

Use of Operation Data to Evaluate the Benefits and Costs of advanced Traffic Management Components



Florida Department of Transportation District Four
and Florida International University

Use of Operation Data to Evaluate the Benefits and Costs of Advanced Traffic Management Components

By:

Mohammed Hadi, Ph.D., P.E. (Corresponding Author)
Assistant Professor
Department of Civil and Environmental Engineering
Florida International University
10555 W. Flagler Street , EC 3605
Miami, FL 33174
Phone: 305-348-0092
Fax: (305) 348-2802
e-mail: hadim@fiu.edu

Luou Shen
Research Assistant
Florida International University

Chengjun Zhan, Ph.D.
Research Associate
Florida International University

Yan Xiao
Research Assistant
Florida International University

Steven Corbin
District ITS Operations Manager
Florida Department of Transportation District 4
2300 W. Commercial Blvd.
Fort Lauderdale, Florida 33309

Dong Chen
District ITS Program Manager
Florida Department of Transportation District 4
2300 W. Commercial Blvd.
Fort Lauderdale, Florida 33309

Word Count = 6,075 words + 5 tables = 7,325 words

A Paper Submitted for Publication at the Transportation Research Record

November 12, 2007

ABSTRACT

Economic measures are important to allow traffic management agencies to select between investment and operation alternatives based on the benefits and costs of these alternatives. However, previous studies have either evaluated the benefits and costs of the management systems as a whole, without considering their individual components, or focused on the evaluation of the service patrol programs.

This study illustrates the use of a detailed Intelligent Transportation Systems (ITS) operation dataset in the evaluation of the economic effectiveness of the individual components of traffic management programs. The analyzed components include the service patrol program, Closed Circuit Television (CCTV) camera subsystem, Dynamic Message Sign/Advanced Traveler Information (DMS/ATIS) subsystem, and the Severe Incident Response Vehicle (SIRV) program. The results showed that for the evaluated system, the SIRV program provides the highest benefit-cost ratio, followed by the CCTV camera subsystem and service patrol program, followed by DMS/ATIS deployments.

This paper also discusses the use of the methods and parameters identified in the study to allow better pre-deployment assessments of incident management systems by transportation agencies. The methods and parameters were used as part of a sketch planning tool that was integrated as part of a demand forecasting modeling environment.

KEY WORDS: Intelligent Transportation Systems, Incident Management, Advanced Traffic Management, Economic Analysis, Benefit-Cost Ratio.

INTRODUCTION

Advanced traffic management systems (ATMS) have been implemented successfully in metropolitan areas around the United States. The main services provided and/or supported by most existing freeway ATMS agencies are incident management and the dissemination of information to travelers.

ATMS agencies have identified performance measurement and analysis as a high priority task for their programs. One type of these measures is economic measures that reflect the effectiveness of the evaluated systems from a financial point of view. Examples of economic measures are the benefit-cost ratio and present net worth in dollar values. These measures are important since they can provide an answer to the question: "For each dollar that we have invested in traffic management agency operation, how much are we getting back in terms of dollar values?" Most of the studies available in the literature have either evaluated the benefits and costs of the incident management system as a whole or focused on the evaluation of the service patrol programs. The literature review performed in this study did not identify previous studies that evaluated the benefits and costs of the individual incident management system components relative to each other. This is in part due to the difficulty in isolating the benefits and costs of individual components. However, in many cases, the decision makers and stakeholders of incident management systems have emphasized the needs to separate the benefits of individual system components to justify the investment in these components. The availability of detailed incident operation data from traffic management centers will make it somewhat easier to identify the benefits and costs of at least some of the individual incident management components, particularly in regions where the different components were implemented at different times, as is the case in Fort Lauderdale, FL.

This paper presents the results of an analysis that was performed to assess the components of Florida Department of Transportation (FDOT) District 4 ATMS in Fort Lauderdale, FL, referred to as the SMART SunGuide system (2). The components evaluated in this study include the service patrol program, Closed Circuit Television (CCTV) camera subsystem, Severe Incident Response Vehicle (SIRV) program, and Dynamic Message Signs (DMS) subsystem. The study makes use of a detailed incident management database maintained by the FDOT District 4. This paper also discusses the use of the methods and parameters identified in the study to allow better pre-deployment assessments of incident management systems by transportation agencies.

PREVIOUS STUDIES

A number of studies have been conducted to measure the economic effectiveness of ATMS agency operations (3, 4). Most of the existing benefit-cost analysis of ATMS agency operations has concentrated on the service patrol program. A 1998 review indicated that the reported benefit-cost ratios of service patrol programs from around the region ranged from 2:1 reported in Norfolk, VA, to 36.1:1 reported in Dallas, TX (5). More recent evaluations have included the benefit-cost analysis of the Los Angeles service patrol program, which estimates a benefit-cost ratio of 5.9:1 (6) and the Incident Management Assistance Patrols (IMAP) program in Raleigh, North Carolina, which shows a ratio of 4.3:1 (7). Other studies have evaluated the overall ATMS agency deployments and operations, rather than individual components. As an example,

a recent evaluation of the NaviGator system in Atlanta, GA, shows an overall ATMS benefit-cost ratio of 4.4:1 (8).

SMART SUNGUIDE OPERATIONS

The FDOT Intelligent Transportation Systems (ITS) deployments in Fort Lauderdale, FL, are managed from the Systems Management for Advanced Roadway Technologies (SMART) SunGuide Traffic Management Center (TMC). The FDOT ITS deployments cover the three major limited access facilities in the area, which include I-95 (25.3 miles), I-75 (19.6 miles), and I-595 (12.9 miles). The major components currently managed by the SMART SunGuide TMC are a CCTV camera subsystem, a service patrol program, a SIRV program, a DMS subsystem, and a traffic incident management team that coordinates incident management activities.

The CCTV cameras have been installed at one-mile intervals on the I-95 corridor. The installation of the CCTV cameras on the other two corridors (I-75 and I-595) will be complete by the year 2008. Detectors (true presence microwave radars) are also being installed at a one-half mile interval on the three managed corridors. However, they were not operational during the analysis period. It should be mentioned that FDOT D4 utilizes the CCTV cameras, not only for incident verification, but also to support incident detection by training operators to monitor the camera images displayed on the video wall to help detecting incidents.

The FDOT operates DMS on the I-95 and I-595 corridors with additional signs planned for the I-75 corridor. In addition, it operates a traveler information web site and contributes to the funding of a regional Advanced Traveler Information System (ATIS) that includes a 511 service and a regional traveler information web site.

The service patrol program provides free highway assistance services during incidents to reduce delay and improve safety for the motoring public and incident responders. The SIRV program includes one vehicle that responds to major incidents along the three managed corridors. The SIRV serves as an incident command station during incident, while the team assists responding agencies, coordinates maintenance of traffic (MOT) activities, and provides a liaison between responding agencies and FDOT resources.

All information gathered from the freeway incident management program of FDOT District 4 in Fort Lauderdale, FL, is stored in a comprehensive database called the SMART SunGuide database. The database was developed based on a comprehensive requirement analysis to include a large set of data attributes allowing detailed incident analysis. These attributes include timestamps of the activities for all agencies involved, the tracking of lane and shoulder closures and clearances, incident location information, incident environmental conditions, incident type and severity, number and types of involved vehicles, and so on. Performance measures are assessed based on the database.

METHODOLOGY

The benefits of the SMART SunGuide TMC operations were assessed utilizing analytical procedures based on the data stored in the SMART SunGuide database and information gathered

from previous studies. The benefits of the SMART SunGuide ATMS are expected to result from two main sources:

- reductions in incident durations, and
- changes in travel behaviors due to the dissemination of information to travelers.

The reductions in incident durations and the changes in driver behaviors (mainly route diversion) are expected to significantly influence various operational performance measures. Some of these measures can be quantified in dollar values and thus can be considered in the “benefit-cost” analysis performed in this study. The measures that were included in the benefit-cost analysis of this study are:

- reduction in travel time/delays to motorists,
- reduction in secondary accidents,
- decrease in fatalities due to the reduction in the average time interval between incident occurrences and the provisions of medical care to injured travelers,
- reduction in fuel consumption,
- reduction in emission rates, and
- monetary benefits to motorists as a result of the free-of-charge services provided by the service patrol operators.

The analysis was initially developed in a spreadsheet environment. However, the procedure was later incorporated as part of the central software used at the SMART SunGuide TMC, to automate the benefit-cost calculations. A summary of the applied method is discussed below.

Estimation of Incident Management Delay Saving

Ideally, the savings in incident delays due to incident management strategies should be measured in the field using travel time/delay data that are collected before and after the implementation of these strategies. However; the collection of this data is difficult and expensive unless traffic detectors are available to measure incident delays. A large proportion of traffic management systems on freeways include or will include traffic detectors that allow the measurements of incident delays with incident management strategies. However, since these detectors are generally not deployed before the implementation of incident management strategies, the incident delays without these strategies are not available in most cases.

One of three methods was considered to estimate the savings in incident delays based on the reduction in incident duration, in the absence of field measurements of the reductions in delay. These three methods are queuing theory, shockwave, and simulation analyses. Traffic simulation analysis is a powerful method to estimate the benefits of traffic and incident management (9, 10). However, the use of simulation models is expensive in terms of data collection requirements, model input preparation, calibration, and validation. When comparing queuing and shock wave analysis, queuing analysis has been more widely used to identify

incident benefits. Detailed discussions of deterministic queuing analysis and shockwave analysis can be found in traffic flow theory text books (11, 12). A paper by Rakha and Zhang (13) demonstrated the consistency in delay estimates that are derived from deterministic queuing theory and shock-wave analyses. Thus, it was concluded that queuing theory provides a simple and accurate technique for estimating delays at highway bottlenecks. Considering this, the approach used in this study utilized deterministic queuing analyses to calculate incident delays with and without incident management.

The following equation was used to estimate the incident total delay TD in vehicle-hours per an incident of a given severity (in terms of lane blockage and duration) in veh-hr:

$$TD = \frac{t_R t_Q (\lambda - \mu_R)}{2} \quad (1)$$

Where:

λ = mean demand (arrival) rate in veh/hr,

μ = mean capacity (service) rate in veh/hr under prevailing (no incident) conditions,

μ_r = mean capacity during the incident lane or shoulder blockage under consideration (μ_r) in veh/hr, and

t_R = incident duration (t_R) in hours with and without incident management strategies in minutes, and

t_Q = the time duration in queue. t_Q in hours is calculated as follows:

$$t_Q = \frac{t_R (\mu - \mu_R)}{\mu - \lambda} \quad (2)$$

The calculation of incident delay was done for each managed freeway segment and for seven periods during the week (five periods during the weekdays and two periods during the weekends). A freeway segment was defined as the link that connects two adjacent interchanges in one direction of travel. The total benefits were obtained as the sum of the benefits over all managed freeway segments.

Estimation of Fuel Consumption and Emission

The reductions in fuel consumption and emission rates due to incident management strategies were calculated using the relationships between speed and the fuel consumption and emissions of different pollutants that were incorporated as part of the ITS Deployment Analysis System (IDAS) sketch planning tool (14). The used relationships estimate the quantity of the pollutants resulting from transportation systems including Hydrocarbon (HC) and reactive organic gases (ROG), Carbon Monoxide (CO), and Nitrogen Oxides (NO_x).

To estimate the emission and fuel consumption benefits for each freeway segment using the above mentioned relationships, it was necessary to estimate the average travel speed for each segment of the three managed corridors and for the seven time periods. Under the no incident scenarios, the speeds were calculated using the relationship between speed and volume/capacity

(v/c) ratios, calibrated for the traffic demand forecasting models in the region. With incidents conditions, the travel speeds were calculated for a given incident scenario as follows:

- The average queue length was calculated using the queuing theory equations.

$$\text{Average queue length, } Q_A \text{ (Vehicles)} = 0.5 t_R (\lambda - \mu_R) \quad (3)$$

- The average queue length as produced by the queuing theory equations was in the unit of vehicles. This number was converted from vehicles to feet based on assumed vehicle distance headway.
- The average travel speed within the queue was assumed to be 2.5 mph and outside the queue was estimated using the relationship between the speed and v/c ratio calibrated for the region.

Using the above assumption, it was possible to calculate the speeds for different segments of the corridor, with and without incident conditions, which was then used in the estimation of fuel consumption and emission benefits.

Estimation of Safety Benefits

The considered safety benefits included the reductions in fatalities and in the number of secondary crashes. These benefits were estimated by calculating the annual frequencies of fatal, injury, and property damaged only (PDO) crashes with no ATMS strategies using the crash rates estimated for Florida conditions in Reference 15. The used rates were 0.086 for fatal crashes, 0.6913 for injury crashes, and 0.9338 for PDO crashes.

A review of previous studies by Mitertek Systems indicates that incident management can reduce accidents by 2.8% based on crash analysis in San Antonio, Texas (16). In this study, a 2.8% crash reduction factor was used to quantify the impacts of traffic management strategies on the number of fatal, injury, and PDO crashes.

Additionally, it is expected that the fatality rate will decrease due to faster health care provided to injured travelers. Based on a review of previous studies, IDAS (14) assumes that detection/verification systems and incident response/management systems individually reduce the freeway fatality rate by 10% and when combined reduce the fatality rate by 21%. In this study, a conservative fatality reduction factor of 10% was used.

Monetary Benefits of Road Ranger Services

One of the significant benefits of the service patrol is the monetary benefits of the provided assistance to Florida Highway Patrol (FHP) and to stranded motorists. Service patrol trucks provide many services to the FHP and motorists free-of-charge. Examples of these services are tire changes, gas and water provision, assisting FHP in MOT during incidents, minor repairs, and jump-starts. If motorists or the FHP decide to call a private towing/automobile service company, they will be responsible for any incurred charges.

In this study, the costs per service for service patrol assistance were estimated based on costs charged by private automobile service/towing companies, as listed below:

- Tow cost: \$97 per mile including three free miles and \$3 per extra miles. \$24 extra is charged for every 15 minutes of service time.

- Flat rate: \$35 per service call.
- MOT rate: \$750 per call with \$125 extra for every hour on the scene. The extra charge is per vehicle. Each lane blockage requires one service vehicle for MOT.

Based on these estimates, the cost for each type of Road Ranger service was calculated, as shown in Table 1. These costs were then used in the following formula to obtain the total annual benefit of these services.

$$SAB = \sum_i (SC_i \times F_i) \quad (4)$$

Where:

SAB = Total annual benefits of provided services in dollar;

SC_i = The cost charged by private companies for providing one service of type i ;

F_i = The annual frequency of service type i , obtained from the SMART SunGuide database.

TABLE 1 Monetary Benefits of Road Ranger Service Patrol

Service Provided	Contributors to Cost	Unit Cost
Abandoned	Tow	\$98.43
Assist FHP	MOT	\$854.12
Debris	Flat rate	\$35.00
Diesel	Flat rate plus fuel cost	\$38.00
Flat Tire	Flat rate	\$35.00
Gas	Flat rate plus fuel cost	\$38.00
Jump	Flat rate	\$35.00
Lock Out	Flat rate	\$35.00
Minor Repair	Flat rate	\$35.00
MOT Non-specific	Flat rate	\$799.31
No Assistance	Flat rate plus oil cost	\$0.00
Oil	Flat rate	\$38.00
Phone	Flat rate	\$35.00
Push	Tow	\$35.00
Tow	None	\$101.15
Translate	Tow	\$0.00
Transport	Flat rate	\$100.03
Unsuccessful Repair	---	\$35.00
Water	Flat rate	\$35.00
Other	Flat rate	\$35.00

Cost Estimation

Table 2 shows the cost estimated for the SMART SunGuide operation and maintenance. These costs were estimated based on a detailed dataset of these costs maintained by the FDOT District

4. One of the challenges that faced the study team was how to distribute the traffic management costs (those for software, hardware, personnel and coordination, etc.) among ITS deployments. Two approaches were considered to allocate the overhead cost. The first is the Relative-Budget-Activity (RBA) cost allocation which allocates the overhead cost according to the ratio of the component's budgeted activity in proportion to the total budgeted activities (17). The second is the Activity Based Cost Management (ABCM) method based on the processes performed within the organization which add cost and value to the products and services produced (18). Because of the difficulty in collecting data for the ABCM approach, it was decided to use the RBA method for allocating the overhead cost to different components. The cost of the fiber communication subsystem was divided between the CCTV and DMS system deployments.

TABLE 2 ITS Component Costs

Deployment		Estimated Capital Cost	Estimated Current Operation Cost	Estimated Maintenance Cost	Annualized Cost Before Overhead Cost Allocation	Allocated Overhead Cost	Annualized Cost
Overhead Cost	TMC	\$6,700,000	\$1,792,555	\$320,265	\$2,745,300	---	---
	Software	---	\$250,000	---	4250,000	---	---
	Consultant	---	\$400,000	---	\$400,000	---	---
	Coordination	---	\$200,000	---	\$200,000	---	---
Road Ranger		---	\$2,500,000	---	\$2,500,000	1,537,156	\$4,037,156
CCTV along I-95		\$6,545,642	---	\$254,000	\$1,043,645	797,784	\$1,841,429
DMS/ATIS		\$6,400,000	---	\$870,000	\$1,803,680	1,109,015	\$2,912,695
SIRV		---	\$500,000	---	\$500,000	307,431	\$807,431
Total		\$19,645,642	\$ 5,642,555	\$1,444,265	\$13,442,625	\$3,751,386	\$9,598,711

Dollar Values

To compare the benefits and costs of the SMART SunGuide deployments, it was necessary to convert the benefits to dollar values. The followings values were used in this conversion.

- The 2005 Urban Mobility Report (19) estimated the value of travel time delay at \$13.45 per hour of person travel and \$71.05 per hour of truck travel. This study uses these numbers and assumes that the average passenger vehicle occupancy rate is 1.2 occupants per vehicle to convert the vehicle-hour of delay to passenger-hour of delay.
- The fuel consumption cost was assumed to be \$2.0 per gallon.
- The dollar values used for emission rates were \$1,774, \$3,731, and \$3,889 per gallon, for the HC, NOx, and CO pollutants, respectively. These are the values used in the IDAS program (14).
- The monetary values of the safety benefits were assumed to be \$3,200,000 per fatal crash, \$74,730 per injury crash, and \$2,000 per PDO crash, based on the values used in Florida (15).

Benefits Due to Dynamic Message Signs

The method used to quantify the benefits due to DMS was an extension of the method used in the IDAS program (14). In IDAS, the benefits are estimated by multiplying traffic person-volume passing the message signs with the percent time that the signs are turned on, the percent of vehicles benefiting from DMS, and the average amount of time savings. The default values used in IDAS are 28% of vehicles passing the message sign can save time and an average time savings of 11 minutes per traveler.

It is expected that the number of vehicles benefiting from DMS and the amount of delay savings are functions of the congestion level in the network. However, only limited data are available to identify these functions. The additional average benefits due to DMS were assumed to vary between 5 minutes and 20 minutes per diverted traveler, depending on the number of lanes blocked and the period of the day.

To estimate the annual benefits, it was necessary to estimate the number of DMS activations per year. The SMART SunGuide software includes a field that indicates if the DMS system is activated for a particular incident. Based on this information, the total number of annual DMS activation for the year 2006 was estimated to be 2,406. It was found that this number is very close to the number of lane blockage incidents. This was not surprising since the FDOT policy is to disseminate incident information on DMS signs only in the case of lane blockage incidents.

ANALYSIS INPUTS

The analysis described in the previous section requires a number of input parameters including the mean demand (arrival) rate in veh/hr, mean capacity (service) rate in veh/hr under prevailing (no incident) conditions, incident frequencies, and incident durations with and without incident management strategies. Below is a description of how these parameters were estimated in this study.

Demands and Capacities

The traffic demands were estimated for all highway segments using the Florida Traffic Information (FTI) database. The average annual daily traffic (AADT) and the number of lanes for each highway segment were obtained from the database. To estimate the demands during different time periods of the day, the hourly variations in demand was obtained based on data collected by permanent traffic count stations located at several corridor locations. By identifying the percentage of daily demands that occur in each time period of the day, it was possible to identify the demands for the AM, PM, midday, evening, late-night, weekend night, and weekend day periods for each segment based on the AADT values. The capacity for each highway segment during no-incident conditions was estimated using the Highway Capacity Manual 2000 (HCM 2000) procedure based on free flow speed (20). The capacity during incident conditions was estimated by calculating the expected reduction in capacity as a function of the number of blocked lanes (or shoulder) and the number of lanes of the highway section under consideration. The HCM 2000 (20) provides estimates of these values.

Incident Durations

The average incident durations were estimated separately for lane blockage and non-lane blockage incidents. This was important due to the large difference in the incident durations between lane blocking and non-lane blocking incidents.

To be able to evaluate incident management benefits, it was necessary to estimate the incident duration for the base conditions (without ITS). This, however, was not possible based on the existing data since the earliest incident duration data available at the traffic management center was for the year 2004. In the year 2004, the service patrol program was operational. Thus, the incident duration for the year 2004 already includes the benefits from service patrol operations. To estimate incident durations without service patrol, it was necessary to increase the 2004 incident durations to account for the benefits from these operations. Khattak (21), based on a review of a number of studies, found that service patrol vehicles reduce incident response time by 19% to 77% and incident clearance time by 8 minutes. The ITSOAM sketch planning tool developed for the New York Department of Transportation (DOT) recommends the use of 35%-60% reduction in response time, 15-25% reduction in clearance time, and 5% reduction in detection time, when evaluating service patrol benefits (22). Based on the above, it was assumed that the service patrol decreases incident detection, verification, and response duration by 30% and incident clearance time by 15%. Table 4 shows the incident duration with service patrol, measured based on the analysis of the database, and for the base conditions (without ITS), estimated as described above.

The reduction in incident duration due to CCTV cameras was calculated based on the SMART SunGuide database. Most of the existing CCTV cameras on the managed corridors were installed on I-95 in 2006, as stated above. To determine the benefits of CCTV cameras; the average detection, verification and response time at locations without CCTV coverage was compared with other locations with no CCTV coverage. In addition, this time was compared for the same locations before and after installing the cameras. It was estimated that CCTV cameras can reduce the detection, verification, and response time by about 13% based on the data analysis.

To calculate the benefits of the SIRV program, all incidents that were flagged in the database as having SIRV incident responses were isolated and analyzed. It was determined that the average duration of these incidents is 86.6 minutes compared to an average of 50.3 minutes for all lane blockage incidents in the region and 40.1 minutes for shoulder blockage accidents. This reflects the severity of the incidents responded to by the SIRV. The SIRV benefits per incident response was estimated to be 9.3 minutes based on the results presented in a 2005 assessment of the FDOT District 4 SIRV program (23).

The reductions in incident durations due to various ATMS components, calculated as described above are incorporated in Table 3. Queuing theory was used to calculate the delay benefits of the Road Ranger, CCTV, and SIRV programs based on the values presented in Table 4. The safety benefits calculated for the whole system was distributed between the Road Ranger, CCTV, and SIRV programs in proportion to their total delay benefits.

TABLE 3 Incident Duration Parameters

Components	Duration Without ITS Component		Duration Reduction		Duration With ITS Component	
	Shoulder Blockage	Lane Blockage	Shoulder Blockage	Lane Blockage	Shoulder Blockage	Lane Blockage
Road Ranger	47.87 min	59.78 min	7.76 min	9.48 min	40.11 min	50.3 min
CCTV	---	59.78 min	---	7.41 min	---	52.15 min
SIRV	---	95.89 min	---	9.3 min	---	86.59 min

Incident Frequency

In addition to estimating the incident durations, it was necessary to estimate the number of incidents managed annually for each highway segment. For each direction d of the three highway corridors analyzed in this study (I-95, I-595, and I-75), the incident rate per vehicle-mile for each time period k for incident type i (IR_{cdki}) was calculated as follows:

$$IR_{cdki} = \frac{IN_{cdki}}{\sum_{cdki} (H_k \times V_{cdk} \times L_d)} \quad (5)$$

Where:

IN_{cdki} = Incident number for incident type i on corridor c and direction d for period k

V_{cdk} = Traffic demand for corridor c for direction d for time period k in vehicles

L_d = Length of corridor d in miles

H_k = Number of hours in time period k

Then, the incident number for incident type i on roadway segment j for time period k (IN_{ijk}) was calculated as follows:

$$IN_{ijk} = IR_{cdki} \times V_{jk} \times L_j \quad (6)$$

Where:

V_{jk} = Traffic demand for segment j time period k in vehicles

L_j = Length of segment j in miles

ANALYSIS RESULTS

The benefit-cost analysis was performed for the years 2005 and 2006. It was found that the lane blockage duration decreased by an average of 7.8 minutes between 2005 and 2006. The total number of incidents detected and managed by the TMC increased from 35,279 to 52,661 and the total number of lane blockage incidents managed by the TMC increased from 1,943 to 2,391. This translates to an increase in the benefit-cost ratio from 10.44 to 14.45. This improvement is attributed to the better management and coordination of incident events and the installation of CCTV cameras on the I-95 corridor.

Table 4 presents the results of the benefit-cost analysis for the year 2006. As can be seen from Table 4, the SIRV program had the highest benefit-cost ratio due to its contribution to the reduction in the durations of the most severe incidents. The dollar value of the annual SIRV

benefits (30.86 million) was about 46% of the dollar benefits of the service patrol. However, the SIRV cost was much lower, resulting in a higher benefit-cost ratio. The estimated benefit-cost ratio for the SIRV is 38.2 compared to 16.6 for the service patrol and 15.5 for the CCTV camera subsystem. It should be noted that the benefits reported in Table 4 for the CCTV cameras are for the I-95 corridor only, since this is the only corridor that had cameras in 2006. As shown in Table 4, the estimated benefit-cost ratio of the DMS/ATIS subsystem (4.25) based on the study assumption is lower than the other three components of ITS deployments evaluated in this study.

TABLE 4 Benefit Cost Analysis Results for the Year 2006

ITS	Fuel	Emission	Delay	Safety	Service Income	Total	Cost	Benefit/Cost
SIRV	\$1,456,274	\$244,144	\$24,371,065	\$4,787,702	---	\$30,859,185	\$807,431	38.22
RR	\$2,906,972	\$453,634	\$48,399,526	\$9,505,101	\$5,655,230	\$66,920,462	\$4,037,156	16.58
CCTV	\$1,365,819	\$242,560	\$22,512,623	\$4,429,520	---	\$28,550,522	\$1,841,429	15.50
ATIS	\$626,349	\$108,920	\$11,630,485	---	---	\$12,365,754	\$2,912,695	4.25
Total	\$6,355,415	\$1,049,258	\$106,913,698	\$18,722,323	---	\$138,695,923	\$9,598,711	14.45

SKETCH PLANNING TOOL IMPLEMENTATION

The previous sections of this paper present the methodology and parameters used in the evaluation of an existing incident management system. The methodology and parameters identified in this study can be used by transportation agencies to assess the potential benefits and costs of incident management system components prior to the deployments of these systems. However, if local values of some or all of the benefit and cost parameters are available, then these values should be used.

A number of sketch planning tools have been developed to support the pre-deployment evaluation of ITS alternatives. One of the most widely used tool is the ITS Deployment Analysis System (IDAS) (14). Despite the powerful modeling capabilities of IDAS, a number of issues are associated with its use to evaluate ITS alternatives. For example, IDAS includes internal models to estimate traffic demands that are different from the calibrated regional demand models. This results in inconsistencies in the evaluation and forecasting processes between IDAS and the regional models. In addition, IDAS evaluation methods were developed in the mid-1990s, when the ITS field was just few years old. Thus, some of these methods need to be updated to reflect what have been learned since the development of this tool. This section discusses the use of the methodology and parameters identified as described earlier in this paper, as part of a sketch planning tool that integrates calibrated regional traffic demand forecasting models with ITS evaluation methods.

Compared to the IDAS methodology, the methodology used in this study has a number of advantages when used to evaluate the benefits of incident management. First, the study methodology allows the user to examine the effect of factors such as incident frequency, duration, and lane blockage statistics. These parameters are built in the IDAS calculations and thus cannot be changed by the user. In addition, this study methodology accounts for the benefits of incident management on secondary incidents and for the monetary benefits of service patrols.

Furthermore, instead of using default reduction factors for emissions and fuel consumption due to incident management as is done in IDAS, the study methodology calculates the emission and fuel consumption with and without incident management based on the reduction in queues due to incident management, as described earlier in this paper. Unlike IDAS methodology, the methodology of this paper recognizes the relationship between information dissemination and incident management and assumes that the number of DMS activations equal to the number of lane blockage incidents. Finally, the diversion rates due to DMS messages are assumed to be a function of congestion levels which is not done in IDAS.

Table 5 presents a comparison of the results obtained using the IDAS and study methodologies when used to assess an incident management system on a freeway corridor. Both methodologies were integrated as part of the regional demand forecasting environment using the Cube software. When the IDAS cost parameters were used in the benefit-cost analysis, Table 5 indicates that the benefit/cost ratio (B/C) was much higher when using the IDAS benefit parameters (B/C equal 41.45) compared to the results when using the benefit parameters of this study (B/C equal 17.42). The B/C dropped to 6.65 when using both the cost and benefit parameters of this study. This B/C value is considered to be a more realistic value than that produce by the IDAS benefit and cost assessment methodology (41.45), based on comparison with previous study results.

TABLE 5 Benefit/Cost Analysis Results of an Incident Management System with Different Sketch Planning Methods

Methodology		IDAS Benefit Method with IDAS Cost Parameters	Study Benefit Method with IDAS Cost Parameters	Study Benefit Method Using Study Cost Parameters
Time Savings	AM Peak Period	\$3,343,679	\$2,612,416	\$2,612,416
	PM Peak Period	\$8,457,561	\$5,413,213	\$5,413,213
	Off-Peak Period	\$718,960	\$2,640,645	\$2,640,645
Safety	AM Peak Period	\$524,101	\$705,918	\$705,918
	PM Peak Period	\$805,034	\$1,089,279	\$1,089,279
	Off-Peak Period	\$2,730,392	\$3,602,225	\$3,602,225
Fuel Consumption	AM Peak Period	\$2,117,632	\$450,219	\$450,219
	PM Peak Period	\$3,200,878	\$972,167	\$972,167
	Off-Peak Period	\$12,212,194	\$295,539	\$295,539
Emissions (CO)	AM Peak Period	\$1,285,919	\$272,581	\$272,581
	PM Peak Period	\$1,970,600	\$588,561	\$588,561
	Off-Peak Period	\$6,737,625	\$181,450	\$181,450
Emissions (HC)	AM Peak Period	\$32,155	\$17,924	\$17,924
	PM Peak Period	\$49,356	\$38,597	\$38,597
	Off-Peak Period	\$167,779	\$11,968	\$11,968
Emissions (NOx)	AM Peak Period	\$75,946	0	0
	PM Peak Period	\$116,409	0	0
	Off-Peak Period	\$397,724	0	0
Total Annual Benefits		\$44,943,944	\$18,889,578	\$18,889,578
Capital Costs		\$114,439	\$114,439	\$1,087,663
O&M Costs		\$972,775	\$972,775	\$1,752,938
Total Annual Costs		\$1,084,214	\$1,084,214	\$2,840,601
Benefit/Cost Ratio		41.45	17.42	6.65

CONCLUSIONS

This study illustrates the use of incident management data to calculate the benefits and costs of ATMS agency operations and as a basis for developing tools for pre-deployment assessment of potential benefits of incident management systems. The availability of detailed and well maintained benefit and cost databases together with the fact that different components of the incident management systems were implemented at different times allowed the estimation of individual components of the incident management program. Based on the analysis of FDOT District 4 data, it appears that the SIRV program provides the highest benefit-cost ratio; followed by the service patrol program and CCTV camera subsystem, which produce comparable results; followed by the DMS/ATIS deployments.

Although the results presented in this paper are based on data from Florida, it can be used in the pre-deployment assessment of the potential benefits and costs of incident management in other regions. The methodology used in this study and the identified benefit and cost parameters identified in this study can be considered by transportation agencies when performing pre-deployment benefit-cost analyses of incident management systems, in the absence of local data. As an example of such applications, this paper presents the implementation of the methodology and parameters of this study as part of a sketch planning tool that was integrated with a traffic demand forecasting model to allow better assessment by transportation agencies of the benefits and costs of incident management systems prior to deployments.

Most of the parameters required for the analysis were estimated based on local data. However, some of the parameters such as the safety benefits and diversion due to traveler information were estimated based on national studies due to the unavailability of this information for the local conditions. It is recommended that this information is collected and analyzed in the future, as more data become available from the ITS system. Additional research is needed to better quantify the diversion benefits of DMS, HAR, and other ATIS devices since the results from the existing revealed and stated preference surveys to determine the diversion rates are inconclusive. In addition, additional research is needed to quantify the benefits of coordination and information sharing between traffic management and public safety agencies.

Queuing theory equations were used in this study to estimate the reduction in incident delays. Although queuing theory equations have been recommended for use in traffic engineering literature for this purpose, it would be useful to verify the results obtained from these equations using field data. It is recommended that data from traffic detectors are used to determine if the incident delay estimates produced by queuing equations are close to those estimated by the traffic detection systems

REFERENCES

1. *ITS Performance Measures – Detailed Definition of Performance Measures*. A Report Produced for FDOT 4 by Cambridge Systematics. January 2006, Fort Lauderdale, FL.
2. *SMART SunGuide TMC - 2005 Annual Report*. FDOT District 4, January 2006, Fort Lauderdale, FL.
3. US DOT ITS Joint Program Office ITS Benefits Database Home.

- <http://www.itsbenefits.its.dot.gov/>. Accessed July 20, 2007.
4. Jodi L.C., Mannering, F.L., Legg, B., Nee, J., and Nam, D. Are Incident Management Programs Effective? Findings from Washington State. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1683, TRB, National Research Council, Washington, D.C., 1999, pp.8–13.
 5. Fenno, D.W, Ogden, M.A. Freeway service patrols: A state of the practice. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1634, TRB, National Research Council, Washington, D.C., 1998, pp.28–38.
 6. Levinson, D. and Parthasarathi, P.K. An economic evaluation of freeway service patrols. IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC, 2001.
 7. Khattak, A.J. and Roupail, N. *Incident Management Assistance Patrols: Assessment of Investment Benefits and Cost*. Publication FHWA/NC/2005-02, US Department of Transportation, 2005.
 8. Guin, A. and Porter, C. Bayne Smith and Carla Holmes. Benefits Analysis for an Incident Management Program Integrated with Intelligent Transportation Systems Operation: A Case Study. Presented at 86th Annual Meeting of the Transportation Research Board, Washington, D.C., 2007.
 9. Birst, B. and Smadi, A.. An Application of ITS for Incident Management in Second-Tier Cities: A Fargo, ND Case Study. Proceeding of Mid-Continent Transportation Symposium, Iowa, 2000, pp. 30-34.
 10. Gillen, D. *Caltrans TOPS Evaluation: Assessing the Net Benefits of ITS Applications*. California PATH Working Paper, UCB-ITS-PWP-2001-2, 2001. <http://www.path.berkeley.edu/PATH/Publications/PDF/PWP/2001/PWP-2001-02.pdf>. Accessed July 20, 2007.
 11. *Revised Monograph on Traffic Flow Theory*. Federal Highway Administration, Washington D.C, 1997.
 12. May, A.D., *Traffic Flow Fundamentals*. Prentice Hall Inc., Englewood Cliffs, New Jersey, 1990.
 13. Rakha, H. and Zhang, W. Consistency of Shock-Wave and Queuing Theory Procedures for Analysis of Roadway Bottlenecks. Presented at 84th Annual Meeting of the Transportation Research Board, Washington, D.C., 2005.
 14. *ITS Deployment Analysis System (IDAS) User's Manual*. Prepared for the Federal Highway Administration by Cambridge Systematics, Oakland, CA, November 2001.
 15. Hadi, M., Quigley, D.E., Sinha, P., and Krishnamurthy, A. *Intelligent Transportation Systems Deployment Analysis System Customization*. Final Report Prepared for the FDOT by PBSJ, Inc., October 27, 2005.
 16. *Intelligent Transportation Systems 2005 Update Benefits, Costs, and Lessons Learned*. Prepared for Federal Highway Administration, US Department of Transportation, May 2005.

17. Wei, D.. Inter-Departmental Cost Allocation and Investment Incentives. *Review of Accounting Studies*, March 2004.
18. Dale, D. Activity Based Cost Management. *Australian Accountant*, March 1991.
19. Schrank, D. and Lomax, T. *The 2005 Urban Mobility Report*. Texas Transportation Institute, Texas A&M University System, College Station, TX, May 2005.
20. *Highway Capacity Manual 2000*. Transportation Research Board, National Research Council, Washington D.C., 2000.
21. Khattak, A., Roupail, N., Monast, K., Havel, J. Method for priority-ranking and expanding freeway service patrols. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1867, TRB, National Research Council, Washington, D.C., 2004, pp.1–10.
22. Jean-Claude, T. and Galina, R. *The ITS Options Analysis Model Technical Documentation*. Produced for the New York DOT by Calspan UB Research Center and University at Buffalo, Buffalo, NY, October 13, 2005.
23. *Severe Incident Response Vehicle (SIRV) Pilot Project Final Evaluation Report (Jan 2005-Dec 2005)*. Florida Department Transportation District IV, Broward County, Florida, 2006.