A FRAMEWORK FOR THE EVALUATION OF THE BENEFITS OF INTELLIGENT TRANSPORTATION SYSTEMS

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Executive Summary

This report discusses methods to assess the benefits of Intelligent Transportation Systems. It provides a comprehensive review of methods currently available in the United States. It develops a framework for benefits assessment using benefit trees and emerging analysis methods for benefit studies at the sketch planning level. These efforts should lead to specifications for information needs for evaluating ITS projects and methods to compare ITS projects with other traditional capacity enhancing projects.

There is significant variance in the complexity and details of ITS evaluation methods. The desired evaluation method depends upon the intended end use of evaluation results, among other factors. For example, one may need an extremely sophisticated evaluation framework if the true economic impact to society is to be determined. A less complex evaluation framework may suffice, however, if the results are used to prioritize ITS projects or track annual progress toward goals. Another consideration is the cost and the availability of data. Complex evaluation frameworks and methods may appear conceptually sound but be very expensive to perform. For statewide sketch planning purposes, a spreadsheet model like SCRITS (SCReening for Intelligent Transportation Systems) may suffice. For more detailed analysis of metropolitan areas, more detailed methods such as the ITS Deployment Analysis System (IDAS) should be used. A balance should be struck between evaluation framework complexity and ability to collect and/or model the relevant evaluation data. Whatever method is used, it should be accompanied by extensive sensitivity and break-even analysis to determine the importance of specific assumptions in the determination of benefits.

The break-even analysis can provide considerable insight about the magnitude of the potential benefits of different ITS programs. It can help identify critical performance variables in the assessment of ITS benefits. Break-even analysis coupled with sensitivity analysis can be used to identify and assess ITS projects for deployment in the ITS planning and programming process with limited data. The break-even analysis can be used to screen, prioritize and select ITS projects from among different ITS options. It can also be used to compare ITS projects in different geographic locations based on different traffic data and break-even points.

Finally, the method is also useful in the identification of data needed for detailed ITS project assessments and evaluations. Efforts are needed to provide better data to be used in ITS project assessment. Such data should include before and after studies of ITS deployments as well as refined cost data and traffic flow estimates.

The case study identified the break-even points of several ITS deployment options, including ramp metering, travel information systems, emergency response systems, and commercial vehicle operations under a variety of scenarios. These results can be used to identify and operate ITS projects so that they are likely to have the greatest payoff from their deployment. The following conclusions can be drawn from the case study.

- ITS systems can be more logically selected and deployed when knowledge of their performance tradeoffs are known.

- ITS systems can have large benefits, which easily exceed their costs. These benefits are especially likely to occur if the existing level of performance of the highway is poor.

- Other effects, such as increased peace of mind, crash reduction, greater reliability in arrival times, non-traveler benefits, agency benefits, and environmental benefits, cannot be easily quantified but would add to the benefits of an ITS system.

- Ramp metering systems benefits depend on tradeoffs between increased freeway speeds with metering vs. ramp delays and arterial speed decreases.

- Weigh in motion bypass of static scales can have a positive net benefit with small levels of usage.

- Incident management systems should be implemented in a way to minimize incident duration. This is an area of very high potential benefits.

- Mechanisms to disseminate real time traffic data should be actively explored to provide the best use of a traveler information system.

- Use of other procedures for ITS analysis and assessment should be explored. In particular IDAS has a good potential for application to ITS project selection and assessment. To be effective it needs to be coupled with good, up to date four step travel demand models. Such models need to be based on good data and be sensitive to a variety of conditions such as intersection delay. Implementation of IDAS should consider how it fits with the state of the art in the travel forecasting process

- The framework for assessment should be expanded to provide for the assessment of ITS project types not considered in this project. Some to consider are rural transportation, public transit and additional CVO items such as enhanced certification procedures.

Introduction

Intelligent Transportation Systems (ITS) cover a broad range of technologies that are aimed to enhance the efficiency, safety and productivity of the existing transportation system. ITS are undergoing a transition from demonstration projects and experimental programs to becoming part of the mainstream set of options available to transportation agencies. As part of this transition, there is a need for better methods to estimate the effects and impacts of deployments of ITS. An overall benefits assessment process for ITS is necessary to assist agencies in the identification of candidate ITS projects for deployment. In addition, methods should be provided to facilitate decision-makers to compare ITS options to more conventional projects such as facility construction and expansion.

The Wisconsin Department of Transportation (WDOT) has developed strategic plans to deploy Intelligent Transportation Systems (ITS) in Wisconsin. This plan includes programs related to the Gary-Chicago-Milwaukee National Priority Corridor, the Interstate Highway 90/94 corridor, commercial vehicle operators, public transit systems and services in rural areas. WDOT has also developed business plans for ITS programs for commercial vehicle operators, traveler information systems, and incident management. These initiatives are far reaching and may have a significant impact on the future effectiveness and efficiency of Wisconsin transportation systems. In order to deploy these systems in the most cost-effective manner, it is essential that there be methods available to properly assess the benefits of ITS initiatives.

This project was developed to assist WDOT in developing methods to identify and screen ITS projects as part of their project planning and programming process. Specifically the project includes an overview of ITS benefits, a survey of recent literature that reports ITS benefits and a break-even analysis that is used to identify ITS performance measures and data needs. In addition, the break-even analysis provides a method to examine the tradeoffs between ITS projects and to indicate the circumstances where ITS projects are likely to have the greatest benefit.

Approaches to ITS Benefits Evaluation

There are two approaches toward the benefit assessment of ITS deployments, the goal-oriented approach and the economic analysis approach. The goal-oriented approach starts with defining goals and objectives, and setting up specific measurements. It focuses on whether the end product has achieved its original goals. The success or failure of a project is determined by comparing its outcome with the project's goals. For example, if the goal is to reduce congestion and increase throughput on an expressway, and the project did reduce delay and improve traffic flow, the project is considered a success. Such an approach is likely to be used at the local or district level for project selection and identification.

The economic analysis approach focuses on cost efficient ways to achieve the goal. For instance, if the goal is to reduce congestion and increase throughput, the economic analysis approach would ask whether the investment in ITS to achieve that goal is economically beneficial, and how the rate of return on investment compares to that of other projects. This approach is most likely to be used at a statewide level for project selection.

Goal Oriented Approach

Many ITS evaluation frameworks and methodologies in the recent literature used the goal-oriented approach (Richeson and Underwood, 1996; Rogova and Summers, 1996; Brand, 1994; Underwood and Gehring, 1994; and Turner and Stockton, 1999). Most ITS evaluation criteria and benefits analyses are based on the six national ITS goals proposed in the *National ITS Program Plan* (US DOT, 1995) developed jointly by the U.S. Department of Transportation (USDOT) and ITS America. These are:

1. **Improve the safety of the nation's transportation system.**
   - Reduce number and severity of fatalities and injuries
   - Reduce severity of collisions
2. **Increase the operational efficiency and capacity of the surface transportation system.**
   - Reduce disruptions due to incidents
   - Improve the level of service and convenience provided to travelers
   - Increase roadway capacity
3. **Reduce energy and environmental costs associated with traffic congestion.**
   - Reduce harmful emissions per unit of travel
   - Reduce energy consumption per unit of travel
4. **Enhance present and future productivity.**
   - Reduce costs incurred by fleet operators and others
   - Reduce travel time
   - Improve transportation systems planning and management
5. **Enhance personal mobility and the convenience and comfort of the surface transportation system.**
   - Provide access to pre-trip and en route information
   - Improve the security of travel
   - Reduce traveler stress
6. **Create an environment in which the development and deployment of ITS can flourish.**
   - Support the establishment of a significant U.S.-based industry for hardware, software, and services

Based on these six goals, further evaluation measures are developed to quantify the evaluation of ITS projects. Because the amount of evaluation measures that are related to these six ITS goals may be large, the ITS Joint Program Office of the U.S. DOT advocates the use of so-called “a few good measures" that are “robust enough to represent the goals and objectives of the entire ITS program, yet few enough to be affordable in tracking the ITS program on a yearly basis” (FHWA, 1997). These “few good measures” include:

- Crashes,
- Fatalities,
- Travel time,
- Throughput,
- User satisfaction or acceptance, and
- Cost.

A similar performance-based approach is used in the U.K. (Tarry, 1996). Performance indicators that include value-for-money indicators were developed in an evaluation framework to evaluate several ITS projects in the U.K., including the SCOOT adaptive signal control system in Aberdeen, dynamic message signs on the M40 in West Midlands, a driver information system in Scotland, and an accident reduction scheme in Yorkshire.

Economic Analysis Approach

The other approach for ITS evaluation uses economic analysis techniques similar to those used for highway project economic analyses. This approach attempts to quantify the specific monetary value of all ITS impacts. It focuses on quantifying the short- and long-term economic impacts of ITS projects on regional and national economies (i.e., employment, productivity, etc.), the users, the private sector, the community and the environment. This approach attempts to reduce everything to a single benefit-to-cost ratio (Zavergiu *et al.*, 1996; Novak and McDonald, 1998; Lee *et al.*, 1997, 1999).

Zavergiu *et al.* (1996) suggest that ITS evaluation should encompass more than benefits accrued to transportation system users; it should also include transportation infrastructure providers and managers, potential private investors/ITS technology providers, the community, and the environment.

Novak and McDonald (1998) focus on the potential macroeconomic impacts of ITS investment in the U.S., including direct employment, economic multiplier, national productivity gains, technological spin-offs, and competitiveness. The measure of these macroeconomic impacts was difficult, though, because the core ITS infrastructure was not widely deployed in most metropolitan areas.

Lee *et al.* (1997, 1999) also examines the economic value of various ITS projects. They have developed a spreadsheet model for conducting cost/benefit analysis of ITS projects. The spreadsheet model converts ITS impacts to monetary values by taking into consideration of both internal (user) benefits and external benefits.

Comprehensive benefit/cost analysis is very tricky because of issues of double counting and proper valuation of benefits. In addition, most ITS projects include multiple components and it is difficult to isolate the benefits of each component. It can be useful if the differences between alternatives only occur on a few measures and if it is used to compare alternatives rather than to develop absolute values of benefits. In such cases, many of the difficult assumptions tend to cancel out and it can provide useful results.

Considerations in ITS Evaluation

Although there appears to be great differences between the goal-based approach and the economic analysis approach, they are closely related. Some goal-oriented evaluation frameworks incorporate an economic analysis, while economic analysis also considers goals and objectives of ITS projects. The difference is that economic benefit is considered to be one of many components of the overall evaluation in the goals-based evaluation, while it is considered to be the sole or most important measure in the economic analysis evaluation.

Both approaches have their limitations. Sometimes the goals of a project are not clear or are themselves in conflict. On the other hand, many benefits are difficult to assign a monetary value, which makes economic analysis challenging. Both approaches are complementary and should be used together or in different situations depending on the scale and the time frame of the analysis. Regardless of the approaches to be used, the following issues should be considered in the evaluation process.

The Scale of the Cost/Benefit Analysis

An evaluation of ITS deployments can be conducted at the project level and system-wide level. A project evaluation focuses on the output of a specific project, while a system level evaluation focuses on the impacts on the system as a whole and the overall outcome of the investment, whether that system is a metropolitan area or a state. A project evaluation usually emphasizes the success or failure on a specific project, while a system evaluation usually emphasizes the outcome of the investment. The system evaluation is often used as a decision-making basis for future investment.

A project usually has very specific goals and objectives to start with. Therefore, a goal-oriented approach is more appropriate at the project level. At the system level, however, goals such as increased system efficiency and productivity can be vague, making it difficult to establish evaluation measures. Furthermore, at the system level the decision-makers are more interested in questions like, "How should we allocate funds that would offer us higher overall returns given the fixed transportation budget? Should we allocate more funding to ITS or to traditional capacity expansion?" Therefore, at the system level, it may be more appropriate to use the economic analysis approach.

Systems level evaluation will also have a different set of considerations from project level evaluation. Certain criteria used at the project level will not appear at the systems level since they cancel out over a large geographic area. The concept of a 'zero sum game' is relevant at the statewide or national level, but for project level analysis, there can be substantial differences (Beimborn, 1993).

Impacted Groups

ITS has direct impacts on users, such as changes in travel time, speed, and the number and severity of crashes. It also has impacts on non-users such as residents, property and business owners, and customers; public agency operators (e.g., police, fire, emergency response, DOT, etc.); and private sector business and industry (e.g., package delivery companies, trucking, hardware/software manufacturers, and other businesses, etc.) (Brand, 1994).

Evaluation Time Frame

ITS could have different impacts depending on the time frame (Brand, 1994). Some impacts, such as increased throughput or decreased travel time, may be seen almost immediately. Other impacts, such as changes in land use or economic productivity, may not be evident for many years. Short-term impacts like throughput increase may be offset by long-term impacts like increased latent demand. It is therefore important to consider the time frame in the ITS evaluation, and to clearly document the short and long term impacts.

Specific measures and parameters

Some ITS benefits can be identified by using specific measures and parameters. Others are more difficult to quantify. The following measures are commonly used to quantify some ITS impacts.

- ***Safety****:* Some measures of the number of incidents, crashes, and fatalities.
- ***Reduction of delay and travel time****:* The measure of delays and travel time reliability.
- ***Cost reduction:*** A measure of productivity and reduced operating costs from ITS services.
- ***Throughput:*** A measure of passengers or people within a specific unit of time who traverse a portion of the road network.
- ***Customer satisfaction:*** The extent to which passengers and other consumers who rely on transport service feel satisfied. While satisfaction is an abstract term, the quality of a service is often measured by the number of people who continue to use it, as well as comments on customer satisfaction or dissatisfaction.
- ***Environmental benefits:*** a measure of impacts on emissions and other environmental factors.

Interrelationships Between Benefits

Because transportation benefits can occur to different groups and organizations, it is useful to portray them using a benefit tree. The benefit tree indicates how a technology affects agencies, travelers, non-travelers, freight and transit carriers, and the general population at different levels, as well as how these levels are related. This technique is valuable in that it can eliminate double counting and establishes a non-monetary measurement through consideration of timesaving, environmental cost consideration, pollution and goodwill.

The benefit trees help distinguish between the two basic types of evaluation measures that are commonly used in ITS evaluations: Internal impacts (benefits) to the users and external (system) impacts (or benefits) to non-users, to the economy and to the community (Lee, 1999). "Internal impacts" refers to direct benefits to the traveler at the individual traveler level, such as improved mobility and travel opportunities, shorter travel times and greater travel time reliability. Internal impacts typically characterize the effects of transportation on impacted groups. External impacts refer to indirect benefits to the transportation system as a whole (less congestion), to the environment (less air pollution), and to the economy (more productivity).

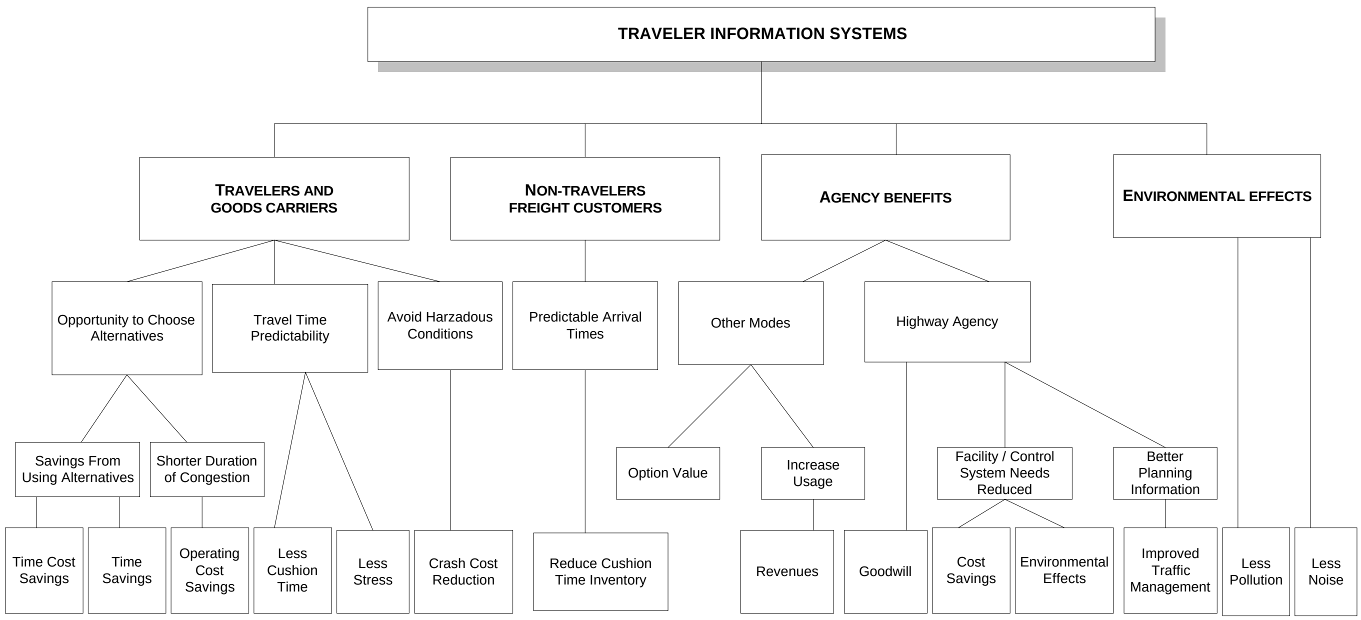
Separate benefit trees have been developed for each of three areas of ITS technology: traveler information systems, incident management systems and commercial vehicle operation systems.

Traveler Information Systems

Traveler information systems provide real-time information to travelers and commercial vehicles about the condition of the transportation system. This information can include indications of the level of congestion and special notices of incidents that affect the flow of traffic. Traveler Information Systems allow transit and automobile travelers to make more informed decisions regarding travel time, modes and destinations.

The Traveler Information Systems benefit tree indicates four areas of impact: direct impacts on travelers and goods carriers, effects on non-travelers and freight customers, effects on transportation agencies and environmental effects as shown in Figure 1.

Figure 1: Traveler Information Systems Benefit Tree.



The availability of real-time traffic information can translate into timesaving and enhanced safety for highway users. Traveler information systems also provide travelers and goods carriers with better predictability of travel time. They can also allow users to avoid hazardous conditions that may lead to reductions in the number and severity of crashes.

Non-travelers and shippers also benefit from traveler information systems by having more predictable arrival times for the goods or persons they are expecting. This can be particularly important for shippers and manufacturers who use just-in-time inventory systems. Transportation agencies accrue benefits through the potential for reduced costs for facilities, operations and planning. Better traveler information systems can provide useful data for systems management and help shape a positive image for public agencies.

The following are some examples from different states and metropolitan areas where significant benefits of traveler information systems have been reported (Table 1).

In Oakland County, Michigan, the use of advanced traveler information systems helped increase traffic speed by 33 percent. Canada has also reported some significant benefits on their provincial highways. An estimated 25% reduction in traffic delays was realized from an urban traffic signal system that was in operation since mid 1995. The Trans-Canada Highway achieved 15% reduction of delays during peak hours in April 1996.

Philadelphia, Pennsylvania established the Traffic and Incident Management System (TIMS) program to help drivers avoid highways with incidents on its I-95 highway. The purpose is to help travelers make informed decisions on rerouting and to reduce secondary incidents. Communication is through digital communication, message signs, and lane control signals, surveillance cameras and loop detectors. It reported a 40% reduction in incident-related freeway congestion, a 55% decrease in freeway closures and an 8% reduction in incident severity.

A comparison study of the Information For Motorist (INFORM, a combination system of ramp metering and motorist information) in Long Island, New York from 1987 to 1990 showed significant benefits of a 13% increase in overall freeway speeds and an increase of 5% for the PM peak and 50% for the AM peak. Denver, Colorado evaluated the Courtesy Patrol Program over six months, and reported cost reduction from delays of $800,000-$1,000,000 for its morning traffic, and $900,000-$950,000 for the evening traffic. This translated into timesaving equivalent to $10 per passenger vehicle hour and $29-$38 per truck hour.

The bus priority system in Portland, Oregon, has been reported to have reduced bus travel time by 5-8%. This was not only beneficial to the passengers; it also improved the image of the transit agency. In North Carolina, the Transit Authority of Winston-Salem evaluated the effectiveness of a computer-aided dispatching and scheduling system on its seventeen bus fleet operations. In a period of six months, operating expenses were reduced by 2% per passenger trip and 9% per vehicle mile. At the same time, the image of the agency was enhanced, and passenger wait time was reduced by 50%.

Table 1. Reported benefits of traveler information systems

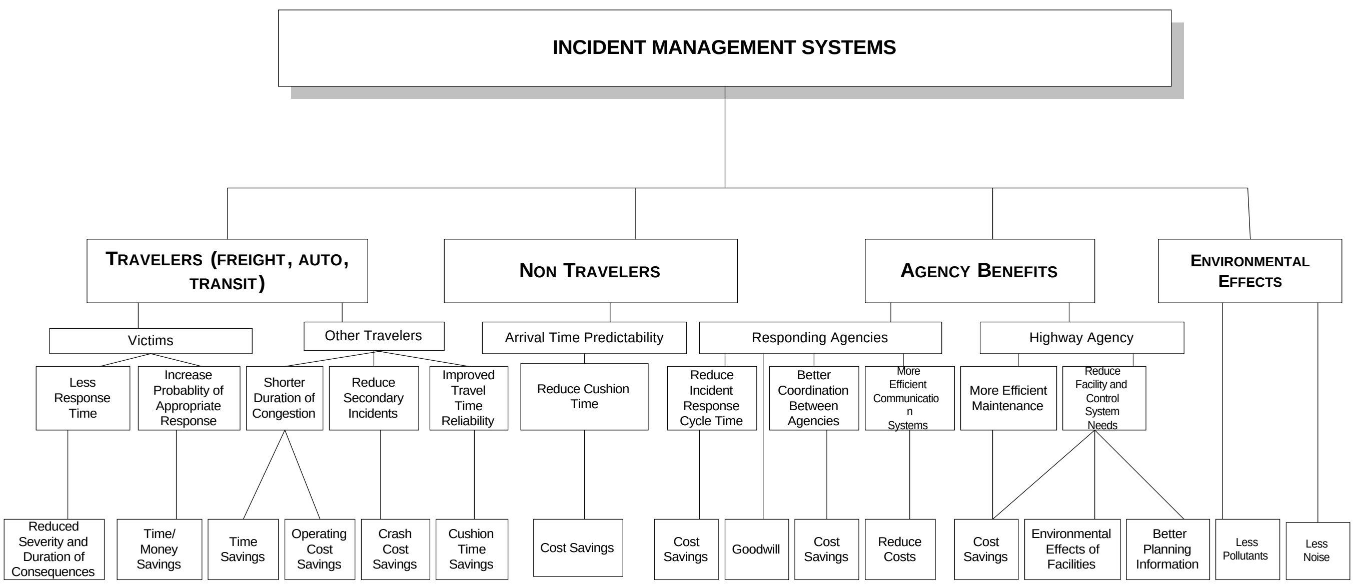
Location	ITS Applications	Realized benefits
Oakland County, Michigan	Advanced Traveler Information Systems	33% increase of speed
Columbia, Canada	Traffic signaling	25% savings in traffic delays
Portland, Oregon	Traffic signaling, bus priority system	5-8% reduction in travel time
Long Island, New York	Information for Motorists (INFORM), ramp metering [Integrated corridor management system, including ramp metering, variable message signs, and signal coordination]	▪ 13% increase in freeway speeds, 5% increase of Vehicle Miles Traveled (VMT) in evening peak, 50% decrease in vehicles traveling at less than 30 mph ▪ Estimated delay savings of 1,900 vehicle-hours per incident and 300,000 vehicle-hours annually. ▪ Travelers reported diverting 5 to 10% of the time for passive messages (no action recommended) and 10 to 20% of the time for action messages.
Los Angeles, California	Traffic surveillance and control program	Varied savings between 13-44%
Marin County, California	Commuter Survey	▪ 69% of respondents stated they would divert, saving estimated 17 minutes each.
Minneapolis, Minnesota	Genesis Project [System designed to provide incident information via pagers]	▪ Users reported discovering information about incidents more than half the time via pager, versus 15% of the time via radio or TV. ▪ When alerted via pager, travelers diverted to alternate routes 42% of the time.
Orlando, Florida	TravTek, [in-vehicle navigation system]	▪ No statistically significant impact on accident rates. ▪ Favorable results from driver workload and perception studies. ▪ Predicted crash reduction of up to 4%
Philadelphia, Pennsylvania	Traffic and Incident Management systems (TIMS)	▪ Reduced secondary incidents by 20%, ▪ Cut freeway closure by 55%, ▪ Reduced severity rate by 8%
Washington, DC	Ramp Rollover Warning System	▪ Eliminated speed-related accidents at the three deployed sites. ▪ Reduced truck speed by 7 mph.
San Antonio, Texas	TransGuide, Phase One [en route driver information component of multi-function traffic management system]	▪ Drivers surveyed reported significant increase (86% vs. 40%) in confidence in information (compared to traditional radio and TV before). ▪ Percentage "likely" to use alternate routes increased from 58% to 71%. (Based on ongoing survey data for group of 600 downtown commuters.)
Seattle, Washington and Boston, Massachusetts	SmarTraveler [Commercially provided traveler information service]	▪ Summary results indicate nearly even split between travelers who reported changing route (45%) and those changing departure time (45%) based on improved information. ▪ Another 5 to 10% reportedly change modes. ▪ Predicted emission reductions: VOC, 25%; NOx, 1.5%; CO, 33%. ▪ Driver behavior based on survey information. Emissions based on simulations that assumed certain levels of participation.
Winston-Salem, North Carolina	Computer-aided dispatch and scheduling system of buses	▪ Over 6 moths, growth from 1,000 to 2000 clients, ▪ 5% growth per passenger-trip, ▪ 2% operating costs per person decrease, ▪ 9% decrease per vehicle mile, ▪ 50% decrease in passenger wait time, ▪ Institutional growth grew to account for 10% of trips

Source: Adapted from Turner *et al.* "ITS Benefits: Review Of Evaluation Methods And Reported Benefits," report Number: FHWA/TX-99/1790-1, October 1998.

Incident Management Systems

Traffic incident management systems are useful in coordinating activities and reducing the duration of the time required for restoration of normal traffic on highways following incidents. It can also potentially reduce adverse environmental effects when incidents are averted or their effects are minimized. In cases of emergencies, proper management and coordination among the road agencies and transport management officials, will allow for timely detection, verification and location of the occurrence, allowing for dispatching of the appropriate emergency vehicle and personnel. Incident management has benefits to travelers, freight carriers, non-travelers, enforcement and operational agencies (Figure 2).

Figure 2: Incident Management Systems Benefit Tree.



Victims of incidents benefit from incident management systems because of the reduced response time. This can lead to reduced severity of the results of a crash and quicker delivery of appropriate care. Other travelers and goods carriers benefit because of a shorter duration of congestion related to the incident. A quicker response time can lead to a reduced probability of becoming involved in a secondary incident and an increase of throughput. Some examples of reported benefits are listed in Table 2.

In Atlanta, the use of a regional communication system during the 1996 Olympics reduced incident verification time by 3.1 minutes (74%), response time by 50%, and lane clearance by 15 minutes (38%), for a total reduction in response time of 76%.

The Courtesy Patrol Service (tow truck operations) in Denver, Colorado helped reduce the cost of incident-induced delays, which resulted in $800,000-$1,000,000 savings for the morning commuters, and $900,000-$950,000 savings for evening commuters.

Detroit, Michigan used signal control systems, which allow for detours around the areas of incidents. A simulation of this system around the Detroit Commercial Business District shows benefits varying from a 60-70% reduction in delays, a 52% of rerouting and detours, up to 41% reduction in travel delays, and an overall 91% savings.

Fairfax County, Virginia has been using cameras at intersections in Fairfax City to monitor violations, resulting in a significant reduction of incidents reported. In November 1997, the number of accidents was reduced from 43 to 28, a 35% reduction after the devices were installed.

In Minnesota, the Highway Helper Program has reportedly been successful in reducing delays from incidents by eight minutes, which translates into cost savings from reduced delays to a total $1.4 million. This is a substantial benefit, considering the program cost $600,000 to operate.

Seattle, Washington reportedly achieved significant benefits from ramp metering. A total of 22 ramp meters were installed, resulting in a 52% decrease in travel time, and a 39% decrease in accident rate. Another successful implementation of ramp meters occurred in the Minneapolis area of Minnesota where a 27 km (17 mile) stretch of freeway resulted in a 27% accident reduction and 35% speed increase.

Some electronic control devices such as cameras have been useful in controlling red light running. Howard County, MD and the City of Los Angeles report a high success rate from implementing this technology. The project was federally funded and an impressive 44% reduction in red light running was achieved.

Table 2. Reported benefits of incident management systems

Location	ITS Applications	Reported Benefits
Atlanta, Georgia	Improved interagency coordination (for the 1996 Olympics)	▪ Reduced verification time from 4.2 to 1.1 minutes (74% reduction), ▪ Generation of response reduced from 9.5 to 4.7 minutes (50%) with maximum time for clearance reduced from 6 hours 15 minutes, to 1 hour, 28 minutes (76% reduction)
Denver, Colorado	Courtesy Patrol Service (tow truck operations)	▪ $0.8-$1.0 million savings for morning traffic, ▪ $0.90-0.95 million in the evening. ▪ Time value of $10.00 per hour
Denver, Colorado	Ramp metering program	▪ 5% to 50% reduction in crash rate ▪ 27% to 37% reduction in travel time ▪ 13% reduction in veh-hours of delay
Detroit, Michigan	Signal control around incident areas	▪ Reduced delays by 60-70%
Detroit, Michigan	Ramp Metering	▪ 50% reduction in total crashes ▪ 71% reduction in injuries ▪ 7% reduction in travel time ▪ 40% reduction in incident delay ▪ 42% reduction in fuel consumption (Reported benefits are estimated.)
Houston, Texas	Ramp metering program	Annual delay savings of 572,095 vehicle hours, valued at $8.4 million
Fairfax city, Virginia	Devices like cameras	35% accident reduction

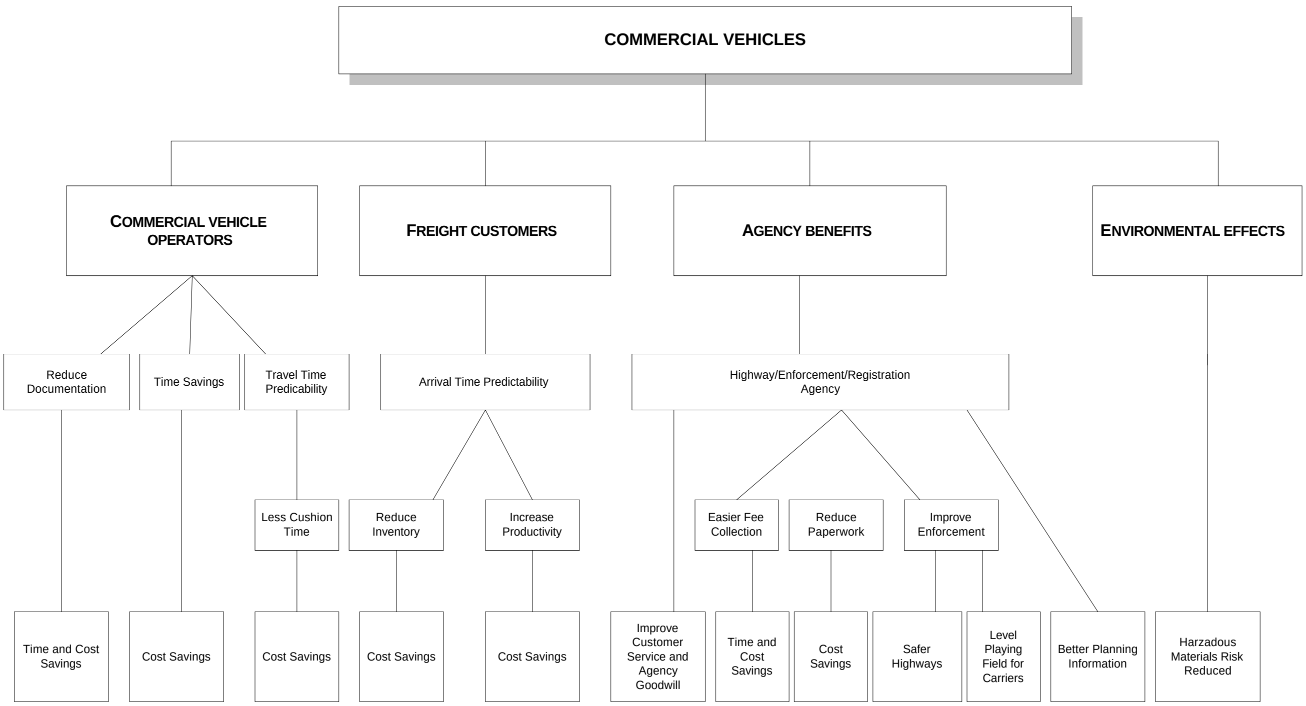
Los Angeles, California	Automated Traffic Signal Control (ATSAC)	▪ 41% reduction in vehicle stops ▪ 13% reduction in travel time ▪ 14% increase in average speed ▪ 13% reduction in fuel consumption ▪ 20% reduction in intersection delay
Toronto, Ontario	Adaptive Traffic Signal Control (SCOOT)	▪ 8% reduction in travel time ▪ 17% reduction in vehicle delay ▪ 22% reduction in vehicle stops ▪ 6% reduction in fuel consumption ▪ Benefits from a two-month (Study of the SCOOT system on two corridors and the CBD)
Abilene, Texas	Automated Traffic Signal Control	▪ 13% reduction in travel time ▪ 22% increase in average speed ▪ 37% reduction in delay ▪ 6% reduction in fuel consumption
Gowanus Expressway, Brooklyn, New York	Automated incident detection and verification system	▪ Time to detect and clear incidents reduced from 90 minutes to 31 minutes (66% reduction); ▪ Breakdowns reduced to 19 minutes.
Minneapolis, Minnesota	Highway Helper Program	Annual benefits of $1.4 million, for a $600,000 program operational cost.
Minneapolis - St. Paul, Minnesota	Ramp metering	▪ 30% increase in traffic speeds ▪ 24% to 27% reduction in total crashes ▪ 27% reduction in crash rate ▪ 14% to 27% reduction in travel time
Philadelphia, Pennsylvania	Traffic and incident management systems	▪ 35% accident reduction, ▪ 8% reduction in incident-severity
Houston, Texas	TranStar (incident management component of multi-function traffic management system)	▪ Estimated per incident delay savings projected to annual estimate of 570,000 hours and $8.4 M. (Savings estimates based on anecdotal estimates of incident duration reduction of five minutes on major incidents.)
San Antonio, Texas	TransGuide Phase One (incident management component of multi-function traffic management system)	▪ 5-minute (21%) reduction in response time to major incidents. ▪ 6-minute (19%) reduction in response time to minor incidents. ▪ Estimated delay savings of 700 veh-hours per major incident, equaling $1.65 M annually in time and fuel. (Based on seven months "before" data and five months "after" data.)
Portland, Oregon	Ramp metering	▪ 3% reduction in total crashes ▪ 7% reduction in transit travel time
Seattle, Washington	Ramp metering, freeway management systems	▪ Volume increases of 10-100% ▪ Speeds increases of 20% ▪ 38% reduction in crash rate ▪ 48% reduction in travel time ▪ 10% to 100% growth in traffic ▪ 48% increase in average speed

Source: Adapted from Turner, *et al.*, “ITS Benefits: Review Of Evaluation Methods And Reported Benefits," report number: FHWA/TX-99/1790-1, October 1998.

Commercial Vehicle Operation Systems

Deployment of commercial vehicle operations systems has benefits that translate into reduced costs for vehicle operators, greater reliability for freight customers, savings for highway and enforcement agencies and some environmental effects. The potential benefits associated with commercial vehicle operations systems areas are shown in Figure 3.

Figure 3: Commercial Vehicle Operator Systems Benefit Tree.



Reduced documentation: When commercial vehicle operator systems are properly coordinated, technologies for surveillance and enforcement will be utilized to provide information and schedules without unnecessary duplication and paperwork. This means that commercial vehicle operations can reduce paperwork by electronic information sharing and automatic data collection, which can reduce the number of personnel required and save time and money.

Reliable and more predictable arrival time: Better commercial vehicle operation systems increase the reliability of goods delivery. This can lead to reduced inventory costs and increased productivity. Furthermore, commercial vehicle operation systems will increase the efficiency of enforcement agencies by reducing paperwork and improving compliance with regulations. It can also provide better information for future planning.

Highway enforcement agency impacts: Commercial vehicle operation systems will increase the efficiency of enforcement agencies by reducing paperwork and increasing the customer service and goodwill of enforcement agencies. In addition there can be better compliance with regulations leading to safer highways as well as better information for future planning.

The reported successful deployment and operations of Commercial Vehicles Operations (CVO) have been significant in four areas: safety assurance, credential administration, electronic screening and carrier operations (Table 3).

Safety Assurance

Improved safety assurance results from information exchange, which provides inspectors information ranging from unsafe commercial drivers, onboard monitoring of cargo and information on potential load conditions.

Credential Administration

CVO promotes and facilitates interagency and interstate data exchange and information sharing. Less time is needed to spend on paperwork, so fewer personnel are needed. The State of Minnesota reportedly reduced its workforce in CVO from over 20 people across 16 districts and 5 in a central location to just 9 statewide.

Electronic Screening

Roadside electronic screening reduces wait time at weight stations. The West Coast has successfully established the HELP Crescent Project, which uses four types of technologies for screening vehicles. Projections indicated annual incident reduction of $1,700,000 per state, tax evasion reduction of $500,000-$1,800,000 per state, reduction of operation costs of $169,000, and another $156,000-$781,000 in savings from automated safety checking.

Carrier Operations

While there is a lot of anecdotal evidence of the successes and benefits resulting from effective fleet management, specific benefit numbers are hard to find. *Telestat Canada* reported an increase of 16% in loaded mileage covered and a cost reduction of $20 per truck mile.

Table 3. Reported benefits of Commercial Vehicles Operations

Location	ITS Applications	Reported benefits
AMASCOT (Automated Mileage and State Line Crossing Operational Test)	Uses GPS technology	▪ 33 to 55% reduction in fuel tax and registration costs.
State of Colorado	Using AVI and WIM technologies	▪ B/C ratios of 7:1 to 10:1 for motor carriers using electronic clearance technologies.
Detroit, MI - Windsor, Ontario	International Border Crossing [automatic vehicle identification and statistic information]	▪ Estimated B/C ratio of 4:1.
Multi-states [Florida, Georgia, Tennessee, Kentucky, Ohio, Michigan, Ontario, Canada]	Advantage I-75 Project [Mainline Automatic Clearance System (MACS) at 30 stations.]	▪ Early B/C ratio estimates were 7:1 for carriers. ▪ Average of 2 to 3 eliminated stops per equipped vehicle. ▪ 0.05-0.18 gallons saved per avoided stop. (Over 4,500 vehicles participated in the first phase of the study.)
National Governor's Association Study		▪ B/C ratios of 1:1 - 7:1 for eight states using electronic clearance.
University of Pennsylvania Study		▪ Expected B/C ratio of 4:1 for small carriers. ▪ B/C ratio of 20:1 for carriers with 100+ vehicles.
West Coast states	HELP Crescent Project	▪ Annual incident reduction of $1.7 million per state, ▪ Tax evasion reduction of $0.5-$1.8 million per state, and ▪ Reduction of operation costs of $169,000, and $156,000-$781,000 of savings from automated safety checking.
Canada	Fleet management	▪ Increase of 16% in loaded mileage, and ▪ A cost reduction of $20 per truck mileage.

Source: Adapted from Turner *et al.*, "ITS Benefits: Review of Evaluation Methods and Reported Benefits," report number FHWA/TX-99/1790-1, October 1998.

Internal and External Evaluation Measures

The benefits tree helps to distinguish between the two basic types of evaluation measures that are commonly used in ITS evaluations: Internal impacts (benefits) to the users and external (system) impacts (or benefits) to non-users, to the economy and to the community (Lee, 1999). "Internal impacts" refers to direct benefits to the traveler at the individual traveler level, such as improved mobility and travel opportunities, shorter travel times and greater travel time reliability. Internal impacts typically characterize the effects of transportation on affected groups. External impacts refer to indirect benefits to the transportation system as a whole (less congestion), to the environment (less air pollution), and to the economy (more productivity). It is important to determine whether the external impacts are the result of the internal impacts or if they occur independently. If they are the result of internal impacts (for example, land value increases from improved travel times), they should not be included in an economic evaluation since they double count the same thing. If they occur independently (for example, emissions reductions), they should be included in both analyses.

Internal benefits of ITS can be valuable to the user. For example, a user of an advanced traveler information system would find real time traffic information before the trip very valuable, so he/she can save travel time by shifting start time. The value of that traveler information system will vary, however, depending on how the user's travel behavior changes. If the traveler decides to change route, the internal benefits can be directly measured using the attribute changes (e.g., timesavings) (Lee and Klein, 1997). But if the user decides to go ahead with the trip anyway or change travel destination, using timesaving could become problematic. If the user decides to go ahead with the trip, he/she could be psychologically more prepared. In this case, a congested travel becomes a "serene" travel (Lee, 1999) even though the travel time does not change. If the user decides to change travel destination, direct comparison of travel timesaving is useless. Therefore, using travel timesaving to measure internal benefits is almost impossible. To measure the value the traveler places on the advanced traveler information system requires the direct measure of consumer surplus, which requires a stated preference survey to elicit a monetary value to reflect the consumer's willingness-to-pay.

External benefits can be demonstrated by congestion relief to other highway users, reduced air pollution, increased productivity, etc. Short-term external benefits are usually measured in congestion relief (hours of delay), changes in vehicle miles of travel (VMT), air pollution (tons of pollutants), gasoline consumption, and the number and severity of crashes. These transportation network attributes are typical output measures in traditional traffic engineering analyses and are readily available or relatively easy to collect. In the long run, external impacts can also be measured by latent demand for highway usage, which is much more difficult to address and thus has not been estimated so far.

In some cases, external benefits at the system level may lead to internal benefits at the individual traveler level. For example, a good throughput may transfer to timesavings for individual travelers. But in many other cases, an external benefit may not lead to users' internal benefits. For instance, ramp metering may lead to increased vehicle throughput along a freeway corridor, but it may not transfer directly to ramp meter users, especially for short-distance commuters. A long delay at the ramp meter could offset the timesaving from a shorter route. Similarly, a good internal benefit of individual travelers may not lead to good external benefits either. For example, if most people get the same real time information and make the same decision either delay the trip or take an alternative route, that information may not transfer to improved traffic throughput and may even worsen traffic on the adjacent highways.

It is thus necessary to distinguish between internal benefits and external benefits estimates in ITS evaluations. For transportation agencies, it's understandable to focus on the measures of external or system benefits. It should be noted, though, that the aggregate nature of system benefits is unable to capture the dynamics of individual traveler responses (Brand, 1994).

Benefit Estimation Methods

There is a suite of tools and methods that have been developed or are under development for ITS benefits estimation. These tools can generally be categorized into two groups. One group of tools provides add-ons to current transportation planning models, which requires a detailed transportation planning database and travel information. These tools include ITS Deployment Analysis System (IDAS), and the Process for Regional Understanding and Evaluation of Integrated ITS Networks (PRUEVIIN). Both are sponsored by the Joint Program

Office of ITS at the USDOT. The Transportation and Analysis Simulation System (TRANSIMS) also attempts to incorporate ITS elements in its simulation models.

The other group of tools is a cost/benefit-based spreadsheet model at the sketch planning level, including SCReening for ITS (SCRITS) and an ITS evaluation spreadsheet model developed by the Volpe Transportation Center. The spreadsheet models are based on cost and benefit parameters and travel timesavings to estimate cost and benefits of specific elements of ITS. These ITS benefits and costs analysis tools operate at different problem scales, have a number of common elements, require different levels of expertise and resources, and provide different levels of results.

ITS Deployment Analysis System (IDAS)

IDAS is designed to be a near-term ITS sketch planning tool to evaluate costs and benefits over a broad range of possible ITS alternatives. It uses an extensive database of ITS technologies and benefit/cost estimates based on national averages of field study and modeling results. IDAS is designed for use by regional and local planning agencies to identify areas of need for ITS and to conduct analysis of associated costs and benefits.

IDAS is based on the framework of the regional transportation forecasting process – the traditional four-step models: trip generation, trip distribution, mode choice, and traffic assignment. The four-step models forecast future travel demand on the transportation system based on a specific set of transportation improvement strategies. They can estimate the effects of adding an additional lane of highway or a new freeway. They are extremely limited, though, in their ability to evaluate the potential effects of ITS improvements. For example, they cannot measure the effects of a ramp metering system or a travel information system on the freeway. IDAS is designed as an add-on to the four-step transportation planning models to assess the effects of ITS improvements.

IDAS uses the results from the four-step planning models to build a base-case scenario. It then adds one or more ITS improvements to the base case, and runs the enhanced travel demand models again to determine the new travel patterns that emerge as a result of the ITS improvements. The incremental costs and benefits resulting from the deployment of the ITS improvements are then compared with the base-case scenario. Specifically, the following steps are involved in assessing the benefits-costs of ITS deployment.

First, IDAS uses the input/output interface to input the data from the four-step transportation planning models into the IDAS software. The data include the regional transportation network in terms of nodes, links, and traffic flows. This establishes the baseline scenarios.

Next, the user uses the alternative generator to select the ITS components to deploy on the transportation network. ITS components cover 12 major categories and 69 individual ITS components. The 12 major components include:

- Arterial traffic management systems
- Freeway traffic management systems
- Advanced public transportation systems

- Incident management systems
- Electronic payment collection systems
- Railroad grade crossings
- Emergency management systems
- Regional multi-modal traveler information systems
- Commercial vehicle operations
- Advanced vehicle control and safety systems
- Supporting deployments
- Generic deployments

Third, the benefits from the deployment of ITS components are quantified in the Benefits Module. The default benefit values are based on the national average of ITS deployments and/or research studies. The user can change the default values based on local knowledge. An internal travel demand model is incorporated here to re-evaluate travel patterns based on the addition of the ITS improvements. Benefits are estimated based on

- Travel time/throughput,
- Environmental impacts,
- Safety, and
- Travel time reliability.

Fourth, costs from the deployment of ITS components are quantified in the Cost Module. The default equipment requirements and their associated costs are the national average, but could be modified based on the available local data.

Lastly, the benefits and costs of ITS component improvements are compared with those of the base-case scenario in the Alternative Comparison Module. All benefits are converted into monetary values. The user can also conduct sensitivity analysis and risk analysis in this step.

IDAS has been developed by the Oak Ridge National Laboratory, Cambridge Systematics Inc. and ITT Systems under the sponsorship of the U.S. Department of Transportation. It has been tested in three planning organizations: Pima Association of Governments (Tucson, Arizona area), Chicago Area Transportation Study, and Metropolitan Transportation Commission at the San Francisco Bay Area.

IDAS has a good potential for application to ITS project selection and assessment. To be effective it needs to be coupled with good, up to date four step travel demand models. Such models need to be based on good data and be sensitive to a variety of conditions such as intersection delay. Implementation of IDAS should consider how it fits with the balance of the travel forecasting process.

PRUEVIIN

PRUEVIIN is an evolutionary extension of current four-step transportation planning tools. It is designed to assess regional and corridor level impacts of ITS improvements in a corridor through use of the regional travel modeling process. It combines the use of the regional forecasting process and simulation modeling to produce a broad range of modal, trip and link based measures of effectiveness of ITS projects alone and in combination with traditional transportation improvements. It uses a set of representative scenarios to address the daily variability in travel demand, weather and incidents.

The PRUEVIIN framework is designed to support alternative analysis. It is particularly appropriate for alternative analysis at the corridor level (Wunderlich, *et al.* 1999). That is, a set of well-defined alternatives is proposed as potential solutions to meeting projected corridor travel demand. These alternatives may contain specific ITS components as well as traditional infrastructure construction components. Corridor level impacts of each alternative are predicted by the use of the meso-scale traffic simulation. Regional travel demand impacts are predicted by the traditional four-step regional planning model. A limited feedback mechanism is used between the two models to reflect changes in average or perceived corridor conditions that may impact regional travel considerations.

TRANSIMS

TRANSIMS is being developed as a region-wide activity-based simulation model to simulate activity chains of individuals, vehicles, and households. It is fine-tuned to represent impacts of integrated ITS systems. It has four major components: 1) Traveler and Transport Systems Data – to estimate activities to be accomplished by each individual during the course of the day; 2) Intermodal Travel Planning – to estimate travel modes and routes of individuals and vehicles; 3) Travel Microsimulation – to simulate actual network movement; and 4) Environmental Simulation – to use output from microsimulation to estimate emissions. TRANSIMS is still in a development and testing phase and its ability to function easily in a typical planning environment is not known at this time.

SCRITS

SCRITS (SCReening for ITS) is a spreadsheet analysis tool for estimating the user benefits of ITS. It is intended as a sketch-level or screening-level analysis tool for allowing practitioners to obtain an initial indication of the possible benefits of various ITS applications (Science Applications International Corporation, 1999). A baseline data such as vehicle miles of travel and vehicle hours of travel from regional transportation models are usually required as input to SCRITS. These baseline data are then compared to outcome (VMT and/or VHT) from SCRITS if ITS applications were employed. The purpose of this approach is to ensure that the results will be comparable to other analysis methods, such as travel demand models or simulation applications.

SCRITS is flexible for the user to specify the geographic/facility coverage, such as regional, corridor, facility, and subarea scales as long as the baseline data are consistent with the areas/facilities being analyzed. The estimated benefits results from SCRITS are on a daily basis, which can be expanded to an annual basis to enable calculations of economic benefit and comparisons to cost. The SCRITS results are not intended for individual peak periods or peak hours.

SCRITS can be best used to test the sensitivity of benefits to a series of assumptions and generate a range of possible results. The results are approximate and should be used as a “first cut" at the estimation of benefits for planning-level evaluation. It covers sixteen 16 different applications in the spreadsheet.

Metropolitan Model Deployment Initiative

The Metropolitan Model Deployment Initiative (Lee, Schimek and Farver, 1997) created a spreadsheet model that measures the benefit-cost ratio of over sixty ITS projects in Seattle, Washington. These projects have been identified to potentially produce impacts on travel such as expressway surveillance, transit automatic vehicle locator (AVL) and signal coordination. The basic premise of this spreadsheet model is that users of ITS deployments can change their travel behavior, which would have impacts on other users and the transportation system characteristics such as congestion, total travel time and emissions. Both users and non-users benefit. The models convert the impacts into monetary value according to cost parameters so that two or more alternatives can be directly compared. The parameters used include wait time, social costs, cost of congestion, emission rates, and schedule delay. Because the impacts occur at different points in time, they are discounted back to a common point in time, typically the current or a recent year. The results of ITS deployment are compared with a base alternative or "without" ITS scenario. The impacts are the differences between the "with" and "without" scenarios.

A Break-even Analysis of the Benefits of ITS Using SCRITS

True benefit-cost analysis cannot be done in a specific location without detailed before and after data on the actual performance of a system. This creates a dilemma, since the benefit-cost comparison is needed to help decide on implementation. Break-even analysis and sensitivity analysis provides a method to determine the minimum level of performance necessary for a system to have a level of benefits that equal its costs. The purpose of the break-even analysis is to identify critical performance variables in the assessment of ITS benefits and to determine their relative magnitude for an acceptable benefit/cost ratio. Such an analysis can be very useful since the results can be interpreted to see whether they appear reasonable and possible to obtain. For example, if a ramp metering system requires a speed increase of 12 miles per hour to break even on a highway that operates at a peak hour speed of 50 mph, it would not be a reasonable alternative since the resulting speed would be in excess of the normal free flow speed on an urban highway. However, if a two mph increase were required to break even on a facility with operating speeds of 35 mph, it would be a very desirable alternative.

A break-even analysis was conducted to estimate the benefits of ITS by adapting a spreadsheet model – SCRITS. SCRITS has been developed to offer a range of benefit estimates for ITS applications for planning purposes at the system (state or metropolitan) level. It should be noted from the outset that the estimated output are approximate and should be used for general planning purposes only, because the tool SCRITS is intended to be a "first cut" at the estimation of benefits for planning level assessment. Furthermore, the analysis focuses on user benefits at the system level only. Benefits of ITS that accrue to agency operations (e.g. staff efficiency, management effectiveness, etc.) are not considered, though these additional benefits to transportation agencies constitute some of the main reasons for implementing ITS. Thus, a narrative that describes the non-quantified elements of ITS benefits should accompany any analysis of ITS benefits.

There are 16 modules in SCRITS for 16 different applications, including:

Freeway Control Systems
- Ramp Metering

Traveler Information Systems
- Freeway Detection Systems
- Closed Circuit TV
- Highway Advisory Radio
- Variable Message Signs
- Pager or FM Sub carrier-based ATIS
- Traffic Information Kiosks
- Internet Traffic Information

Transit Systems
- Bus AVL system
- Bus Fare Collection Systems
- Bus Signal Priority Systems

CVO Systems
- CVO Kiosks
- Weigh in Motion Systems

Other Systems
- Railroad Crossing Systems
- Electronic Toll Collection Systems
- Traffic Signal Systems

This study does not consider the transit or other related modules of SCRITS and concentrates on highway ITS applications likely to be implemented in Wisconsin, i.e., Ramp Metering, Freeway Detection Systems, Closed Circuit TV, Highway Advisory Radio, Variable Message Signs, Traffic Information Kiosks, Internet Traffic Information, CVO Kiosks, Weigh in Motion Systems and Traffic Signal Systems.

The SCRITS benefit-cost analysis process is relatively straightforward. Costs of each element are put on an annual basis by using an annualization factor for capital costs and adding the annual operating and maintenance costs. Benefits can be timesavings, crash cost reductions or in some cases the dollar value of reductions of emissions. For each module assumptions must be made of the performance of the system before and after it is installed. Typically these include estimates of the number of persons who receive the benefit, the magnitude of the benefit per person and a valuation of the benefit in dollar terms. For example, ramp-metering benefits are determined by looking at average operating speeds on the freeway and parallel arterials before and after implementation. These are used to calculate a net change in vehicle hours of travel. Ramp delay is also estimated and added to the vehicle hour total. The analysis is done for each direction of the highway for peak, off peak and weekend time periods (depending on when the system operates). The savings in vehicle hours is then multiplied by a value of time to determine the benefits.

Assumptions

General assumptions are made of various parameters to conduct the analysis. For the examples discussed in this paper, these are as follows:

Financial Assumptions:

- Discount rate – 5 %
- Value of time – $9.85 per vehicle hour
- – $21.13 per truck vehicle hour
- Cost per accident – $15,000
- Reduction in crashes due to metering – 20%
- Weekdays per year – 250

Baseline Data and Traffic Assumptions

The baseline data for this analysis was derived from the design study report for a pilot ITS deployment project on the Madison Beltline in Dane County, Wisconsin (HNTB Corporation and Transcor, 2000). This project envisions deployment of ramp meters, detection systems and traffic condition cameras along overlapping routes of USH 12/14/18/151 on the Madison beltway south of the city. The roadway section is twelve miles long and the project will have five locations with ramp meters (four westbound and one eastbound), five locations with video cameras, and fifteen locations with roadway detection systems. These elements would be linked to a central facility for freeway monitoring and control.

Traffic levels were derived from WDOT traffic volume reports and the project design report. These were a daily VMT (vehicle miles of travel) of 1,204,000 for the freeway and 200,000 for adjacent arterials. It was also assumed that there was a 50/50 directional split in the traffic with 26% of the volume occurring in the westbound direction and 28% in the eastbound direction volumes during the peak three hours each day for both the arterials and the freeway. Westbound ramp metering was applied to 33% of the westbound traffic (two of six interchanges metered) and to 20% of the eastbound traffic (one of five interchanges metered). SCRITS uses these numbers to determine the traffic affected by the metering. Affected VMT is the product of total VMT, directional split, peak percentage and ramp metering coverage. Freeway timesavings and arterial delays were calculated based on the affected volume and the speed differentials as a result of metering. Average ramp volumes during the peak periods were 1600 vph westbound and 5500 vph eastbound. Ramp delays are applied to these volumes.

A Note of Caution:

Any analysis is only as good as the data it uses. In order to do the break-even analysis as outlined in this report, assumptions had to be made about the costs and performance of the various ITS elements. Attempts were made to use realistic data, but it should be recognized that the scope of this project did not permit an exhaustive effort to gather and verify data. The analysis herein uses the Madison beltline data as a basis to test the model and to develop break-even curves. Although the data was derived from the Madison beltline study, numerous assumptions had to be made to make it compatible with SCRITS. The assumptions need to be reviewed and examined by persons familiar with the project before the results shown here are directly used for the beltline.

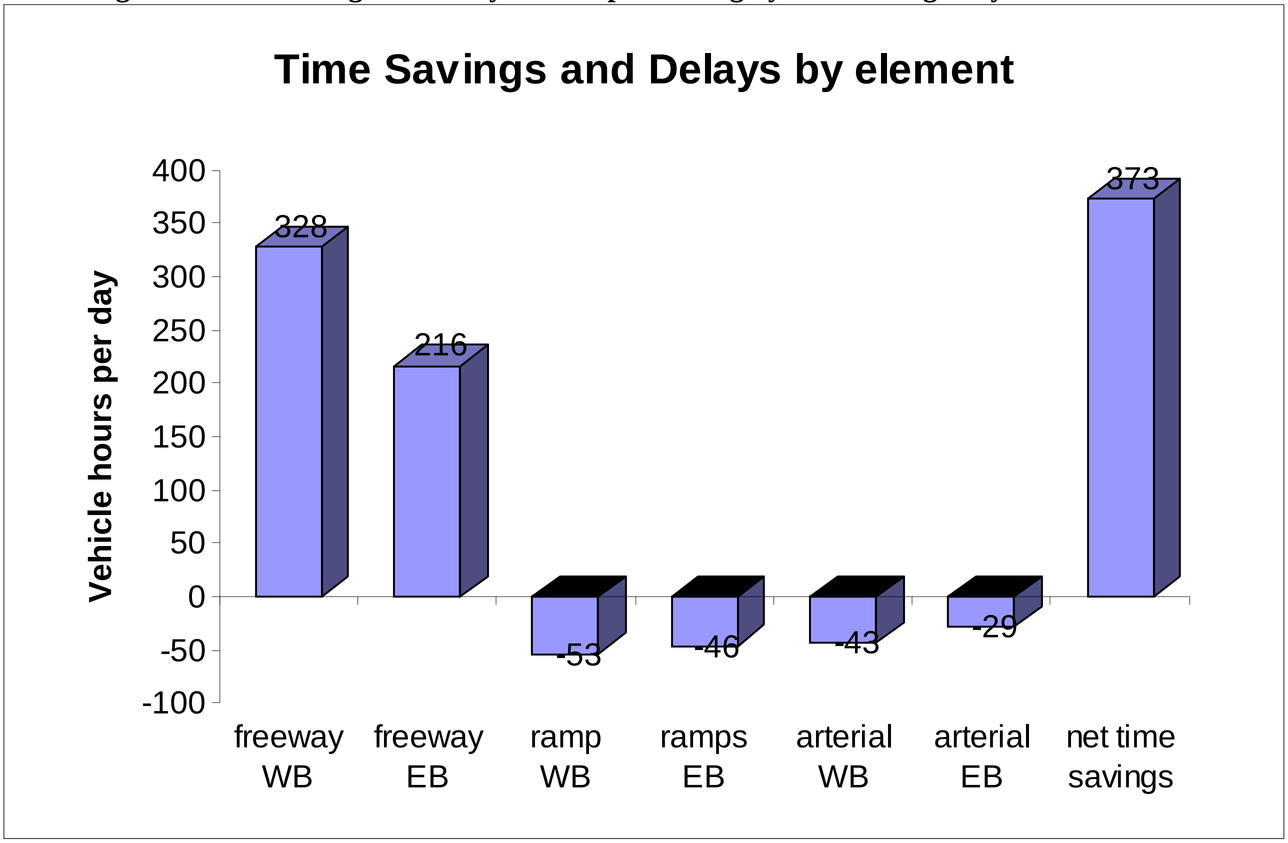
Furthermore, SCRITS analyzes one ITS element at a time and does not have a good way to deal with combinations of elements, except by the judgment of the analyst. When combinations of ITS components are being looked at, special attention is needed to determine how they collectively lead to benefits. SCRITS is a screening tool that provides order of magnitude estimates and indicates circumstances where ITS projects are likely to have good results. It is not intended as a substitute for more detailed analysis.

Break-even Analysis Results

Ramp Metering

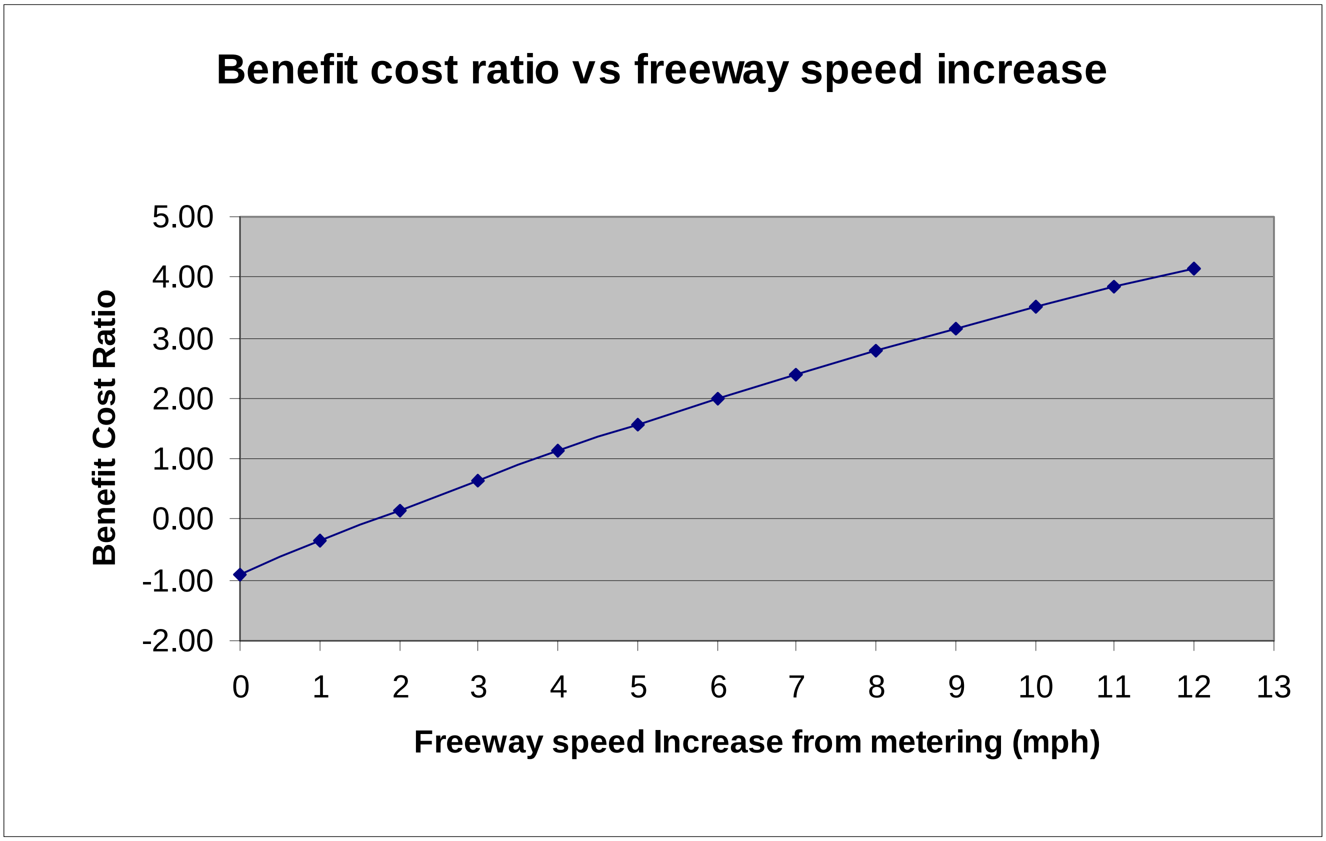
Benefits from ramp metering are primarily based on accident reductions and the expected increase in speeds from ramp metering minus delays on parallel arterials and ramps. There are positive benefits if ramp metering saves freeway vehicle time that exceeds the increased delays on arterials and ramps. Figure 4 indicates the timesavings and delays by element types assuming a 10 mph increase in freeway speeds, a 4 mph decrease in arterial speeds and an average delay of 30 seconds per vehicle of ramp delay and a reduction in crashes of 20% for the Madison beltline example. The example shows that with these assumptions, the freeway timesavings exceeds the arterial and ramp delays and that the project would have a large timesavings benefit with these values (Figure 4). The actual magnitudes of the numbers will vary considerably depending on assumptions made about the performance of the various elements.

Figure 4. Timesavings and delays of ramp metering by affected highway elements.



The break-even analysis helps to provide insight into the circumstances that have a positive benefit/cost performance. The level of the benefit/cost ratio varies directly with the increase in freeway speeds as shown in Figure 5. The project breaks even when the speed increase is about 3.7 mph with the data used in this analysis. With this speed, the freeway timesavings are equal the delays on the ramps (30 sec per vehicle) and arterials (4 mph decrease in arterial speed). It should be pointed out that this analysis does not consider shifts in traffic volumes between facilities. For example, ramp metering may increase speeds and attract additional traffic from adjacent arterials or from other sources. This may in turn reduce speeds on the freeway as a new equilibrium point is reached. Data would be needed on the extent of such shifts to incorporate them in the analysis.

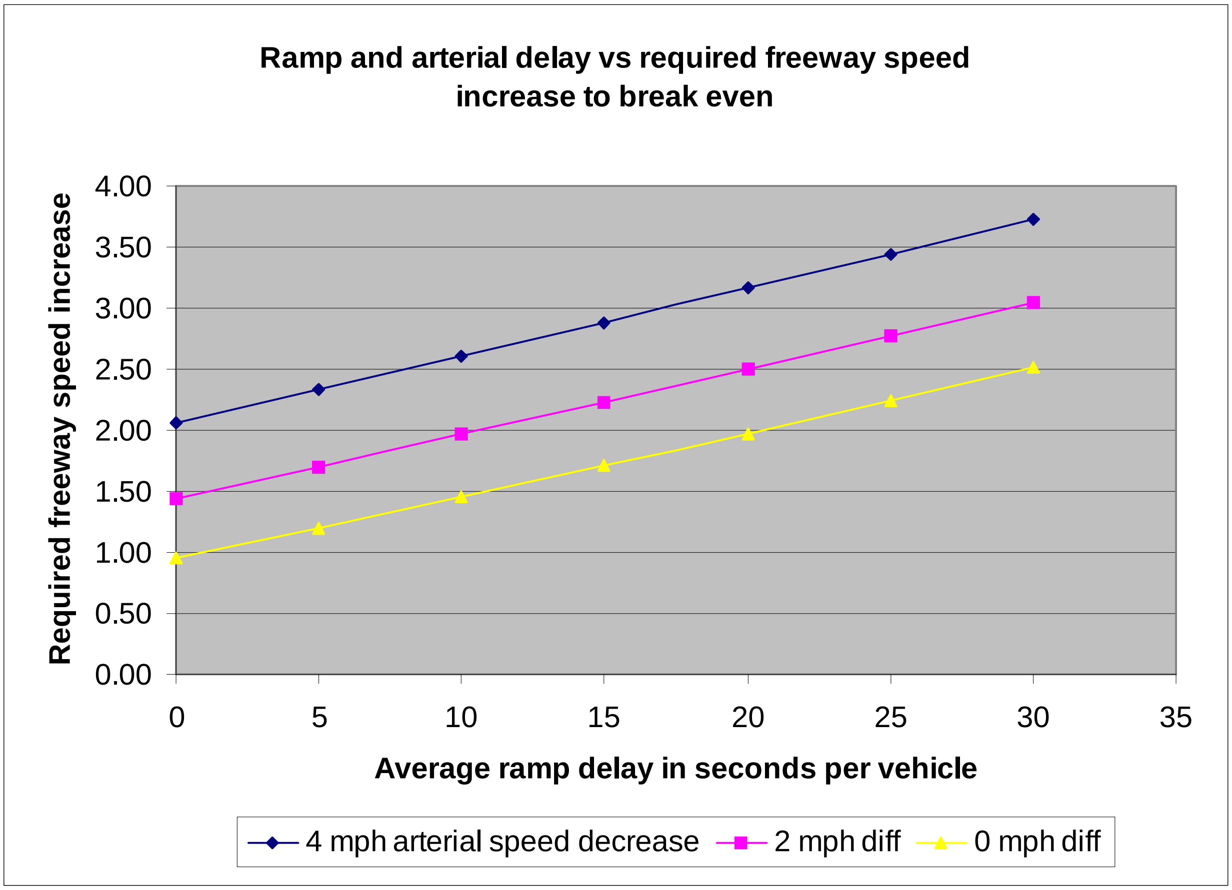
Figure 5. Benefit/cost ratio based on different highway speed improvement from ramp metering.



Additional break-even analyses were done to determine combinations of speed changes and delay that are needed to cover the annualized costs of the ramp meter installation. Benefits were set equal to the annualized costs and the equations were solved backwards to find the required freeway speed increase for various combinations of ramp delay and arterial speed decreases. The results of this analysis are shown in Figure 6. Crash reductions were held constant for these examples.

In this situation, the required freeway speed increase varies somewhat with assumptions about arterial and ramp delays. A freeway speed increase of 0.9 mph is needed when there is zero delay on arterials and ramps in order to cover the annual costs of the metering. Beyond that there is a variation of about 3 mph between the extremes indicating that in this example, the ramp metering is not very sensitive to assumptions about operational delays. The break-even speeds are well below the expected gains from metering as reported in detailed CORSIM analysis as done by Strand Associates for the project (Strand Associates, 2000). This indicates that the project will likely have substantial benefits if it results in even a small increase in freeway speeds.

Figure 6. Break-even points of highway speed improvement based on ramp and arterial delays.



Finally, a break-even analysis was done between traffic volume and freeway speed increase. These results are shown in Figure 7 with various levels of ramp delay. As traffic volume increases, it requires less speed improvement on the highway to break even. The break-even speed improvements also vary with the level of ramp delay. This analysis does not include the decrease in speeds that would also occur from a declining level of service that may result from increased volumes.

From this analysis, several conclusions can be drawn:

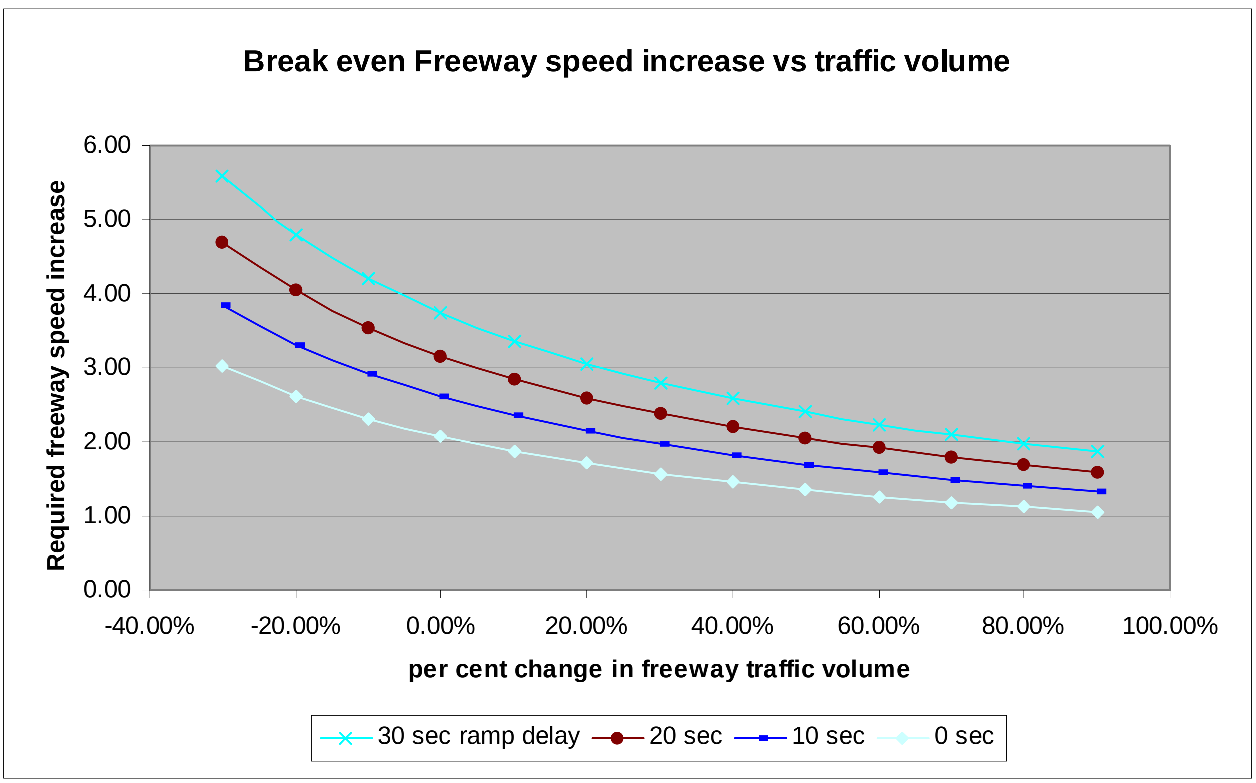
- Installation of a ramp metering system involves tradeoffs between increased freeway speed vs. delays on ramps and nearby arterials. Delays on ramps and arterials must be offset by speed increases on the freeway itself and/or by crash reductions in order to have a positive benefit/cost ratio.

- Key performance indicators for ramp metering systems are the speed increase on the freeway, average delay per vehicle on metered ramps and speed decrease on adjacent arterials, and changes in freeway traffic volumes.

- Ramp metering is likely to have a significant benefit/cost ratio in situations where freeways face peak hour congestion. Relatively small increases in freeway operating speeds (about 3.7 mph in the metered region for the case study) are necessary in order to have a positive benefit/cost ratio. These increases remain small across a range of delay values for ramps and arterials. Based on the 20% to 30% speed improvement reported in Seattle, Minneapolis and other cities (Turner *et al.*, 1998), the magnitudes of the increase shown in the case study should be attainable in most situations, especially when freeways operate at a poor level of service.

- In situations where freeway volume is relative low but the entering ramp volumes are very high, ramp metering systems may make less sense since ramp delays could be considerable as compared to gains in freeway performance.

Figure 7. Break-even highway speed improvements for different traffic volume.

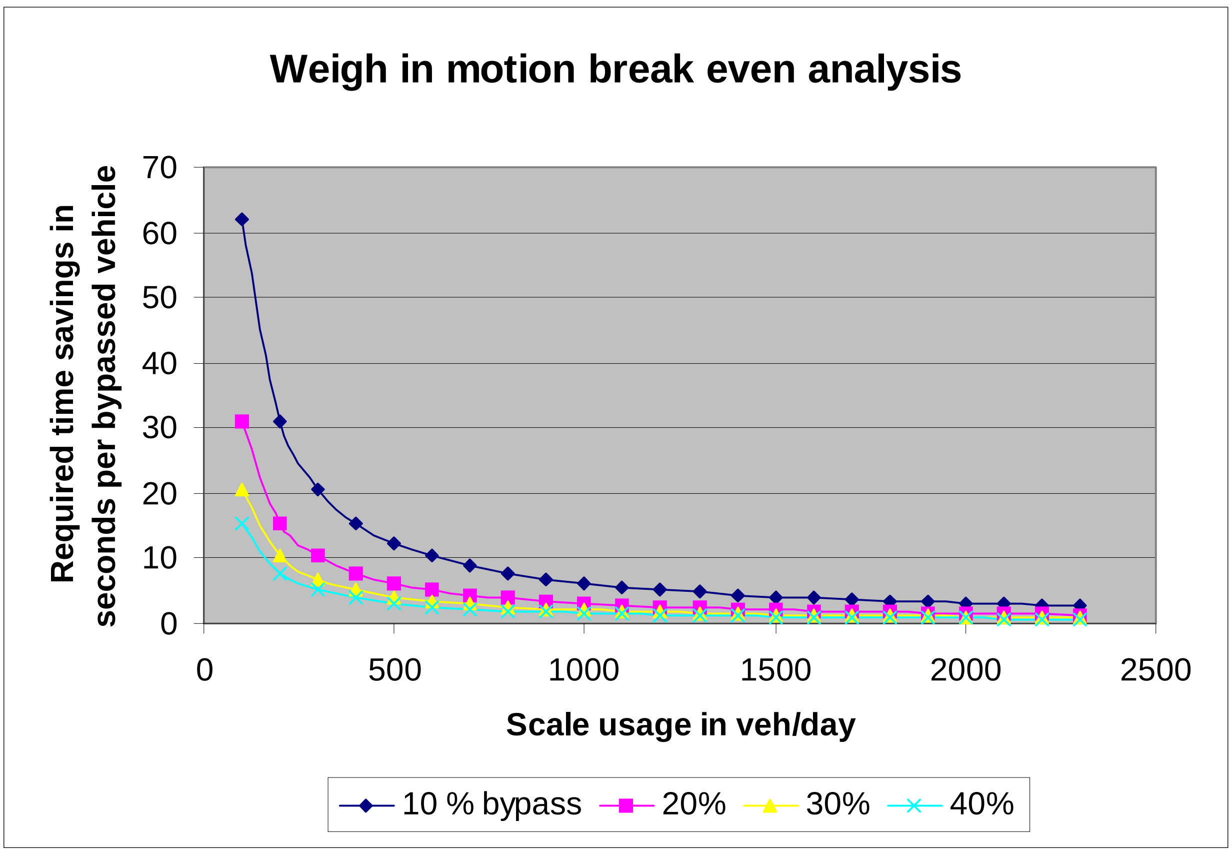


Commercial Vehicle Operator Systems

There are a variety of CVO systems. Our analysis considered weigh in motion systems. The benefits from timesavings and vehicle operating cost savings as a result of bypassing static scales are calculated. For this analysis data supplied with SCRITS was used. This was a single scale with 5000 vehicle per day usage and an average delay of 4 minutes per vehicle. The cost of the scale was assumed to be $200,000 with a seven-year life and an annual operating cost of $20,000 per year. Vehicle operating cost was given as 30 cents per stop. Bypass rate, timesavings per stop and scale usage were varied in the break-even analysis with the results as shown in Figure 8.

As the chart shows, the break-even point is a relatively low number in nearly all cases. A minute or less timesavings per bypassed vehicle can create benefits that easily covers the annual costs of a system with the data as used. The break-even point drops sharply with traffic volume at the scale and with higher bypass rates. It appears that a weigh in motion system that allows vehicles to bypass static scales is a good investment in nearly all cases except when the volume of vehicles that would use it is very low.

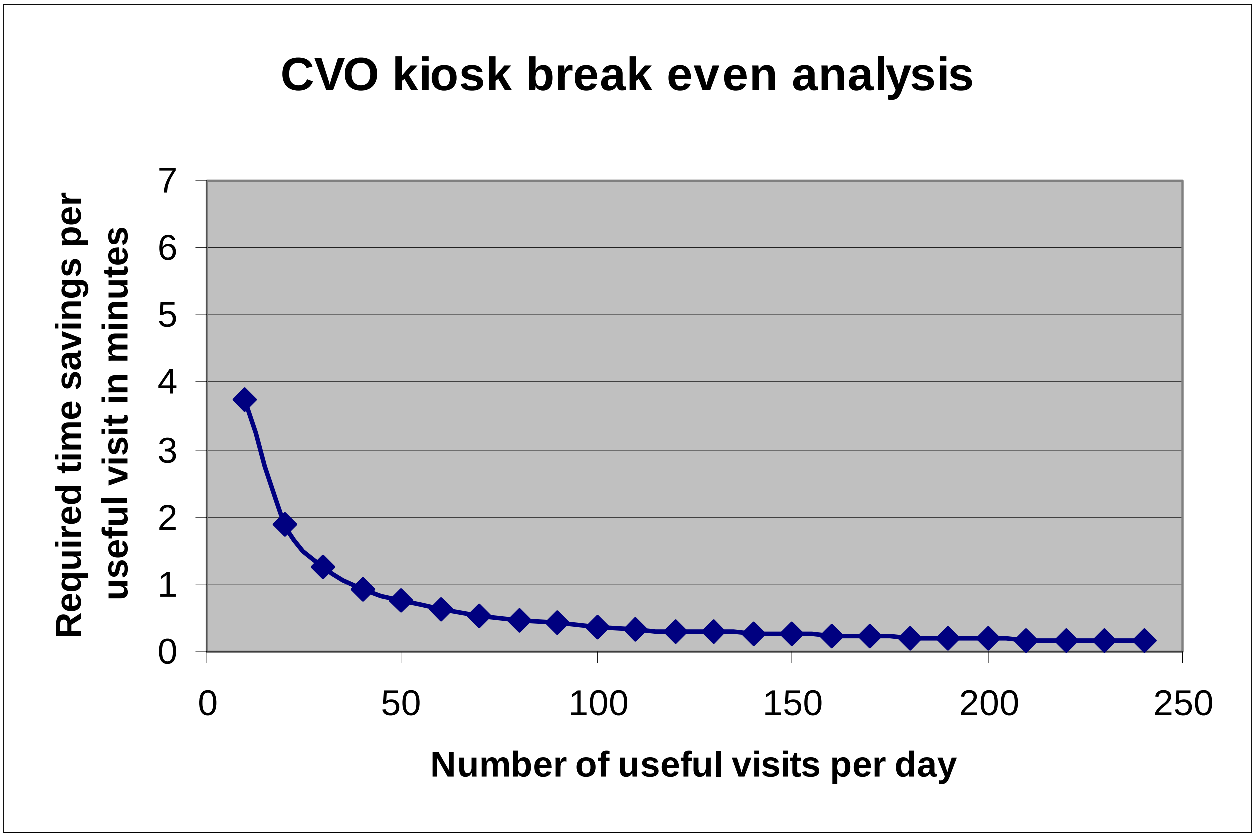
Figure 8. Weigh in motion break-even analysis.



CVO Driver Kiosks:

CVO driver kiosks are assumed to be located at truck stops or similar sites and would be used to provide drivers with information about congestion on the surrounding highway system. Benefits occur when drivers can use this information to save time by taking alternative routes. There is a strong relationship between benefits of such a system and the level of kiosk use and its ability to provide useful information as shown in Figure 9. If the kiosk has only few persons who use it and receive useful information, then the break-even timesavings has to be high. As the number of useful visits increases the break-even point drops rapidly. This indicates that CVO kiosks need to be deployed in locations where there are high numbers of drivers, in situations where traffic conditions are highly variable and in places where there are a variety of alternative choices available for alternative routing to avoid delays.

Figure 9. Break-even analysis for CVO kiosks.



Other CVO Systems

In addition to the CVO systems discussed here there are other systems that may have significant benefits. Methods to increase the efficiency of credentials administration area may provide positive benefit cost ratios and increases of the efficiency of freight movement. The overall framework used here can be adapted to look at such systems. What is required is a quantification of timesavings and/or administrative cost savings that can be set equal to costs to determine break-even values. In the CVO area, there is a further issue of who should pay for the costs and policies need to be developed to relate fees for services to benefits and costs of systems. The issue how costs are allocated and who pays of it is beyond the scope of this study.

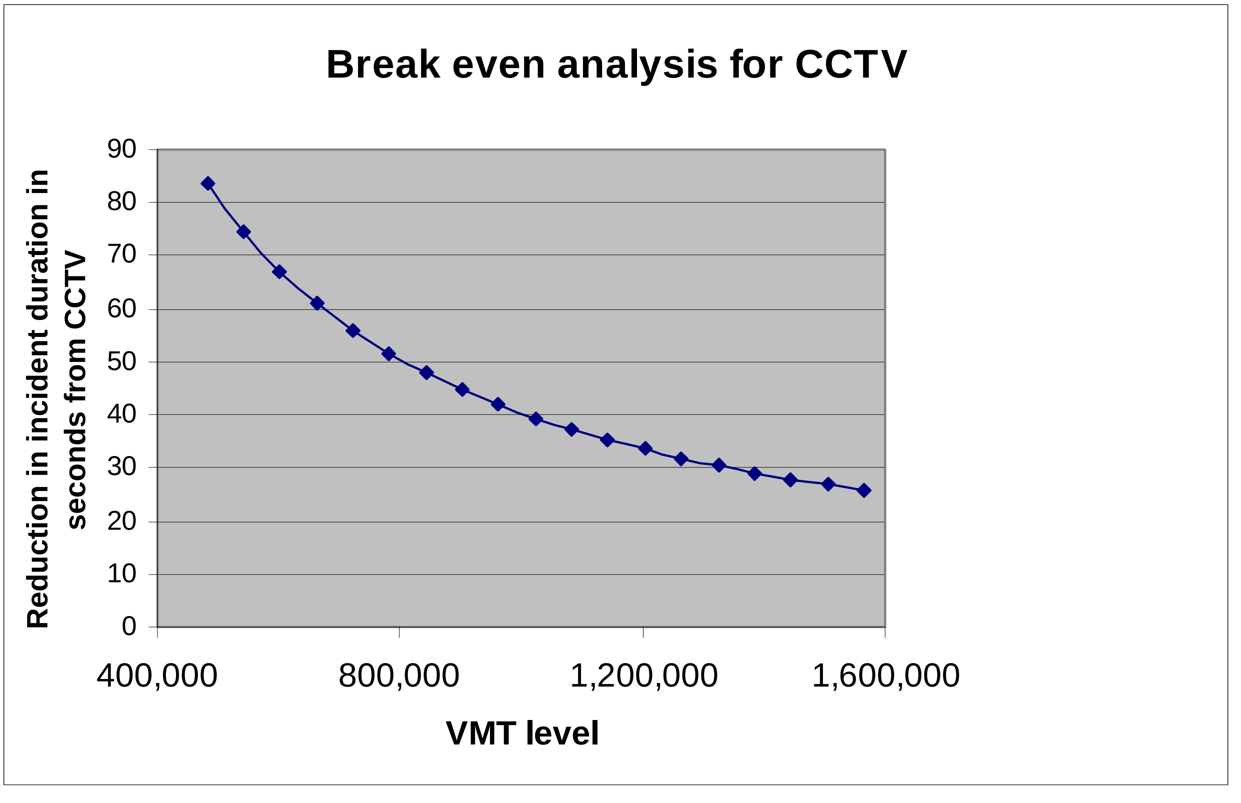
Traveler Information Systems:

There are many options in traveler information systems. Some options relate to highway incident management, such as detection systems and CCTV video. Others are travel information dissemination methods, such as Highway Advisory Radio, Variable Message Signs, Pager or FM Sub carrier-based ATIS, Traffic Information Kiosks and Internet Traffic Information. SCRITS determines benefits on the basis of the reduction of incident duration and the number of affected motorists that use the information. Since each module of SCRITS is separate, results of the break-even analysis must be interpreted carefully. If a combination of elements is used, their timesavings and incident duration reduction needs to be the sum of different components of the traveler information systems. SCRIPTS does not offer a way to calculate the cumulative benefits of different components.

CCTV

The Madison beltline project will have five camera locations and it was assumed that each camera could cover ¼ mile in each direction, giving CCTV coverage of 19% of the roadway length. Although SCRITS calculates the emissions reductions from the system, these numbers are not used in their benefit/cost analysis. SCRITS uses a table look up process to determine a ratio of incident related delay to non-incident related delay as a function of peak hour traffic ratios and the presence of shoulders on the freeway. Reductions in vehicle operating costs are also included, and benefits are determined over an entire week, including weekends. The default lookup table from SCRITS was used in this analysis. The ratio of average, annual daily traffic to capacity was set to yield an average peak hour traffic speed of 45 mph. With these assumptions and the cost data as given earlier, the break-even results are shown in Figure 10.

Figure 10. Break-even analysis for CCTV.

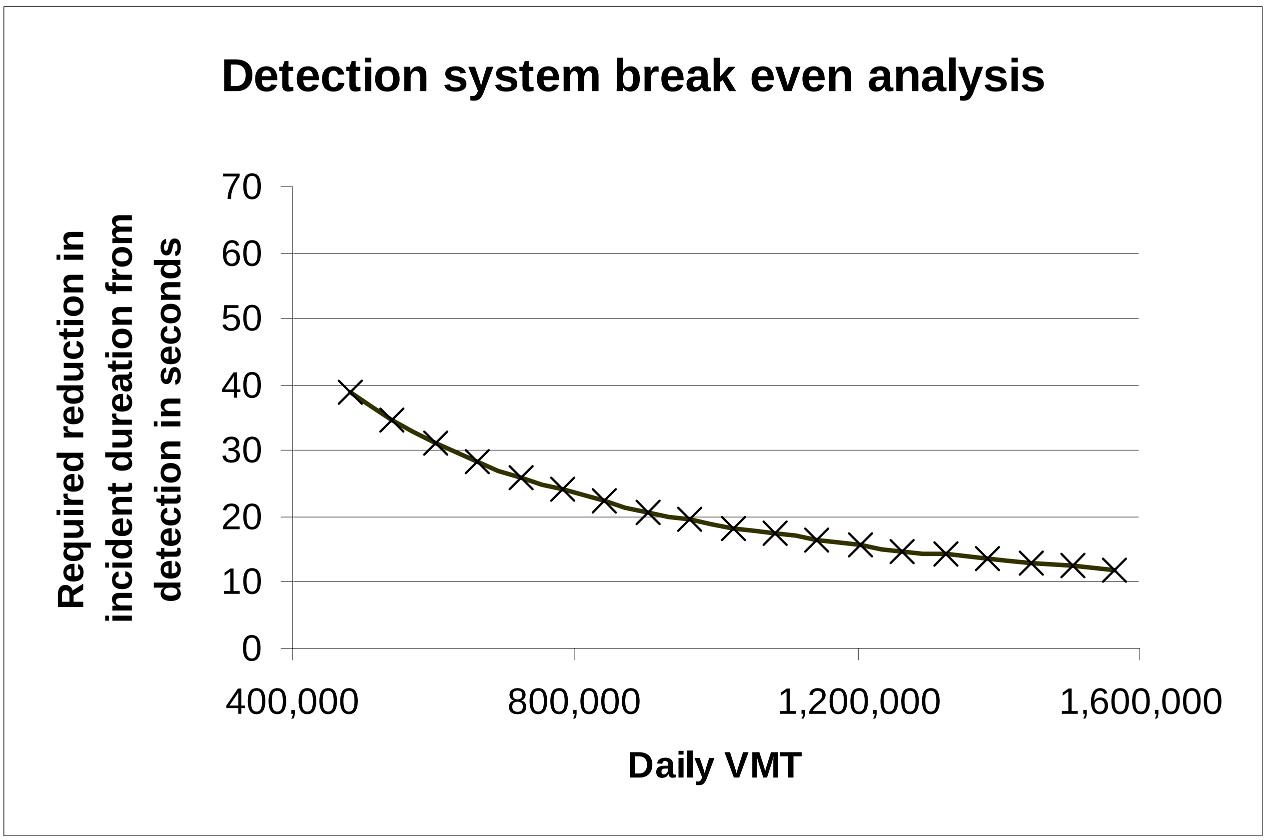


The analysis indicates that relatively small reductions in incident duration are needed to provide a break-even benefit/cost level. VMT on the case study is about 1,200,000 per day and this requires a reduction of about 34 seconds in incident duration to break even. A variation in traffic volume has an effect on the break-even point, but the required timesaving are relatively small at all traffic levels. The traffic volume results should be viewed carefully since the AADT to capacity ratio is not changed with the lower traffic volumes.

Detection Systems

Analysis of the detection system is similar to that of the video system using the same set of assumptions and traffic data. The break-even results are shown in Figure 11. The break even numbers are about half of those of the CCTV system, because of lower annual costs. Like the CCTV, the magnitude of the break-even values is small. At the base VMT of about 1,200,000, only a 15 second reduction in incident duration is needed to have a benefit/cost ratio of 1.0.

Figure 11. Break-even analysis for the detection system.

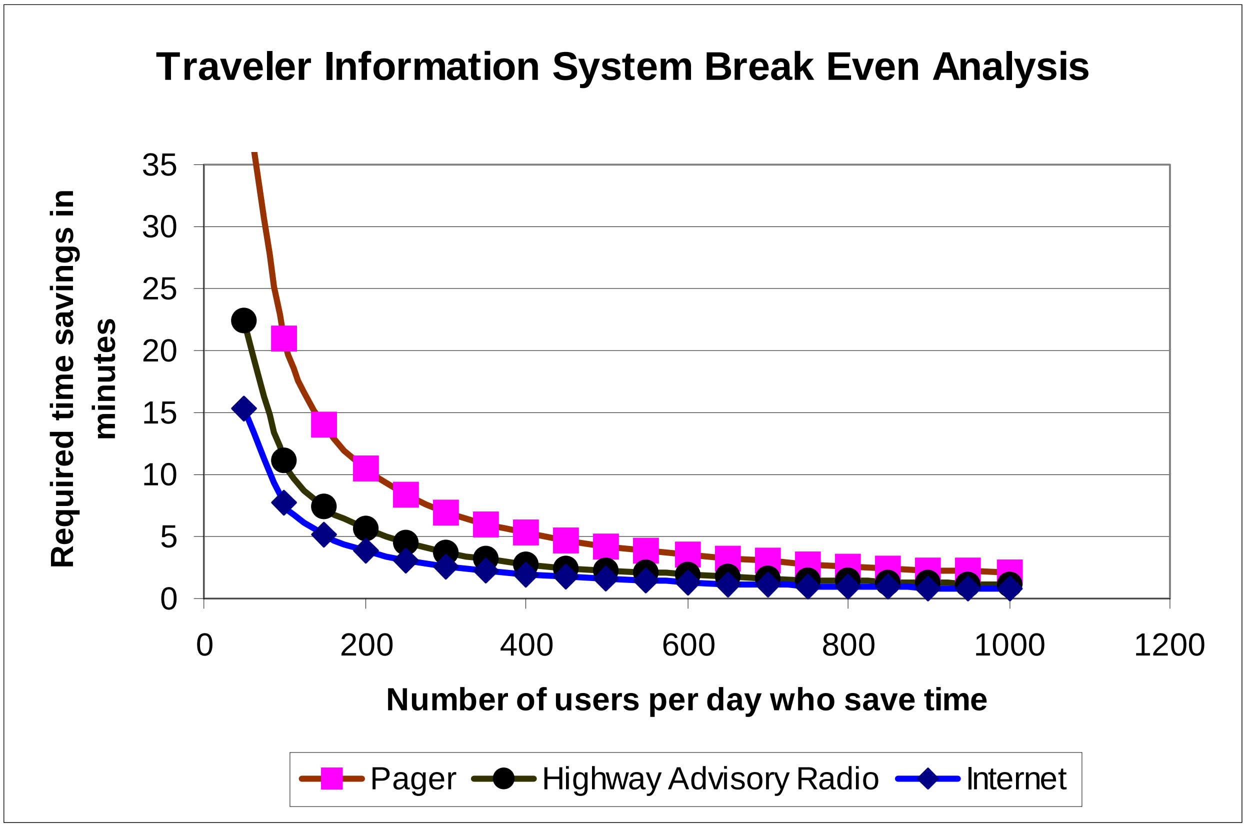


Highway Advisory Radio, Pagers and the Internet

For benefits to occur with these systems, drivers must be able to use this information to save time by taking alternative routes or otherwise changing their travel pattern. There is a strong relationship between benefits of such a system and the level of successful use and its ability to provide useful information as shown in Figure 12. If the system has only few persons who use it and receive useful information, the break-even timesavings have to be high. As the number of successful uses increases the break-even point drops rapidly. The break-even points for highway advisory radio, pagers and the Internet are shown in Figure 12. The break-even points for pagers are higher than the radio because of a shorter project life of the pager system. The break-even points are lower for the Internet information systems than for the other methods because of relatively low initial costs for web page setup and design.

This indicates that the highway advisory radio, pagers and the Internet information systems need to be deployed in locations where there are high numbers of drivers, in situations where traffic conditions are highly variable, where there are good alternative routes available and in places where useful information can be supplied from other traveler information systems.

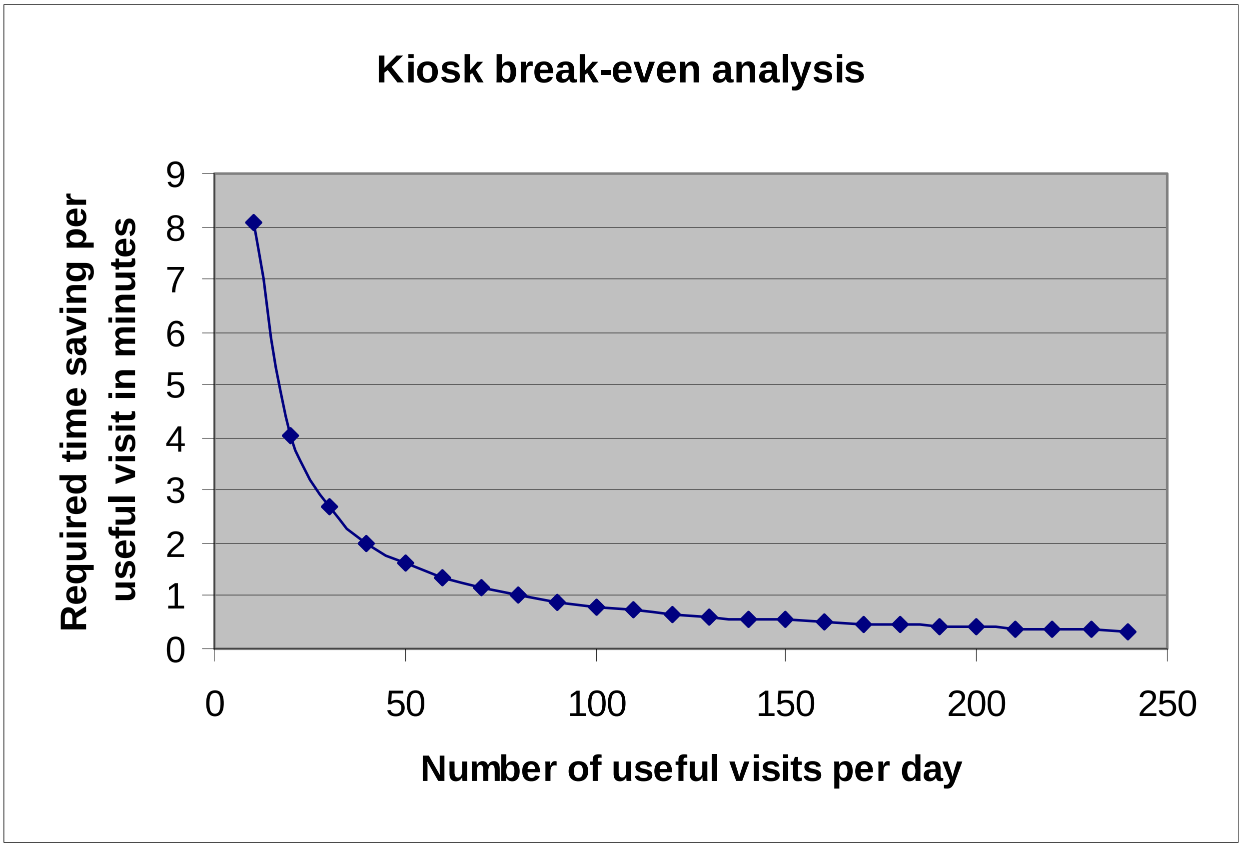
Figure 12. Break-even analysis for traveler information systems.



Kiosks

Kiosks could be provided at work locations or at major trip generators to provide real time traffic information to travelers. Like the other systems, the benefits of kiosks depend on the number of times they provide useful information. Kiosks at locations with large numbers of potential users will have proportionally more benefits than sites with few potential users. The break-even point drops rapidly with successful uses as shown in the figure. The x-axis scale is smaller than for the other systems because of the limitations on the number of users who can visit a kiosk in the course of a day. The break-even points are about twice as large as with CVO kiosks because of a lower value of time (Figure 13).

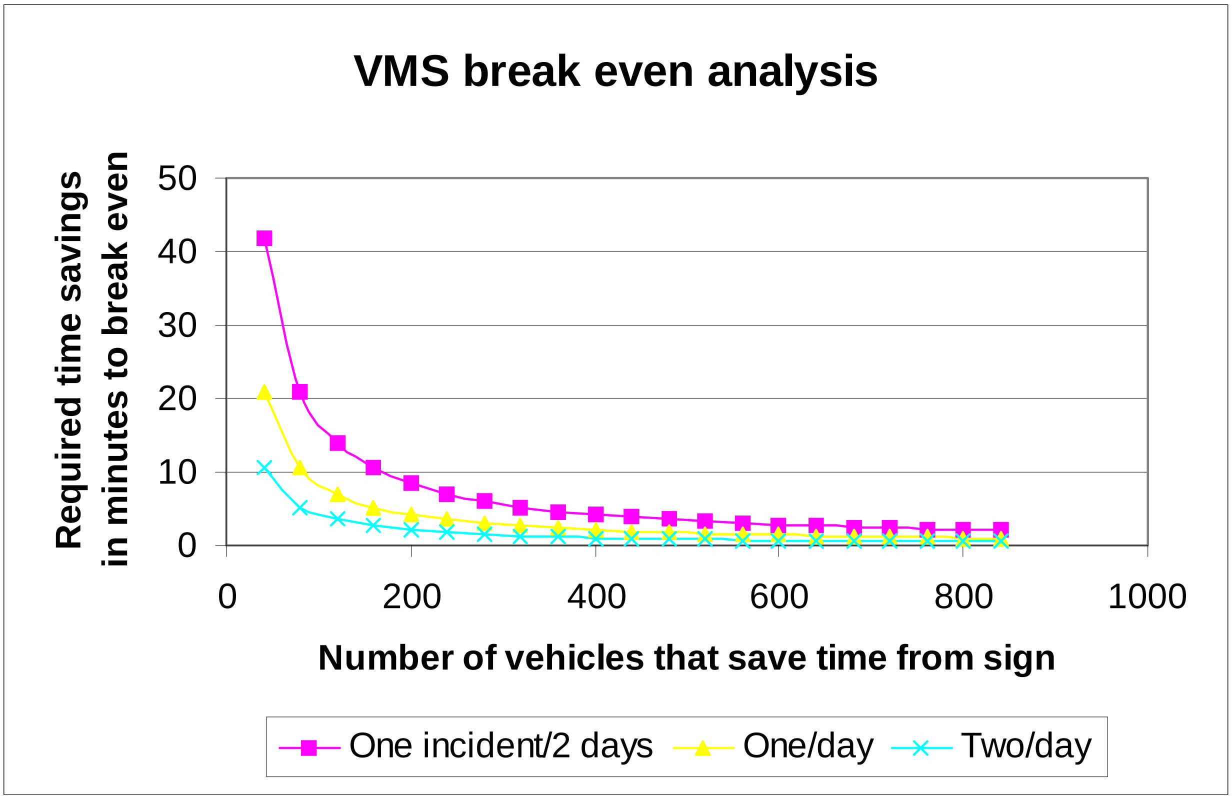
Figure 13. Break-even analysis for kiosk systems.



Variable Message Signs

The benefits of variable message signs depend on how often it is used and the savings that vehicles experience from the use of the sign. Cost data and other parameters used were the default data from SCRITS. The break-even analysis results are shown in the next figure. Frequency of incidents makes a big difference in the break-even points. If the sign is only used occasionally to report incidents, and few vehicles can change their routes, the break-even times are quite high (Figure 14). Signs have good benefit/cost ratios when there are higher frequencies of incidents and travelers have good options that can save them time.

Figure 14. Break-even analysis for variable message signs.



Summary of Break-even Analysis of Traveler Information Systems

From the break-even analysis for traveler information systems, the following conclusions can be drawn.

- Systems that detect highway incidents such as CCTV and vehicle detection systems have very low break-even values. Such systems need to reduce incident duration by a minute or less to have a benefit/cost ratio of 1.0 or more over a wide range of traffic volumes. A small time reduction in responding and clearing an incident can lead to large benefits. Based on the observed response time reduction between three and five minutes reported in Atlanta and San Antonio (Turner *et al.*, 1998), incident detection systems could have large benefits.

- The benefits of alternative means of providing traveler information (highway advisory radio, pagers, kiosks, Internet and variable message signs) depend on the ability of users to make adjustments in their travel patterns as a result of the information and the number of users of each system. Systems that serve a large number of users at once such as pagers, Internet, or highway advisory radio have advantages over kiosks, which can only serve a few users at once.

- Traveler information systems benefits derive from the ability of drivers to use the information to select alternative routes or other travel options that allow them to avoid incidents and have reduced travel times.

- The benefit/cost benefit for variable message signs depends on the frequency with which they are used to report incidents and the ability of travelers to save time as a result of the information. Priorities for installation should be at locations where there are good alternative routes available and where there is a high frequency of incidents.

Discussion

The benefits discussed in the break-even analysis are only a partial picture of what would occur if various ITS systems were deployed. The calculated benefits are for the whole system and will vary for individual users. In some cases, external benefits at the system level may lead to internal benefits at the individual traveler level. For example, a good throughput may transfer to timesaving for individual travelers. But in many other cases, an overall benefit may not lead to an individual's internal benefits. For instance, ramp metering may lead to increased vehicle throughput along a freeway corridor, but it may lead to delays for ramp meter users, especially for short-distance commuters. Similarly, a good internal benefit for individual travelers may not lead to good external benefits either. For example, if most people get the same real time information and make the same decision (either delay the trip or take an alternative route), that information may worsen traffic on the adjacent highways.

Users' internal benefits of ITS are more difficult to measure than benefits at the system level. For example, a user of an advanced traveler information system would find the real time traffic information before the trip very valuable, so he/she can save travel time by shifting start time. But the value of that traveler information system will vary depending on the user and the user's travel behavior changes. If the traveler decides on changing route, the internal benefits can be directly measured using the attribute changes (e.g., timesaving) (Lee and Klein, 1997). But if the user decides to go ahead with the trip anyway or change travel destination, using timesaving could become problematic. If the user decides to go ahead with the trip, he/she could be psychologically more prepared. In this case, a congested travel becomes a "serene" travel (Lee, 1999) even though the travel time does not change, or the traveler can inform others about his/her travel status so that other party is more prepared. If the user decides to change travel destination, direct comparison of travel timesaving is difficult. To properly measure the value the traveler put on the advanced traveler information system from an economic sense requires the direct measure of consumer surplus, which requires a stated preference survey to elicit a dollar value which reflects the consumer's willingness-to-pay.

Data Requirements

The research provides some guidance of the types of data that should be collected to analyze the benefits of ITS. Most of the analysis conducted in this study measured benefits in terms of timesavings. Or crash cost reductions. Ramp metering systems need data on speeds and traffic volumes on the freeway, adjacent arterials and ramps. In addition ramp delay information is necessary to determine timesavings benefits of metering systems. In the case of detections systems, information is needed on how the detection system affects the duration of incidents on the highway and how travel times are affected by the incident. Traveler information system benefits depend upon the number of users that can make changes in their travel as a result of better information and the amount of time that they save as a result of better information. Benefit assessment of CVO systems depends on timesavings that vehicle operators receive as a result of better technology. Along with the time savings for all types of ITS, good cost data and cost allocation methods are needed to properly conduct a benefit cost analysis. Finally it should be noted that there potentially are many other benefits of ITS that may occur as shown in the benefit trees. It was not possible within the limited scope of this study to provide methods to assess other benefit types. This does not mean that they are unimportant and a comprehensive analysis should consider a wider set of benefits

Conclusions

This study shows that simple spreadsheet methods such as SCRITS can be adapted to provide screening tools for ITS project assessment with limited data requirements when supplemented with break-even and sensitivity analysis. In particular, break-even analysis offers a method to screen promising ITS projects and provide considerable insight into the sources of benefits for ITS systems and into the relative size and sensitivity of benefits. These are reported in detail in that section.

There is significant variance in the complexity and details of ITS evaluation methods. The desired evaluation method depends upon the intended end use of evaluation results. For example, one may need an extremely sophisticated evaluation framework if the true economic impact to society is to be determined. A less complex evaluation framework may suffice, however, if the results are used to prioritize ITS projects or to track annual progress toward goals. Another consideration is the cost and availability of data. Complex evaluation frameworks and methods may appear conceptually sound but may be very expensive to perform. For statewide sketch planning purposes, a spreadsheet model like SCRITS may suffice, but for more detailed analysis at the metropolitan level, more detailed methods such as IDAS should be used. Whatever method is used, it should be accompanied by extensive sensitivity and break-even analysis to determine the importance of specific assumptions in the assessment of benefits.

Given the understanding that the conclusions may change with more extensive data, some of the key findings are as follows:

- ITS systems can be more logically selected and deployed when knowledge of their performance tradeoffs are known.
- ITS systems can have significant benefits that easily exceed their costs. These benefits are especially likely to occur if the existing level of performance of the highway is poor.
- Other effects such as increased peace of mind, crash reduction, greater reliability in arrival times, non-traveler benefits, agency benefits and environmental benefits cannot be easily quantified but would add to the benefits of an ITS.
- Ramp metering systems benefits depend on tradeoffs between increased freeway speeds with metering vs. ramp delays and arterial speed decreases. Ramp metering projects should be concentrated on places where the level of performance of a highway facility is poor and ramp volumes are moderate.
- Weigh in motion systems appear to have a positive net benefit even with small levels of usage.
- Systems should be implemented in a way to minimize incident duration. This is an area of very high potential benefits.
- Mechanisms to disseminate real time traffic data should be actively explored to provide the best use of a traveler information system.

It should be noted that the break-even analysis using SCRITS was done with limited data and it has potential as a tool for project identification and sketch planning. The inputs to SCRITS should be carefully scrutinized prior to its widespread use as a screening and benefits assessment tool for ITS projects. Such data should include before and after studies of ITS deployments as well as refined cost data and traffic flow estimates. An extremely sophisticated evaluation framework may be required, and very detailed data needed to determine the true economic impact to society. Whatever method is used, it should be accompanied by extensive sensitivity and break-even analysis to determine the importance and robustness of specific assumptions in the determination of benefits.

Recommendations

It appears that methods such as SCRITS can be adapted to provide screening tools for ITS project assessment. In particular break-even analysis gives a method to identify promising

ITS projects and to determine the critical factors that lead to significant benefits. The following recommendations are made:

- Efforts are needed to provide better data to be used in ITS project screening and assessment. The inputs to SCRITS should be carefully scrutinized prior to its widespread use as a screening and benefits assessment tool for ITS projects. Such data should include before and after studies of ITS deployments as well as refined cost data and traffic flow estimates.

- The break-even approach as developed in this project can be adopted as a method for ITS project selection. ITS projects should be accompanied with a benefit/cost analysis that reports quantified benefits as well as other effects that cannot be quantified, such as those shown in the benefit trees. In addition life cycle costing methods should be explored to enhance the process of project selection.

- Consideration should be given to add sections to the Facilities Development Manual to describe how to identify and analyze ITS projects using the SCRITSUWM spreadsheet

- Any analysis that is used for project selection and screening should be accompanied by sensitivity and break-even analysis to build confidence in the results and lead to more informed decision making.

- Ramp metering projects should be concentrated on projects where the projected level of performance of a highway facility is poor. Situations where freeway speeds are low and ramp volumes are moderate are particularly likely to have high benefit/cost ratios.

- Incident detection and traveler information systems should be concentrated on projects where there is significant incident related delay and where good alternative routes are available. Internet information systems and highway advisory radio appear to have a good likelihood of favorable benefit/cost ratios with even low levels of utilization.

- Weigh in motion systems appear to have very low break even points and can have a good benefit/cost ratio, even if bypass rates are relatively low.

- Use of other procedures for ITS analysis and assessment should be explored. In particular IDAS has a good potential for application to ITS project selection and assessment. To be effective it needs to be coupled with good, up to date four step travel demand models. Such models need to be based on good data and be sensitive to a variety of conditions such as intersection delay. Implementation of IDAS should consider how it fits with the state of the art in the travel forecasting process

- The framework for assessment should be expanded to provide for the assessment of ITS project types not considered in this project. Some to consider are rural transportation, public transit and additional CVO items such as enhanced certification procedures.

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