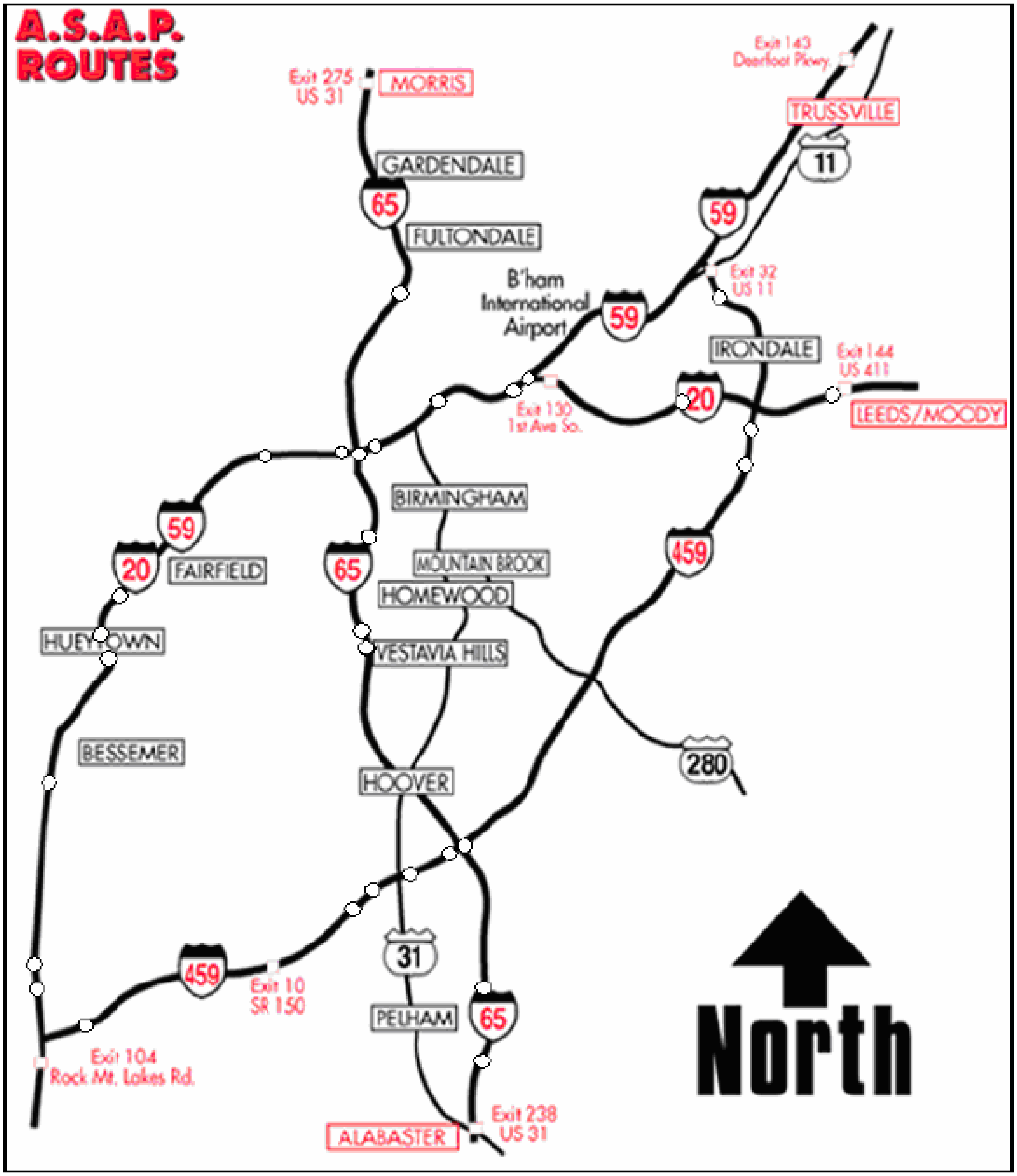

Figure 3-1: Spatial Distribution of Incident Simulations (after ALDOT, 2006)

Table 3-3: Incident Scenario Details

Scenario	Incident Link		Time of Day		Number of
	Highest- 1758	Lowest- 1	Highest - 2200	Lowest - 600	Lanes blocked
					Highest
	Random Node	Assigned Link	Random Number	Assigned Time	Lowest
1	1255	(1255, 1258)	867	8 am - 9 am	1
2	874	(874, 875)	1608	4 pm -5 pm	0
3	683	(683, 684)	1630	4 pm -5 pm	0
4	307	(310, 307)	2049	3 pm - 4 pm	0
5	507	(505, 507)	707	7am - 8 am	1
6	168	(168, 169)	1018	10 am -11am	0
7	421	(421, 422)	1757	5 pm- 6 pm	2
8	807	(807, 809)	1689	4 pm - 5 pm	0
9	155	(154, 155)	2178	9 pm -10 pm	0
10	743	(743, 744)	1239	12 pm -1 pm	0
11	1130	(1130, 1133)	1087	10 am - 11 am	0
12	1502	(1502, 1504)	1174	11 am - 12 pm	0
13	1513	(1511, 1513)	603	6 am - 7 am	1
14	611	(611, 612)	1897	6 pm - 7 pm	0
15	826	(826, 827)	1886	6 pm - 7 pm	0
16	923	(923, 924)	1978	7 pm - 8 pm	0
17	385	(385, 388)	2142	9 pm - 10 pm	0
18	699	(699, 701)	1418	2 pm - 3 pm	0
19	1360	(1360, 1363)	1880	6 pm - 7 pm	0
20	1278	(1278, 1279)	2002	8 pm - 9 pm	0
21	659	(659, 660)	864	8 am - 9 am	0
22	59	(59, 60)	1769	5 pm - 6 pm	0
23	1735	(1735, 1736)	1712	5 pm - 6 pm	2
24	1558	(1558, 1559)	1975	7 pm - 8 pm	1
25	458	(458, 459)	2051	8 pm - 9 pm	0
26	1096	(1096, 1097)	1458	2 pm - 3 pm	0
27	852	(852, 854)	1408	2 pm - 3 pm	0
28	536	(536, 537)	1158	11 am - 12 pm	0
29	1567	(1567, 1568)	764	7 am - 8 am	0
30	1387	(1386, 1387)	768	7 am - 8 am	0

It is virtually impossible to label one single value as an exact benefit due to the erratic nature of traffic behavior. Therefore, to capture this variability, this study has taken a series of snapshots of the ASAP program in action through several CORSIM simulations. According to the Federal Highway Administration's Traffic Analysis Toolbox, Volume 4, a microsimulation traffic analysis should be evaluated a minimum of 8 times to achieve a 95% confidence level and a confidence interval of 2 times the standard deviation of the data set (FHWA, 2004). Based upon this information, each individual scenario stated was run within CORSIM eight times to acquire this statistical effectiveness. The average delay values of the 8 runs for each scenario were then used to continue on with the analysis.

As shown in the existing literature, average incident durations are reduced by as little as 5 minutes and as high as 25 minutes with the assistance of the service patrol. Actual duration values from the A.S.A.P. logbooks formed the basis for the values used in the simulation. This analysis created 5 distinct cases relating to 5, 10, 15, 20 and 25 minute reductions. These 5 different incident duration reductions, in addition to the no-assistance condition, create 6 different incident duration reductions (one of which had a zero value to represent the no-assistance condition). After executing 8 runs for each of the 30 incident scenarios, for each of the different 6 incident duration values, a total of 1440 CORSIM runs were performed for this effort.

CHAPTER 4: MOBILITY BENEFITS

The mobility benefits associated with the operation of the A.S.A.P. program can be quantified in the form of reduction in delay to the traveling public. Measurement of travel time delay directly in the field is difficult; therefore, the traffic simulation program CORSIM was used to estimate overall delay in vehicle-hours. As noted in previous chapters of this report, rather than estimate benefits as single value, a range of values is used. This represents the many factors that influence travel time delay on the freeway network and the ultimate economic evaluation of the reduction in delay. The factors considered as variables in the analysis of mobility benefits include: spatial distribution, temporal distribution, incident duration reduction, value of travel time, and average vehicle occupancy.

Based on the distribution of incident types, number of lanes blocked, time of day, and location, as obtained from A.S.A.P. records, 30 incident scenarios were modeled in CORSIM. The results of the CORSIM simulations provided travel time delay values across the incident scenarios for each value of incident reduction attributable to the service patrol operation, as noted in Chapter 3. Application of travel time values and average vehicle occupancy are applied after the simulations, as noted below.

4.1 Travel Time Values

Due to the variability associated with studies of socioeconomic phenomena, and the wide variety of travel time values noted in the literature, varying the value of travel time was an obvious choice for this analysis. This input can have a large effect upon the economic evaluation of potential benefits of incident management programs as it controls the estimated time value of those individuals delayed by the incident. Based upon the literature review and engineering judgment, this analysis was performed using values of \$8/hr, \$10/hr, \$12/hr, \$14/hr, and \$16/hr per passenger for private vehicles. Similarly, five values of \$30/hr, \$40/hr, \$50/hr, \$60/hr, and \$70/hr per truck were selected for heavy vehicles. Based on these two sets, composite values were calculated based upon a typical traffic distribution found in the Birmingham area of 85% private vehicles and 15% heavy trucks. A simple calculation provided weighted travel time values of \$11.3/hr, \$14.5/hr, \$17.7/hr, \$20.9/hr, and \$24.1/hr. These weighted values were applied to the entire traffic stream as a whole.

4.2 Average Vehicle Occupancy

In addition to travel time values, selection of values for vehicle occupancy requires careful thought. This input can also have a large effect upon potential benefits of incident management programs as it controls the number of individuals affected by the incident. Field studies were conducted in 2006 by the Regional Planning Commission of Greater Birmingham at two locations on Interstate 65. Average vehicle occupancies of 1.07 and 1.09 were found at the two sites (He, 2007). Based upon the literature review and local field studies, the range of 1.0 to 1.2 passengers per vehicle was deemed adequate to capture the total variability found within this input yielding six unique vehicle occupancy numbers of 1.0, 1.04, 1.08, 1.12, 1.16, and 1.20 passengers per vehicle.

4.3 Estimation of Mobility Benefits

The variation of each of the above parameters created an extremely large number of possible combinations of inputs for each traffic scenario. Delay values (in vehicle-hours) were generated for each of the 30 incident scenarios. These are averages of the values from the eight simulations runs for each scenario. With five duration reductions, five travel time values, six average vehicle occupancy values, a total of 4,500 benefit values were calculated. Due to the large amount of figures calculated through this analysis, informative benefit ranges were effectively obtained.

Calculation of potential benefits was a simple cross-classification multiplication procedure performed in Microsoft Excel. Each scenario result was multiplied by every combination of travel time value and vehicle occupancy value to create 4,500 unique benefit estimates from a single assist of the ASAP service. Equation 1 represents this cross-classification procedure.

$$Benefit(\$) = (CORSIMOutput(veh * hrs)) * \left(TravelTimeValue\left(\frac{\$}{pass * hr} \right) \right) * \left(Occupancy\left(\frac{pass}{veh} \right) \right) \quad (1)$$

A total yearly benefit estimate of the ASAP program was calculated by multiplying the range of benefit values calculated for a single incident by the total number of assists per year. These total yearly benefit estimates were then compared to a calculated 2005 ASAP program annual cost to calculate a range of benefit-cost ratios.

CORSIM provides a detailed output file that includes measures of volumes, travel speeds, average speed, delay time, emissions reports, etc. Within this study, the difference in total network travel time between assistance and no-assistance situations was selected as the measure of effectiveness to analyze the impact of ASAP assistance. Table 4-1 illustrates these corresponding calculated differences. The positive hourly differences indicate delay savings due to ASAP assistance. Conversely, the negative hourly differences indicate increased delay.

Table 4-1: Difference in Network-Wide Travel Times as a Function of Incident Duration Reductions

			Incident Duration Reduction				
			Average Difference in Network-Wide Travel Time (Veh-Hrs)				
#	Incident Time	Incident Type	5min	10min	15min	20min	25min
Scenario 1	8 am - 9 am	1-Lane	1	-11	-10	-19	46
Scenario 2	4 pm -5 pm	Shoulder	2	12	7	9	8
Scenario 3	4 pm -5 pm	Shoulder	-2	0	7	58	-3
Scenario 4	3 pm - 4 pm	Shoulder	-1	30	10	27	17
Scenario 5	7am - 8 am	1-Lane	9	11	79	52	50
Scenario 6	10 am -11am	Shoulder	3	-2	-9	-2	-12
Scenario 7	5 pm- 6 pm	2-Lanes	27	21	33	68	39
Scenario 8	4 pm - 5 pm	Shoulder	3	-3	-2	-1	-31
Scenario 9	9 pm -10 pm	Shoulder	-1	-7	-2	-2	-2
Scenario 10	12 pm -1 pm	Shoulder	-4	-4	-1	3	1
Scenario 11	10 am - 11 am	Shoulder	-1	-7	7	1	0
Scenario 12	11 am - 12 pm	Shoulder	-3	1	-11	-4	5
Scenario 13	6 am - 7 am	1-Lane	77	133	246	387	454
Scenario 14	6 pm - 7 pm	Shoulder	4	0	-2	-4	-16
Scenario 15	6 pm - 7 pm	Shoulder	2	2	-1	12	15
Scenario 16	7 pm - 8 pm	Shoulder	0	2	-5	-6	0
Scenario 17	9 pm - 10 pm	Shoulder	3	4	2	10	9
Scenario 18	2 pm - 3 pm	Shoulder	-3	-7	-7	-12	-8
Scenario 19	6 pm - 7 pm	Shoulder	2	5	17	-2	8
Scenario 20	8 pm - 9 pm	Shoulder	1	-3	-19	-14	-13
Scenario 21	8 am - 9 am	Shoulder	-1	7	20	26	13
Scenario 22	5 pm - 6 pm	Shoulder	-4	-1	-7	-1	-16
Scenario 23	5 pm - 6 pm	2-Lanes	18	48	68	25	101
Scenario 24	7 pm - 8 pm	1-Lane	40	75	85	118	151
Scenario 25	8 pm - 9 pm	Shoulder	-4	-3	4	3	-2
Scenario 26	2 pm - 3 pm	Shoulder	5	-3	6	-2	-1
Scenario 27	2 pm - 3 pm	Shoulder	-4	-3	-3	4	3
Scenario 28	11 am - 12 pm	Shoulder	2	5	0	-5	0
Scenario 29	7 am - 8 am	Shoulder	-11	4	-17	1	1
Scenario 30	7 am - 8 am	Shoulder	-8	-5	-15	-14	25

As each result represents the average of an eight run sample, the no-assistance results and corresponding assistance results can be compared using statistical methods. Two sample t-tests were used to determine statistical significance. As the difference in means were relatively small with regards to the size of the raw data, only two scenarios presented statistically significant differences. However, three other scenarios presented differences that, while not statistically significant, may be considered important from a practical perspective, based on engineering judgment. Although such differences are not statistically different, they are large enough to dramatically influence the results of this study and must be considered.

Table 4-2 presents results of both statistical and practical significance. Of these five scenarios, only scenarios 13 and 24 were significantly different with regards to t-statistics. Scenarios 5, 7, and 23 contained results that were labeled as practically different. These 5 scenarios represent both 2-lane blocked simulations and three of the four 1-lane blocked simulations. It is not surprising to see that the more severe incidents were those in which ASAP presented a clear positive impact.

Table 4-2: Statistically Different and Practically Different Results

Incident Duration Reduction					
#	5min	10min	15min	20min	25min
Scenario 5	9	11	79	52	50
Scenario 7	27	21	33	68	39
Scenario 13	77	133	246	387	454
Scenario 23	18	48	68	25	101
Scenario 24	40	75	85	118	151

When considering all 30 scenarios as a whole, a clear trend emerges. The ASAP program created almost uniformly increasing delay reductions with increasing incident duration reductions. This trend is consistent from reducing delay by an average of 5.1 vehicle-hours for a 5-minute duration reduction up to 28.1 vehicle-hours for a 25-minute duration reduction. These data are graphically illustrated as Figure 4-1, in which a steady trend of increasing delay reduction as a function of increasing incident duration reduction can be observed.

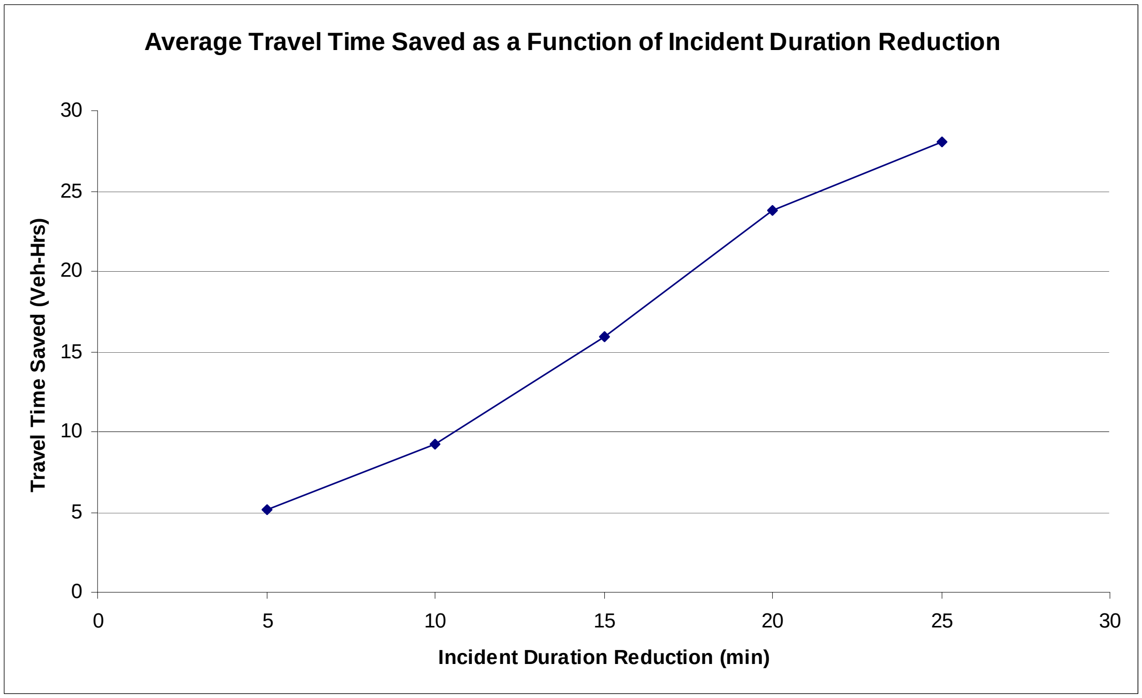

Figure 4-1: Average Travel Time Saved as a Function of Incident Duration Reduction

Dollar benefit amounts were calculated through the cross-classification procedure discussed. The resultant travel time differences were multiplied by every combination of value for travel time and average vehicle occupancy. Averaging all 4,500 calculated dollar amounts reveals a range of $57.69 to $812.08 for a single assist, with an average program benefit of $319.93 for a single assist. Figure 3 depicts this average range of benefits calculated through the cross-classification procedure for each incident duration reduction. It is important to note that, as expected, the average mobility savings are all positive and increase with increasing duration reductions. Multiplication of the previously calculated range by 17,090 assists in the 2004-2005 year provides a total yearly benefit range of approximately $985,900 to $13,878,400, with an average, or most likely value, of $5,467,600. The lower values of this range are associated with the low value for travel time and low vehicle occupancy. Conversely, the upper value of this range represents a larger value of travel time and higher vehicle occupancy.

CHAPTER 5: SAFETY BENEFITS

Safety benefits can be achieved by the A.S.A.P. program by reducing the occurrence of secondary crashes, that is, crashes that occur in the queuing upstream of an incident that has occurred. The presumption is that some of these secondary crashes would not occur because of the presence of the service patrol; the reduction in incident duration results in fewer opportunities for such crashes to occur. As noted in the literature review, not only is this effect less studied than the mobility benefit, but a lack of consensus on reduction values as well as what constitutes a secondary crash also is the case. These factors support the range-based approach to estimating the safety benefits of the A.S.A.P. program.

To estimate the safety benefits of the service patrol, the occurrence rate of secondary crashes and the reduction in their occurrence attributable to the service patrol must be estimated. To quantify these benefits economically, dollar values of the associated fatalities, injuries, and damage must be estimated. Regarding the secondary crash rate and reduction attributable to the A.S.A.P. program, a range of values for each was developed based on the findings of the literature review.

5.1 Secondary Crash Occurrence Rates

The traffic simulation modeling effort described in Chapter 3 did not simulate crashes; therefore, values to establish an estimated range of secondary crash rates to be used in the present study were based on those found in the literature review. As noted in that chapter of this report, a study of the service patrol in the Los Angeles area found a secondary crash rate of 1.5% to 3.0%, while secondary crash rates of between 6 and 10% were found in a study of two years of the service patrol in southeastern Wisconsin. Based on these studies, a range of values from 1.5% to 10% was deemed appropriate for this study.

5.2 Secondary Crash Reduction Rates

A study of the Hoosier Helper program in northwestern Indiana found a reduction in secondary crashes of 18% in the winter and 36% in all other seasons, which should be equivalent to approximately 22% throughout the year. More recently, a comprehensive study of the benefits of the service patrol in the Hudson Valley region of New York State found a range of reductions from 12% to 50%. To incorporate inherent uncertainties associated with estimating the reduction in secondary crashes due to the presence of the service patrol, the wider range of 12% to 50% is used in this study. Based on these values, a low-end estimate of the reduction of secondary crashes would be a reduction by 12% of the 1.5% of secondary crashes, yielding a potential avoidance rate of 0.18%. At the other extreme, using the values noted above, the service patrol could be said to reduce the 3.0% follow-on crash rate by 50%, resulting in an avoidance rate of 1.5%.

5.3 Estimation of Safety Benefits

The range-based approach taken to estimate benefits produces an estimate of secondary crash avoidance by a factor of 0.18% to 1.5% of the total number of incidents attended to by the A.S.A.P. program. For the 2004-2005 study period, this translates to a range of 32 to 256 crashes avoided. The approximate midpoint of this range (140) was taken as a most likely value. To convert the potential number of crashes avoided to an economic benefit, an estimate of the economic value associated with such crashes must be made. Much research has been done to develop such values. Organizations including the National Highway Traffic Safety Administration (NHTSA) and the National Safety Council have conducted such studies. Since an estimation of the values of hypothetical crashes avoided in Birmingham was beyond the scope of this study, the results of broad, national-level studies are used in the current study.

In 2002, NHTSA released the report entitled, "The Economic Impact of Motor Vehicle crashes 2000" (Blincoe et al., 2002). This comprehensive study analyzed the lifetime costs associated with fatal, injury, and property damage crashes. National average values were generated to address direct fatality and injury-related effects such as medical costs, insurance administration, market and household productivity loss and legal costs, as well as non-injury components of travel delay and property damage. Nationally, the average distribution of crashes across the three broad categories of fatal, injury, and property damage only crashes is approximately 1% (fatal), 24% (injury) and 75% (PDO). This distribution was applied to the crash avoidance estimates. Finally, since the economic data were based on crashes in the year 2000, these values were brought forward to 2005 based on the commonly-used inflationary measure of consumer price index (CPI), developed by U.S. Bureau of Labor Statistics. From 2000 to 2005, the CPI increased by 13%.

The 2002 NHTSA report uses the Modified Abbreviated Injury Scale (MAIS) to sub-classify the 'Injury' crash type into six distinct groups to differentiate among injury levels and to classify an injury due to accidents for analysis and economic evaluation purposes (Blincoe et al., 2002). The MAIS injury categories are as follows:

MAIS 0: Uninjured
MAIS 1: Minor injury
MAIS 2: Moderate injury
MAIS 3: Serious injury
MAIS 4: Major/multiple
MAIS 5: Unsurvivable

PDO is used to describe those crashes in which nobody was injured in any manner. MAIS 5 represents an 'Unsurvivable' injury crash type which is different from the fatal crash type. The MAIS 5 describes a crash type in which the occupant or occupants of the vehicle have been critically injured due to the crash, but the crash would not have killed the occupant or occupants immediately, at the crash site. Fatal describes the crash type which resulted in immediate death of the occupant or occupants.

The unit cost of injuries as well as the number of crashes for the year 2000, were obtained from the NHTSA report. Though the report provided both reported and unreported crashes, it did not specify how the numbers of unreported crashes were obtained. Therefore, for the purpose of this study, only the crash numbers for reported crashes were used. The following procedure was developed to determine the single representative cost of injury across the MAIS. The number of injuries in each MAIS category were divided by the sum of injuries across all MAIS categories and then multiplied by their respective cost. For example, the total number of injuries occurring in year 2000 was 6,133,070, of which,MAIS 0 accounts for 2,002,667 injuries or 0.3265 of the total number of injuries. This percentage was multiplied by $1,962 (the cost of MAIS 0 in year 2000) to arrive at the weighted average cost of $640.66 for MAIS 0. This was done for each category and the resulting values were summed to obtain a weighted average cost, representative of the cost of an injury crash type. These calculations are shown in Table 5-1.

Table 5-1: Cost of Representative Injury Crash

Injury Scale	Crash Cost in year 2000 ($)	#Reported Injuries in year 2000	Weighted average Crash cost per MAIS category ($)
MAIS 0	1,962	2,002,667	640.66
MAIS 1	10,562	3,599,995	6,199.69
MAIS 2	66,820	366,987	3,998.34
MAIS 3	186,097	117,694	3,571.21
MAIS 4	348,133	36,264	2,058.46
MAIS 5	1,096,161	9,463	1,691.32
	Total	6,133,070	**18,160**

The average injury crash cost of $18,160 was brought forward from 2000 to 2005 using the 13% inflation factor based on the CPI, resulting in an average injury crash cost of $20,520 in 2005. The value for a PDO crash in the year 2000 was $2,532, which corresponds to $2,860 in 2005 dollars. Similarly, the value of $977,200 for a fatal crash in 2000 was brought forward to a value of $1,104,200 in 2005.

The crash costs noted above were then applied to the national general crash type distribution (1% fatal, 24% injury, 75% PDO) to create a weighted value of $18,112 per crash across all crash types. The final step to obtain an estimated crash cost savings due to the A.S.A.P. program is to apply this weighted value to the estimated number of crashes avoided. The low end estimate (for 32 crashes) comes to $579,600; the high end estimate (for 256 crashes) is $4,636,600, and the most likely value (for 140 crashes) is $2,535,700.

CHAPTER 6: ENVIRONMENTAL BENEFITS

Another key benefit of the A.S.A.P. program is the reduction in emissions resulting from quicker incident clearance and the corresponding reduction in travel delay and time spent idling. A detailed analysis of this benefit is warranted since the original source of funding for the program was through the federal funding category Congestion Mitigation and Air Quality (CMAQ), a category first made available in the Intermodal Surface Transportation Efficiency Act of 1991 for the purpose of sponsoring transportation programs that improve air quality. This chapter includes an explanation of the air quality related benefits provided by A.S.A.P. and how these benefits are determined. This includes reporting the emission outputs from CORSIM simulation runs, computing the dollar value for the possible emission reductions, and describing the future use of the air quality benefits for calculating an overall benefit-cost ratio. In brief, for each incident scenario developed in the traffic simulation modeling described in Chapter 3, the difference was calculated between networkwide emissions of HC, CO, NO_x for the cases "with ASAP assistance" and "without ASAP assistance". An average difference was calculated from all 30 scenarios. This average difference in networkwide emissions for the two cases was considered as an average emission reduction per incident (separate for each pollutant) and used in the calculation of the economic value of the air quality benefits. The following sections explain the detailed analysis of emission outputs and assumptions made while calculating the benefits.

6.1 Traffic Simulation Outputs

When a CORSIM simulation model is run, the program creates both networkwide and link specific outputs. Link specific outputs reveal only the events that happened on that certain link and nowhere else. Link emissions rates were also observed to find out the possible benefits of emission reduction on an incident link and its nearby links. For each pollutant, CORSIM provides emission outputs in grams per mile for each vehicle type separately. Table 6-1 shows the percentage of the different types of vehicles in the network used for analysis.

Table 6-1: Vehicle Types Used in the CORSIM Network

	Fleet					
	Auto - 85%		**Trucks - 15%**			
Vehicle Types	1	2	3	4	5	6
% in Fleet	25%	75%	31%	36%	24%	9%

To calculate the networkwide benefits, the value of emissions reduction in grams or kilograms was needed. The detailed procedure adopted to calculate grams or kilograms reduction for each of the pollutants' emission is explained in the next section.

6.2 Vehicle Emissions Estimation

First, the average rate of emissions for HC, CO, NO_x (for each vehicle type) in grams/mile was calculated from the results of five multiple runs of both 'with ASAP' and 'without ASAP' case for each incident scenario. Similarly, average VMT was calculated for each scenario and for both cases. The miles traversed by each vehicle type during the simulation were then calculated by multiplying the percentage of that particular vehicle type in the network by total VMT. The grams or kilograms of emissions of the each pollutant for each scenario were found by multiplying the VMT of each the vehicle type by the respective average emission rate. Table 6-2 shows the method adopted for calculating the total emissions for each vehicle type. Then the emissions of each vehicle type were summed to get the networkwide emissions for each pollutant.

Table 6-2: Method for Calculating Vehicle Emissions for Each Vehicle Type

Fleet	Vehicle Type	Percentages in Fleet (CORSIM)	Vehicle miles traveled by vehicle type	Emissions
Auto (85% of total volume as used in the ASAP network)	1	25%	= Total VMT × 85 % × 25 %	= VMT for type 1 × Average Emission rate for Pollutant (grams/mile)
	2	75%	= Total VMT × 85% × 75%	= VMT for type 2 × Average Emission rate for each Pollutant (grams/mile)
Trucks (15% of total volume as used in the ASAP network)	3	31%	= Total VMT × 15% × 31%	= VMT for type 3 × Average Emission rate for each Pollutant (grams/mile)
	4	36%	= Total VMT × 15% × 36%	= VMT for type 4 × Average Emission rate for each Pollutant (grams/mile)
	5	24%	= Total VMT × 15% × 24%	= VMT for type 5 × Average Emission rate for each Pollutant (grams/mile)
	6	9%	= Total VMT × 15% × 9%	= VMT for type 6 × Average Emission rate for each Pollutant (grams/mile)

6.3 Estimation of Average Emission Reduction per Incident

With the above explained procedure the network emissions (grams) were calculated for ‘with ASAP case’ and ‘without ASAP case’ for each of the 30 incident scenarios. To determine the benefits from ASAP, total emissions of ‘with ASAP’ was subtracted from total emissions of ‘without ASAP’. This difference was calculated for each of the pollutants separately. This resulted in the 30 values of emission reductions for each of the pollutants. The average value was then calculated for these 30 observations. This was considered as an average emission reduction per incident and used in the calculation of the dollar value of the air quality benefits from ASAP. Table 6-3 shows the calculation of the average emission reduction for each of the pollutants, i.e., for HC, CO, NO_x separately.

Table 6-3: Calculations of Average Emissions Reduction Per Incident

	HC				CO				NO_X			
Scenario	**W/o ASAP**	**W/ ASAP**	**Difference**		**W/o ASAP**	**W/ ASAP**	**Difference**		**W/o ASAP**	**W/ ASAP**	**Difference**	
	Grams	Grams	Grams	Kg	Grams	Grams	Grams	Kg	Grams	Grams	Grams	Kg
1	1496818.1	1495024.1	1793.9	1.79	33502605.3	33460440.4	42164.8	42.16	4103055.6	4101933	1122.7	1.12
2	1704387.0	1705361.3	-974.2	-0.97	39229120.4	39203158.0	25962.3	25.96	4599314.3	4595101	4213.0	4.21
3	1700500.1	1701604.0	-1103.7	-1.10	39007120.6	39014148.8	-7028.2	-7.03	4584988.0	4582304	2683.7	2.68
4	1595797.5	1595947.9	-150.2	-0.15	36477490.5	36466731.2	10759.3	10.76	4325672.1	4326506	-833.6	-0.83
5	1963255.6	1961930.4	1325.2	1.32	44817396.8	44830691.9	-13295.1	-13.30	5326592.1	5324510	2081.7	2.08
6	1192985.4	1192497.2	488.2	0.49	26220772.8	26202335.0	18437.7	18.44	3279877.3	3277926	1950.9	1.95
7	2191536.6	2189559.2	1977.4	1.98	50137284.5	50098553.5	38730.9	38.73	5879072.3	5872981	6091.5	6.09
8	1705297.9	1704947.2	350.7	0.35	39112922.0	39119894.3	-6972.2	-6.97	4594930.1	4593691	1239.2	1.24
9	657237.8	658169.8	-931.9	-0.93	13609791.8	13631356.2	-21564.4	-21.56	1837898.7	1839634	-1735.5	-1.74
10	1313450.8	1306401.2	7049.6	7.05	29226417.1	29062647.8	163769.3	163.77	3597297.6	3578559	18738.7	18.74
11	1189118.1	1189226.0	-107.8	-0.11	26138436.2	26137001.7	1434.4	1.43	3270240.9	3269333	908.0	0.91
12	1262781.8	1263512.8	-730.9	-0.73	28069438.3	28079964.5	-10526.2	-10.53	3474988.8	3477024	-2034.9	-2.04
13	1496443.0	1498691.2	-2248.2	-2.25	32904259.5	32944753.0	-40493.6	-40.49	4114217.1	4119042	-4824.9	-4.83
14	1303942.5	1304044.9	-102.3	-0.10	29020698.6	29025579.2	-4880.7	-4.88	3571849.3	3572938	-1088.4	-1.09
15	1302870.8	1299797.6	3073.1	3.07	28978368.0	28940002.0	38365.9	38.37	3569987.7	3566336	3651.8	3.65
16	954089.3	952738.0	1351.3	1.35	20428382.5	20405586.2	22796.2	22.80	2644150.2	2641068	3081.8	3.08
17	658417.3	656415.4	2001.9	2.00	13642316.8	13591810.4	50506.3	50.51	1841402.8	1835317	6086.2	6.09
18	1430594.0	1428671.6	1922.4	1.92	32381018.3	32332242.0	48776.2	48.78	3909503.9	3904954	4549.9	4.55
19	1196075.6	1195437.5	638.1	0.64	26287012.7	26270395.1	16617.5	16.62	3286450.5	3285953	497.4	0.50
20	769961.1	770309.7	-348.6	-0.35	16132406.8	16153390.7	-20983.8	-20.98	2143324.9	2144054	-729.0	-0.73
21	1327259.9	1325908.1	1351.8	1.35	29706905.7	29679792.6	27113.0	27.11	3639461.7	3636496	2966.0	2.97
22	1741440.1	1737665.6	3774.5	3.78	39958120.3	39830037.7	128082.6	128.08	4682881.3	4670139	12742.1	12.74
23	2192581.5	2188664.4	3917.1	3.92	50241379.0	50062584.7	178794.3	178.79	5886630.9	5869865	16765.5	16.77
24	1192413.9	1189665.7	2748.3	2.75	25556381.6	25478599.3	77782.2	77.78	3305084.8	3296918	8166.4	8.17
25	769174.2	768293.4	880.8	0.88	16131126.3	16108971.1	22155.0	22.16	2140335.6	2137930	2405.5	2.41
26	1436018.1	1434706.4	1311.7	1.31	32552343.2	32482083.3	70259.9	70.26	3922121.1	3919092	3028.7	3.03
27	1432985.3	1430682.9	2302.4	2.30	32496935.0	32420211.5	76723.4	76.72	3919074.4	3913848	5226.9	5.23
28	1266121.4	1265022.3	1099.1	1.10	28161196.0	28124621.5	36574.4	36.57	3483635.8	3481182	2453.52	2.45
29	1575542.4	1573514.6	2027.8	2.03	36001900.6	35939055.8	62844.8	62.84	4274842.6	4271034	3808.4	3.81
30	1568442.3	1566764.0	1678.3	1.68	35798701.9	35755529.7	43172.1	43.17	4257825.1	4250062	7763.1	7.76
	Average Difference per Incident			1.21	Average Difference per Incident			35.87	Average Difference per Incident			3.70

6.4 Estimation of Air Quality Benefits

The calculated emission reductions per incident were considered as an average value for the whole network and represented an average value of an emission reduction for all types of incidents considered across the 17,090 incidents that were recorded for A.S.A.P. for the study period. The value of saved emissions was determined from average industry standards for this type of evaluation (Stamatiadis et al., 1997; Skabardonis et al., 1998). Table 6-4 shows the dollar values for HC, CO and NO_x saved.

Table 6-4: Dollar Value of Emission Reduction

Pollutant	Dollar value of emission reduction
HC	$ 0.23 per Kg
CO	$ 0.02 per Kg
NO_x	$ 0.76 per Kg

Based on the above values and calculated emissions saved per incident, the benefits (economic value) are shown in Table 6-5. The total reduction in HC, CO and NO_x was calculated by multiplying the number of incidents per year by emissions saved per incident (kg/incident). Then the total kilograms of HC, CO, NO_x saved were multiplied by the dollar value per kg of HC, CO and NO_x respectively. Then the total dollar value of benefits was calculated by adding the benefits of each of the pollutants considered.

Table 6-5: Calculation Table for Dollar Value of Total Emissions Saved per Year

	Kg/incident	Kg/year	Dollars/kg	Total Dollar Value
HC	1.212	20,716.	$0.23	$4,764.85
CO	35.87	613,006	$0.02	$12,260.13
NO_x	3.70	63,219	$0.76	$48,047.12
				$65,072.09

Therefore, the average, or best-estimate, benefits of \$65,072 for HC, CO, and NO_x emissions were saved during the July 2004 through June 2005. This represents only one year and may underestimate the air quality benefits of the A.S.A.P. program. If the number of A.S.A.P.-assisted incidents were to increase annually, benefits will also increase.

CHAPTER 7: CUSTOMER SERVICE BENEFITS

Perhaps the most tangible category of benefits that can be provided through a freeway service patrol is those directly received by the motorists. The services provided to motorist – free of charge – are actual savings to the motorist who may have had to pay someone for those services to be delivered. In spite of this obvious value of programs such as A.S.A.P., this category of benefits has not been as well-studied over the years as have the mobility and environmental benefits. The literature review uncovered two such studies performed in evaluations of programs in the Houston and Atlanta areas, and an additional study associated with emergency call boxes in the Columbus Georgia area. In the call boxes study, values were assigned to the service ultimately provided by the state in response calls placed. The values assigned to the services provided in each of these three studies were considered in the process of establishing values for the services provided by the A.S.A.P. program. Further detail on these studies can be found in the review of the literature in Chapter 2 of this report.

The service categories outlined in prior studies were mapped to the types of assist provided by A.S.A.P. Using the consumer price index as determined by the U.S. Bureau of Labor Statistics, the values for each of these services were brought forward from the time period considered in each study to the year 2005 for compatibility. The manner in which this was done is similar to that described in Chapter 5 regarding the economic value of crashes. From the study of the Houston program, the value for each service provided was obtained along with the distribution of service categories. In that study, only seven categories of services were identified. For the current study, a weighted average of $33.49 per assist (in 1992 dollars) of the value of services rendered in Houston was determined. This amount was then brought forward to 2005 dollars at $44.60. A similar process was applied to the services values from the Columbus program, yielding a weighted average of $26.93 in 1999, which corresponds to $30.60 in 2005. Finally, data from the Atlanta study – perhaps the most similar to the current study with respect to proximity, size of the area, and time period covered – were analyzed. This study, covering the year 2005, reported an average benefit value of $60.25.

Based on these three studies, a range of values from $30 to $60 per assist was deemed appropriate, with the midpoint of $45 assumed to be the most likely value. When applied to across the 17,090 assists recorded by A.S.A.P. during the study year, the low-end estimate for the economic value of customer service benefits becomes $512,700, the high-end estimate is $1,025,400, and the most likely value is $769,050.

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

The Alabama Service and Assistance Patrol (A.S.A.P.) is a freeway service patrol operated by the Alabama Department of Transportation in the Birmingham area. This study provides an economic evaluation of the program using assist and program cost data provided by ALDOT for the twelve-month period July 2004 through June 2005. In the preceding chapters of this report, after a review of the literature and summary of the traffic simulation model, estimated values of benefits were provided for each category studied: mobility, safety, environmental, and customer service. Mobility benefits consist of the value of travel time saved due to the operations of the A.S.A.P. program, safety benefits are those associated with secondary crashes avoided through the operations of the program, environmental benefits are those attributable to reduced emissions, and the value of services directly provided to motorists through the program constitute the customer service benefits.

Due to the assumptions that needed to be made to establish values of these categories, a range of benefits, rather than a single value, was reported, except for the environmental benefits. Since the environmental benefits were based directly on the simulation model and assumptions did not need to be made about socioeconomic values, a single value was reported. These values are summarized in Table 8-1.

Table 8-1: Summary of Benefits

Benefits Category	High Estimate	Low Estimate	Most Likely
Mobility	$ 13,878,400	$ 985,900	$ 5,467,600
Safety	$ 4,636,600	$ 579,600	$ 2,535,700
Environmental	$ 65,000	$ 65,000	$ 65,000
Customer Service	$ 1,025,400	$ 512,700	$ 769,000
Total Benefits	$ 19,540,400	$ 2,078,200	$ 8,837,300

The total benefits shown in Table 8-1 were then divided by the program cost of $593,000 for the study period to determine a range of benefit-cost ratios. The most likely value for the benefit-cost ratio is approximately 14.9 ($8,837,300 divided by $593,000). The high-end estimate is 33.0 and the low-end estimate 3.5. Therefore, even when using the most conservative estimate of benefits provided for in this analysis, the benefits of the A.S.A.P. program still outweigh the costs by a factor of about 3.5. These values are in line with the range of values noted in the review of the literature on the benefits of service patrol programs.

Based on the findings of this study, it can be recommended that the A.S.A.P. program continue to be fully supported. Consideration should also be given to potential areas for service expansion. General guidance would be to consider sections of freeway on which volumes exceed 1500 vehicles per hour per lane during the potential hours of operation of the patrol on segments considered. Other factors to consider in delineation of expansion areas include, but are not limited to, segments of freeway on which the mean speed of traffic during peak periods drops substantially below the mean speed during low-volume conditions and the crash rate per length of roadway as well as per vehicle-miles of travel of candidate segments. A detailed analysis of such locations merits additional study.

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