Final report of ITS Center project: Application of U.S. DOT evaluation guidelines.

UVA Center for Transportation Studies

A Research Project Report

For the Center for ITS Implementation Research

A U.S. DOT University Transportation Center

Application of US DOT ITS Evaluation Guidelines

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INTRODUCTION

Intelligent transportation systems (ITS) represent the application of information processing, communications technologies, advanced control strategies, and electronics to the field of transportation *(12)***.** In other words, ITS means electronics, communications, or information processing used singly or in combination to improve the efficiency or safety of a surface transportation system *(3)*.

Integration of ITS into the transportation system requires justification along with other infrastructure improvements. To accomplish this, the basic level of ITS at which benefits/costs have been established is "the market package", a collection of equipment or technologies that work together to deliver a particular ITS service *(8)*. The market packages are to be listed in Table 1. Another concept, "the market area", is a collection of market packages that serves a group of buyers and users of ITS who have similar needs or objectives. The world of ITS is seen to be comprised of nine market areas (Figure 1).

ITS strategies differ from traditional transportation improvements in that they are operationally and information oriented, and aimed at events and unusual conditions. Because of the differences between the impacts of ITS and those of traditional transportation improvements, there is a growing need for new systematic evaluation methods to show the impacts of ITS projects.

TABLE 1 ITS Market Packages

Advanced Public Transportation Systems
- Transit Vehicle Tracking
- Transit Fixed-Route Operations
- Demand Response Transit Operations
- Transit Passenger and Fare Management
- Transit Security
- Transit Maintenance
- Multi-modal Coordination
- Transit Traveler Information

Advanced Transportation Management Systems
- Network Surveillance
- Probe Surveillance
- Surface Street Control
- Freeway Control
- HOV Lane Management
- Traffic Information Dissemination
- Regional Traffic Control
- Incident Management System
- Traffic Forecast and Demand Management
- Electronic Toll Collection
- Emissions Monitoring and Management
- Virtual TMC and Smart Probe Data
- Standard Railroad Grade Crossing
- Advanced Railroad Grade Crossing
- Railroad Operations Coordination
- Parking Facility Management
- Reversible Lane Management
- Road Weather Information System
- Regional Parking Management

Emergency Management
- Emergency Response
- Emergency Routing
- Mayday Support

Advanced Traveler Information System
- Broadcast Traveler Information
- Interactive Traveler Information
- Autonomous Route Guidance
- Dynamic Route Guidance
- ISP Based Route Guidance
- Integrated Transportation Management/Route Guidance
- Yellow Pages and Reservation
- Dynamic Ridesharing
- In Vehicle Signing

Advanced Vehicle Safety Systems
- Vehicle Safety Monitoring
- Driver Safety Monitoring
- Longitudinal Safety Warning
- Lateral Safety Warning
- Intersection Safety Warning
- Pre-Crash Restraint Deployment
- Driver Visibility Improvement
- Advanced Vehicle Longitudinal Control
- Advanced Vehicle Lateral Control
- Intersection Collision Avoidance
- Automated Highway System

Commercial Vehicle Operations
- Fleet Administration
- Freight Administration
- Electronic Clearance
- CV Administrative Processes
- International Border Electronic Clearance
- Weigh-In-Motion
- Roadside CVO Safety
- On-board CVO Safety
- CVO Fleet Maintenance
- HAZMAT Management

(Source: http://www.odetics.com/itsarch/ National ITS Architecture)

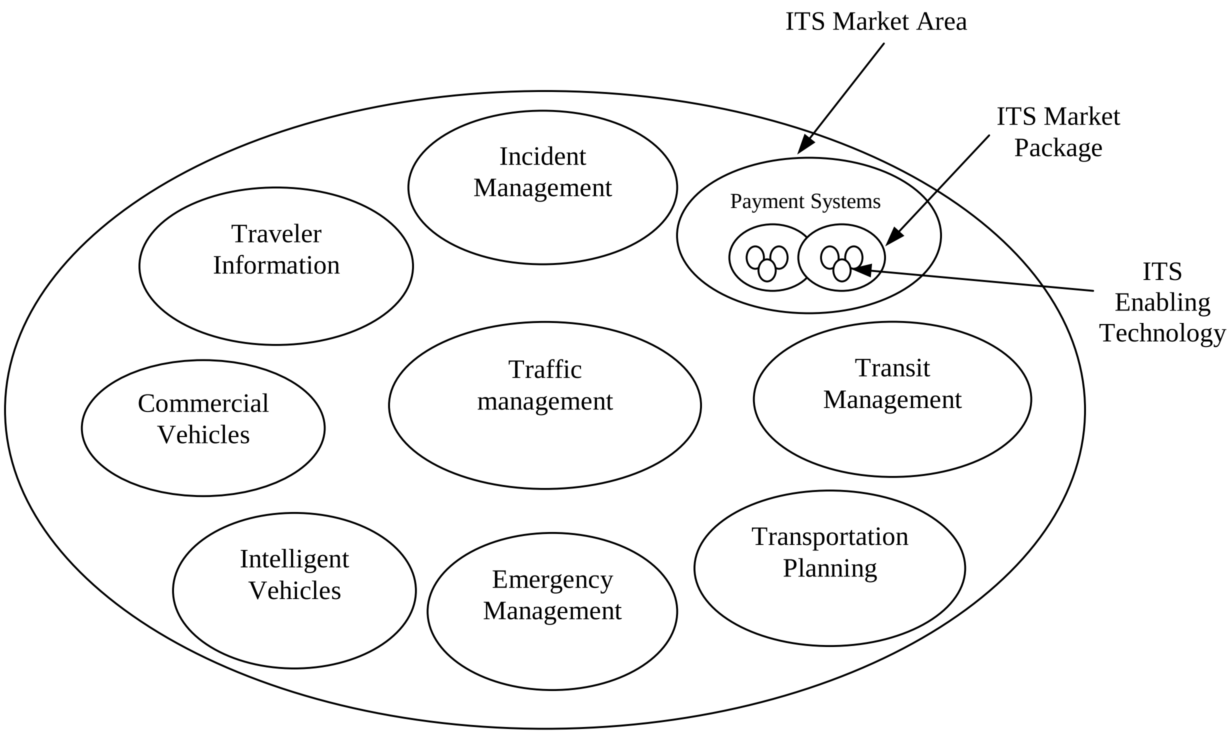

FIGURE 1 Nine Market Areas as a Structure of the World of ITS

(Source: Intelligent Transportation Systems Architectures, Judy McQueen, 1999, Bob McQueen, Artech House, Inc.)

EVALUATING ITS DEPLOYMENT PROJECTS

According to the TEA-21 ITS Evaluation Guidelines, evaluations are critical to ensuring progress to achieve ITS deployment goals, assisting in understanding the impacts of the ITS Program activities, and allowing for the program's continued refinement *(9)*. Evaluations can be both qualitative and quantitative; however, it is often desirable to employ a combination of qualitative and quantitative assessments for a complete evaluation.

There are two major types of evaluation recommended for ITS deployment, formative and summative evaluation *(9)*. Formative evaluation is carried out during the course of the development work in order that the objectives of the project be attained. This evaluation is, therefore, designed to provide useful short-term feedback into the deployment process. Summative evaluation is a retrospective assessment of the whole deployment with the aim of justifying the finished work and identifying lessons to be learnt for the next similar projects.

One example of formative evaluation is the evaluation of the first Phase of an Alternate Bus Routing project. The Alternate Bus Routing project provides real-time alternate routing information to the New Jersey Transit buses traveling north bound on the Garden State Parkway. The primary purpose is to determine the feasibility of the technology and make sure that the project be implemented properly. Problems identified in the formative evaluation, such as sensor inability to detect a tagged vehicle, incorrect route assignment, and inability to compute travel time for a tagged vehicle traveling on the network, are to be solved in future *(18)*.

Evaluation of the CHART Program (Chesapeake Highway Advisories Routing Traffic) is an example the summative evaluation. CHART focuses on improving traffic conditions on the interstate highways and state highway arterials in the area of Washington, D.C., Baltimore, Annapolis and Frederick, MD. The final evaluation concluded that the overall benefits exceed the system capital and costs and that the program has a direct impact on delay reduction and fuel saving *(17)*.

Evaluation Process

The ITS Joint Program Office recommends employing the following six-step process for ITS project evaluation *(9)*.

- *Form the Evaluation Team*

Team members are designated by each of the project partners and stakeholders. In order to conduct an effective evaluation, an independent evaluator should participate in the process periodically.

- *Develop the Evaluation Strategy*

The Evaluation Strategy relates the purpose of the project to the overall ITS goal areas. Currently, ITS goal areas include traveler safety, traveler mobility, transportation system efficiency, productivity of transportation providers, and conservation of energy and protection of the environment. At this stage, those goal areas which have the highest priority for the specific ITS project are identified. Appropriate measures of effectiveness are also determined to investigate the impacts of the ITS deployment. This process gives partners insights regarding areas of agreement and disagreement and assists them in obtaining consensus.

- *Develop the Evaluation Plan*

The next step is to refine the evaluation approach by formulating statistical hypotheses where they apply. In addition, the Evaluation Plan identifies qualitative studies that will be performed. A special emphasis should be placed on the non-technical factors, such as institutional issues, that influence project performance.

- *Develop One or More Test Plans*

A Test Plan specifies all of the details about how the test will be conducted, and identifies the number of evaluation personnel, equipment, supplies, procedures, schedule, and resources that are required to complete the test.

- *Collect and Analyze Data and Information*

This step involves the implementation of each Test Plan. Analysis of the data collected in this stage forms the basis of the final conclusion.

- *Prepare the Final Report*

The evaluation strategy, plans, results, conclusions, and recommendations should be documented in a Final Report.

MOEs Suggested by ITS Evaluation Guidelines

The TEA-21 ITS Evaluation Guidelines suggests that the evaluation of ITS projects should encompass five major goals *(9)*. Also, several related measures have been identified as useful to capture the impacts of ITS projects. Table 2 indicates the goal areas with key measures, which is followed, with detailed explanations and recommendations for evaluating ITS projects.

TABLE 2 ITS Evaluation Goals and Measures

Goal Area	Measures
Safety	Reduction in the overall rate of crashes Reduction in the rate of crashes resulting in fatalities Reduction in the rate of crashes resulting in injuries
Mobility	Reduction in travel time delay Reduction in travel time variability Improvement in customer satisfaction
Efficiency	Increases in freeway and arterial throughput
Productivity	Cost savings
Energy and Environment	Decrease in emission levels Decrease in energy consumption

(Source: http://www.its.dot.gov/eval/ResourceGuide/EvalGuidelines, Transportation Equity Act For The 21st Century; Guidelines For The Evaluation Of Operational Tests And Deployment Projects For Intelligent Transportation Systems (ITS))

- *Safety*

Safety benefits are mainly associated with the reduction of transportation related accidents or a decrease in the severity of accidents. Accident rate reduction constitutes one of the most direct measures and improvements are typically measured by a comparison of 'before' and 'after' accident studies. It is important to ensure that safety improvements are over the whole region rather than moving the accidents between different locations. It is also critical to isolate other external influences from the measurement, like reduction in kilometers traveled or better law enforcement.

In addition, since data collection of automobile accidents is not a perfect science and the details describing the accidents are often approximate and incomplete, some proxies may be used for the data required. Popular examples include the reduction in the overall number of recorded incidents on a stretch of highway, and reduction in the incident response time. It might also be helpful to relate the safety measurement to the insurance industry statistics.

- *Mobility*

Delay to a user of a system is typically measured in seconds per vehicle or minutes per vehicle of delay. Delay can be measured in many different ways. For example, the "floating car" method can be used to measure the delay experienced before and after installation of the system. Delay can also be measured by comparing the number of stops experienced by the drivers before and after the introduction of an ITS project.

Travel time variability indicates the fluctuation in overall travel time of trips between an origin and destination pairs via the transportation network. By improving response time to incidents, and providing information on delays, ITS services can reduce the variability of travel time. In turn, the increased reliability can help travelers and freight companies make planning and scheduling decisions. Several types of statistics, like the standard deviation or variance around the mean, the range of travel time values, can be computed to indicate the variability of travel time. Travel time variability can be calculated under different time horizons, such as within day and day-to-day variability of a given trip or goods movement from an origin to a destination.

- *Efficiency*

A major goal of ITS projects is the optimization of flow on existing facilities. One way to accomplish this goal is to increase the effective capacity. A frequently used observable measure is the 'throughput', which involves taking volume counts of the number of persons or vehicles traversing a roadway section or network per unit time.

- *Productivity*

Cost savings is used to quantify improvements in productivity. The components of the costs include the acquisition cost (capital cost), operating/maintenance cost, income from revenue-generating transportation facilities, and user costs. Cost savings can be either the difference in costs before and after installation of a system or the difference between the cost of an Intelligent Transportation System and traditional transportation improvements that are designed to address the same problem.

- *Energy and Environment*

The air quality and energy impacts of ITS services are of particular importance, especially for the areas where the air quality standards specified in the Clean Air Act Amendments of 1990 have not been met. Typical pollutants to be measured include carbon monoxide (CO), nitrogen oxides (NOx), and volatile organic compounds (VOC's) like hydrocarbons (HC). Simulation models, such as CORSIM, INTEGRATION, are often used to estimate the resulting changes in emission levels and energy consumption before and after installation of an ITS product.

There are many challenges to evaluating the environmental impacts of ITS projects. First of all, the impact of an individual ITS project is very small, especially when compared to the environmental conditions of the larger geographic region. In addition, many external variables, such as weather conditions, pollutants emitted by non-mobile sources and even pollutants carried from other metropolitan areas to the study area, make it more difficult to explicitly and accurately evaluate the impacts of an ITS project.

Examples of MOEs Used in ITS Project Evaluations

Case 1 - By applying a variety of advanced technologies including adaptive ramp metering, adaptive, traffic signals, motorist information, and surveillance systems, ICTM (Integrated Corridor Traffic Management) aims at optimizing corridor capacity, traffic operations, and safety *(16)*. The selected corridor was an 8-mile section of the I-494 in the south of the Twin Cities. Besides I-494, the whole section includes four parallel and seven perpendicular arterial streets. Table 3 lists the measures employed in their evaluation and meanwhile relevant to the goal areas of mobility and efficiency.

TABLE 3 Evaluation Goals and Relevant Measures in Project ICTM

Goal Area	Measure
Efficiency	▪ Net traffic flow
Mobility	▪ Density along the freeway ▪ Travel time ▪ Frequency of stop ▪ Overall delay ▪ Space mean peed ▪ users' and operators' perceived traffic operation within the corridor ▪ Percentage breakdown of users' response to and perception of the ICTM system

(Source: *http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/9xb01!.pdf*, Integrated Corridor Traffic Management Final Evaluation Report, Booz. Allen, Hamilton, April 2000*)*

The evaluation derived its conclusion from a variety of quantitative and qualitative data sources. These sources included travel time runs, screenline traffic counts, automated databases from loops detectors, written surveys and interviews with local project stakeholders and corridor motorists. The evaluation came to the following conclusion:

- During nonincident conditions, traffic patterns were changed through improved use of corridor capacity because trips were diverted from the corridor to local street. This conclusion was drawn through a comparison of the traffic counts for the year 1996 and 1999. Appendix A gives the traffic flow collected at the screenlines. Meanwhile, surveys to the motorists also support this conclusion.

- Traffic operations experienced improvement during non-incident conditions. The MOEs, including travel time, frequency of stops, space mean speed, and overall delay, were analyzed in the before-and-after cases. Please refer to Appendix A for the comparison results for various analysis periods and link orientations.

- Motorists made more intelligent route choices during incidents because the surveyed motorists were generally satisfied with the advisory system and indicated a preference to alter their travel behavior.

Case 2 - CHART (Chesapeake Highway Advisories Routing Traffic) is a highway ITS program initiated by the Maryland State Highway Administration. CHART focuses on the areas of Washington, D.C., Baltimore, Annapolis and Frederick, MD and encompasses about 375 miles of interstate highways and 170 miles of state highway arterials. The CHART program is composed of four major components: traffic monitoring, incident response, traveler information and traffic management *(17)*. The evaluation of the performance of the CHART program was implemented through the application of a freeway corridor simulation model (FREQ). Table 4 summarizes the MOEs employed in this study.

TABLE 4 Evaluation Goals and Relevant Measures in the CHART Program

Goal Area	Measure
Mobility	▪ Incident duration ▪ Total vehicle hours of delay ▪ Change in delay due to incident ▪ Incident vehicle hours delay ▪ Change in delay due to CHART ▪ Average travel speed

	▪ Travel time
Efficiency	▪ Vehicle miles traveled ▪ Vehicle hours traveled ▪ Passenger hours traveled
Productivity	▪ Passenger/Fuel Costs
Energy and pollution	▪ Emission (CO, HC, NOx) ▪ Fuel consumption

(Source: http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/7pw01!.pdf, CHART Incident Response Evaluation Final Report, CORSIM Corporation, May 1996*)*

The most significant finding of the evaluation is that the benefits of the CHART incident response program, including the estimated reduction in delay, fuel consumption and secondary incidents, exceed the system's capital investment, operating and maintenance costs by a ratio of over 7 to 1. Please refer to Appendix B for a detailed review of the evaluation results.

MOEs Sensitive to Specific ITS Strategies

Table 1 gave an index of goals and measures to evaluate overall impacts of different ITS projects. However, as introduced in the section "Introduction", "market package" is the basic level of ITS at which benefits/costs can be evaluated. It has also been advocated to incorporate some MOEs which are sensitive to each specific ITS strategy *(7)* (here, 'strategy' refers to a similar concept to 'market package'). For this purpose, Table 5 relates certain measures with some popular ITS strategies.

TABLE 5 MOEs Sensitive to Specific ITS Strategies

ITS strategies	Measures of Effectiveness

Ramp metering (ATMS)	▪ Average Speed on the Freeway ▪ Average Speed on Arterial Streets ▪ Delay at Ramp Meters ▪ Average Queue Length at Metered Ramps ▪ Number and Severity of Accidents ▪ Number and Severity of Other Incidents ▪ Public Reaction
Regional Multimodal Traveler Information (ATIS)	▪ Origin to destination trip time ▪ Amount and source of information received ▪ Frequency of route diversion ▪ Frequency of mode split ▪ Frequency of trip time changes
Incident Management (Advanced Vehicle Safety System)	▪ Incident detection/verification time by incident type/severity ▪ Incident response time by incident type/severity ▪ Incident clearance time by incident type/severity ▪ Time periods and locations of incident occurrences
Traffic Control System (ATMS)	▪ Speed on a sample of arterial streets ▪ Traffic volume (as a control variable) ▪ Number of stops ▪ Average vehicle delay at signals ▪ Number and severity of accidents ▪ Number of special events, construction/maintenance, incident applications of the system
Electronic Toll Collection (Payment System)	▪ Traffic flow rate through electronic lanes ▪ If mixed lane, number of regular and tagged vehicles through those lanes ▪ Operational problems with system/downtime
Automated Fare Payment Systems (APTS)	▪ Number of passengers with automated fare payment ▪ Average amount of time for an automated payment versus a normal payment (including bus passes) ▪ Reduction in average dwell time per boarding passenger for buses with automated fare payment ▪ Gains in operational efficiency (accounting, reduced theft, etc.)
Transit Management (APTS)	▪ Schedule Adherence ▪ Bus Replacement Response Time ▪ Change in passenger wait time at bus stops ▪ Perceived convenience to passengers ▪ Increase in transit patronage linked to information (e.g. identified through survey)

(Source: Integrating Intelligent Transportation Systems within the Transportation Planning Process: an Interim Handbook, January 1998, TransCore)

Suggested Measures of Effectiveness

Based upon the Evaluation Guidelines and a review of recent research papers and reports, the following matrix *(Table 6)* is suggested to evaluate ITS projects. This table encompasses all the five areas that have been identified as the major goals by the Evaluation Guidelines. Because different ITS strategies often address different traffic problems and are the basic level for evaluation, the table classifies the measures according their sensitivity to the ITS strategies.

Data availability is a critical factor in determining whether the evaluation can be conducted successfully. For example, in order to assess whether safety has been improved resulting from an ITS project, it is often desirable to collect accident data over several years. Therefore, during the beginning years of an ITS project, we cannot get sufficient data to evaluate the level of safety. For another instance, unlike certain data that can be obtained electrically (e.g. volume, speed), some data acquisition requires manual work (e.g. number of stops, time waiting for service). In such cases, it might become economically inefficient to get these accurate data only for an evaluation purpose. In fact, survey of the system operators or users often turns out to be a fast and economic way to collect data. This method has been widely accepted nowadays. Another approach to solve the problem of insufficient data is to employ traffic simulation models. Actual detector counted value of traffic volume can be input into the models to estimate the benefits in the area of safety, mobility, pollution and energy.

TABLE 6 Suggested Measures of Effectiveness to Evaluate ITS Strategies

Goal Area	Measures of Effectiveness	Traveler Information	Incident Management	Traffic Management	Payment System	Commercial Vehicles	Emergency Management	Transit Management
Safety	♦ number and reduction rate of accidents							
	- crashes resulting in fatalities			√		√		
	- crashes resulting in injuries			√		√		
	- crashes resulting in P.D.O.			√		√		
Mobility	♦ average delay and queue length at signals, ramps, toll gates, inspection sites or transfer points			√	√	√		√
	♦ number of stops			√				
	♦ speed in a stretch of freeway or arterial streets			√				
	♦ frequency of travel time changes or adherence to schedule	√		√				√
	♦ travel time from origin to destination	√		√				√
	♦ variance around the mean of travel time	√		√	√			√
	♦ time waiting for service				√	√		
	♦ incident detection and clearance time		√				√	
	♦ percentage of correct/false incident identification		√					
	♦ Frequency or rate of route diversion or mode split	√						√
	♦ percent of total link traffic made up of trucks and buses							√
	♦ ratio of vehicle trips to person trips							√
	♦ transit ridership and passenger miles of travel							√
	♦ driver and passenger fatigue, stress and convenience	√		√	√	√	√	√
Efficiency	♦ traffic volumes	√		√				√
	♦ vehicle miles/hours of travel (VMT/VHT) by mode	√		√				√
	♦ number of vehicles passing a gate, inspection sites	√			√	√		√
	♦ volume to capacity ratios	√		√				√
Productivity	♦ acquisition cost	√		√	√			√
	♦ operating/maintenance cost	√		√	√	√		√
	♦ income from revenue-generating agencies	√		√	√			√
	♦ user costs	√		√	√			√
Energy and Environment	♦ vehicle emission	√		√		√		
	♦ noise pollution			√				
	♦ fuel consumption	√		√		√		

INCORPORATING ITS INTO THE PLANNING PROCESS

Federal Register (23 CFR part 1410) published on May 25, 2000 includes a notice of proposed rule making (NPRM) for statewide or metropolitan transportation planning which includes provisions for incorporating ITS strategies and investments into the statewide and metropolitan planning and programming process. Since the success of ITS integration depends greatly on the two fundamental issues – technical and institutional integration, the new regulations emphasize that 1) agreement should be reached among the MPOs, State DOTs, transit operators and other agencies addressing policy and operational issues; 2) the ITS project should be interoperable and should utilize ITS related standards (e.g. the National and Regional ITS Architecture), and the routine operation of the projects (12).

The transportation planning processes calls for a coordinated approach to assess transportation needs, evaluate a range of solutions, and produce an agreement among relevant agencies *(12)*. The new regulation no longer requires the Major Investment Study to appear as a separate process; instead it will be integrated into the planning process. A key step in the planning process is to estimate the impacts of alternatives. Methods that have been used to estimate the benefits/costs of various strategies includes the 'Combination of Planning and Simulation Models' and the 'ITS Deployment Analysis System' (IDAS).

Combination Of Planning And Simulation Models - Seattle Case Study *(6)*

By providing improved information to travelers and adjusting traffic control policies in real-time, ITS allows travelers and transportation managers to react to changing conditions and to more effectively use transportation capacity. In order to model time-varying conditions and demands, as well as individual vehicle-level capabilities and routing decisions, a model framework, which is comprised of a set of transportation models, has been proposed and utilized *(6)*. The structure for this analytical framework is represented in Figure 2. In the framework, planning and simulation analysis is executed as an iterative process. Estimates of mode split and assigned traffic volumes are produced by the planning model and input to the simulation models. The revised speeds from the simulation models are then fed back into the planning model. The process is repeated until travel speed and volumes converge. This evaluation framework will be explained in detail through a presentation of Seattle Case Study in the following.

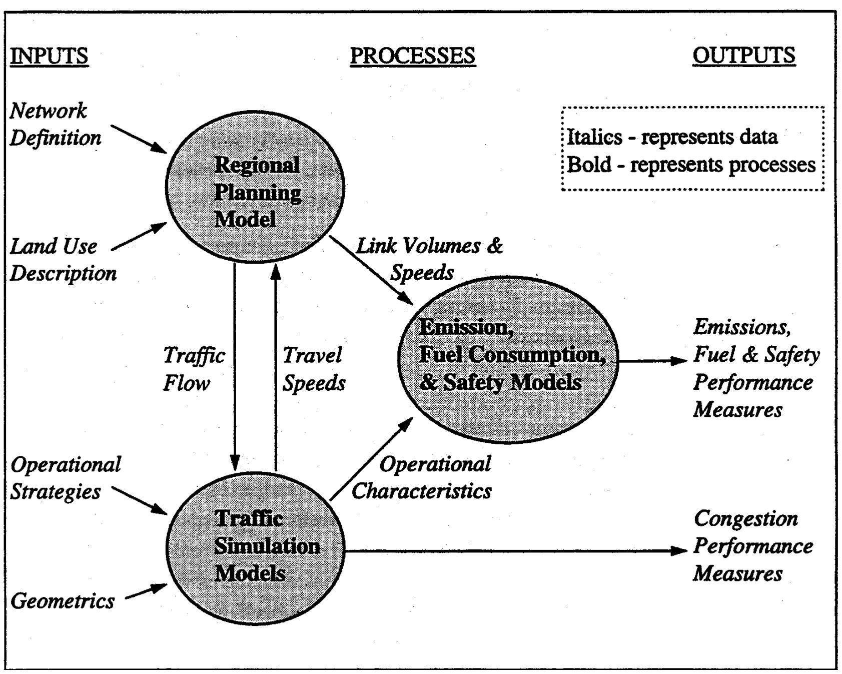

FIGURE 2 ITS Modeling Framework

(Source: Intelligent Transportation Systems Impact Assessment Framework: Final Report, Volpe National Transportation Systems Center, September, 1995)

Description of the Study Area

The area of the project is located north of Seattle, Washington. It is one of the densest areas in the Seattle region and serves as a major origin/destination and through commuter corridor into the Seattle activity centers. Interstate I-5 and State Route 99 are the major north-south transportation facilities serving the corridor.

Problem Statement and MOEs

The project intends to alleviate north-south congestion and improve mobility throughout the area. Based on this objective, the set of MOEs shown as Table 7 was defined.

TABLE 7 Measures of Effectiveness to evaluate the Seattle project

Primary measures:	1. Travel time by mode (HOV, SOV, and transit) 2. Throughput (person, vehicle) 3. Mode choice, trips by mode 4. Vehicle miles traveled by mode (HOV, SOV, and transit) 5. Person miles traveled by mode (HOV, SOV, and transit) 6. Deferred trips 7. Capital costs 8. Operating and maintenance costs
Derived measures	1. Value of time savings 2. Delay reduction (recurrent and nonrecurrent) 3. Model shift from SOV 4. Congestion index 5. Reliability and variance reduction (standard deviation of

	arrival times, travel times) 6. Mobility index 7. Level of service by link

Alternatives

In all, six alternatives were introduced for alleviating congestion in the area. The alternatives encompass both traditional transportation improvements and traditional transportation improvements plus ITS solutions. The alternatives include: do-nothing, ITS rich (only ITS improvements), SOV capacity expansion without ITS enhancements, SOV capacity expansion with ITS enhancements, HOV/busway without ITS enhancements, and HOV/busway with ITS enhancements. Figure 3 shows these alternatives.

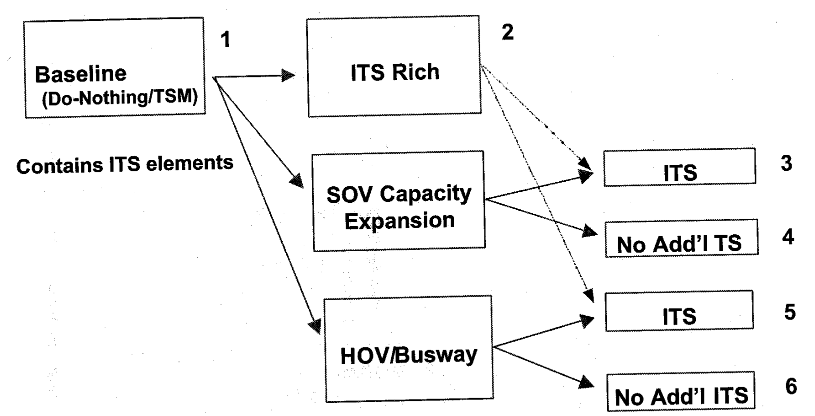

FIGURE 3 Description of Alternatives - Seattle Case Study

(Source: Incorporating ITS into corridor Planning: Seattle Case Study – Executive Summary, August 1999)

Analysis Procedure

In order to fully capture the ITS/operational improvements, especially the responses to time-variant conditions (recurrent and non-recurrent), a two-level modeling process was adopted. At the higher (regional) level, the overall travel patterns and the system's responses to average/expected conditions are analyzed using a traditional regional planning model (EMME/2). Output from this analysis is then fed into a more detailed sub-area simulation model capable of modeling time-varying conditions and demands, as well as individual vehicle-level capabilities and routing decisions (INTEGRATION). At the lower level, the detailed traffic operations, queuing, and buildup/dispersion of demand are captured, as well as the real-time response of travelers to information. Feedback is then carried out to ensure that the impacts to expected conditions, estimated in the sub-area model, are reflected in the regional analysis.

Another key element in capturing the impacts of ITS is the use of a representative day scenario analysis to address non-recurrent conditions. Each scenario, or representative day, is selected to capture a type of incident or occurrence that may produce a significant influence on the traveler and his/her choices of route. The variables in the scenario include: incident/accidents, overall travel demand, and weather conditions. In all, 30 scenarios were defined. Their corresponding probability of occurrence in the analysis periods were also identified. In the end, the results from the representative day simulations were combined to estimate the impacts and fed back to the regional travel forecasting process. Figure 4 describes the analysis procedure employed in this case study.

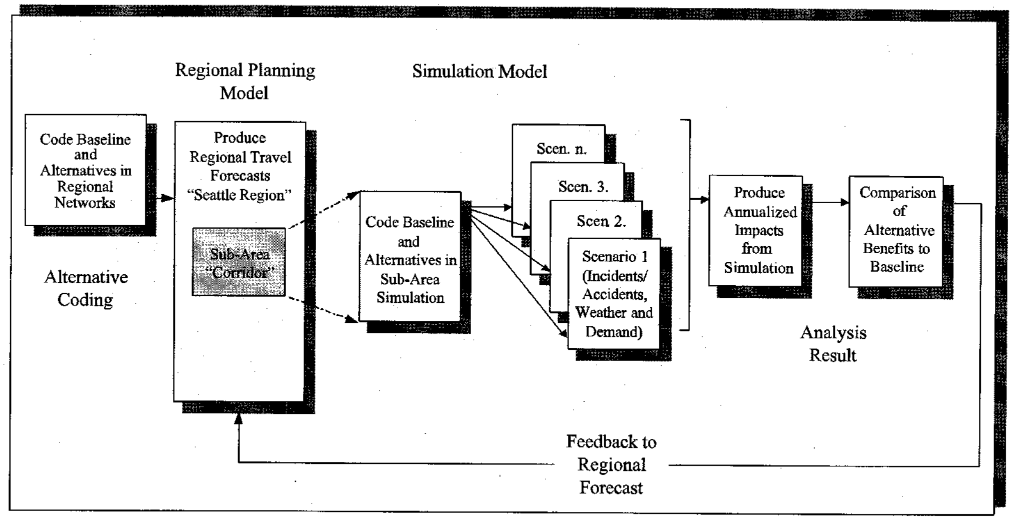

FIGURE 4 Analysis Methodology Overview - Seattle Case Study

(Source: Incorporating ITS into corridor Planning: Seattle Case Study – Executive Summary, August 1999)

The overall results indicated that, when comparing ITS Rich to the Baseline, the studied corridor experienced a 4.3% increase in average daily vehicle, 14.6% reduction of annualized delay, 30% reduction in travel time variability and 25% reduction in the traveler risk of a significant delay.

ITS Deployment Analysis System (IDAS)

IDAS systematically and quantitatively estimates costs and benefits associated with the deployment of ITS as well as other transportation options. It has been designed as a post-processor to travel demand models in transportation planning purposes. IDAS consists of five major analysis modules: an input/output interface module, an alternative generator module, a benefits module, a cost module and an alternatives comparison module. Figure 5 shows the general structure of the IDAS modules and sub-modules *(5)*.

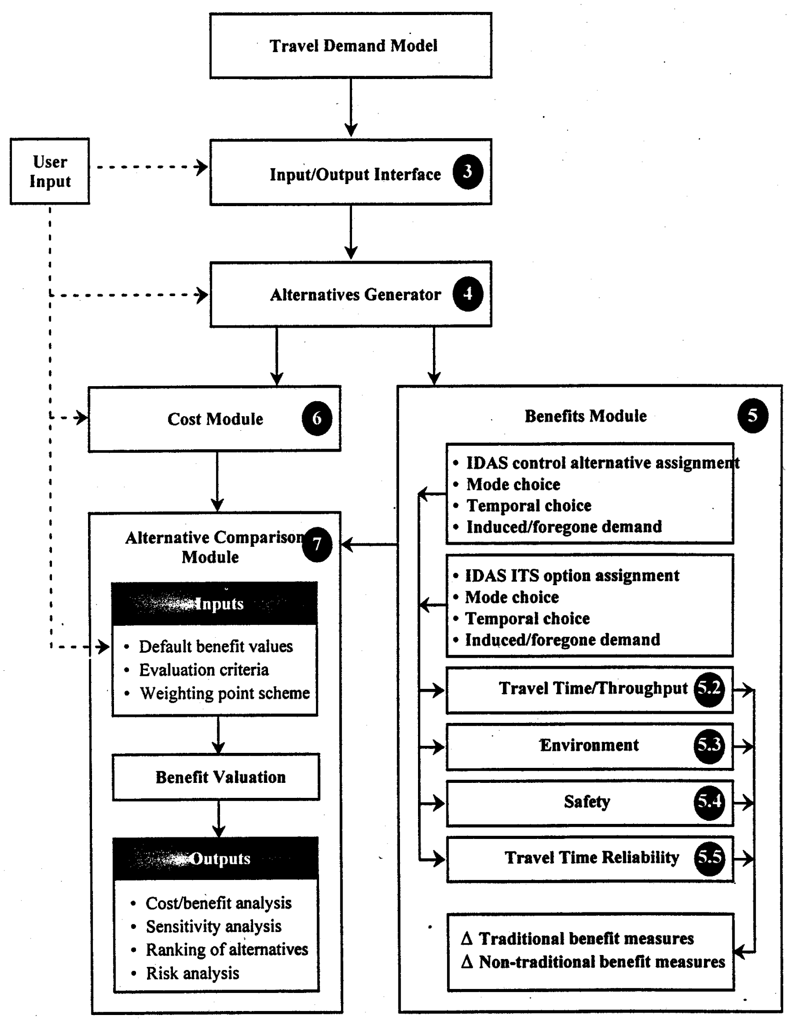

FIGURE 5 IDAS Model Structure

(Source: ITS Deployment Analysis System, Build 1, Cambridge Systematics, Inc. December, 1998)

The development of IDAS has experienced two phases: Build 1 and Build 2. The final version include the following abilities 1) to specify ITS deployments and their characteristics in transportation planning networks; 2) to analyze the impacts of transportation infrastructure improvement alternatives; 3) to provide life-cycle cost estimates; 4) to compare the results of alternative ITS deployment *(14)*. Table 8 lists the ITS components in Build 2.

TABLE 8 ITS Components in IDAS Build 2

ITS Element	ITS Component
Traffic Signal Control	▪ Traffic Signal Coordination (pre-timed and actuated isolated signals, pre-timed and actuated signal coordination, traffic adaptive signal coordination)
	▪ Bus and Emergency Vehicles Traffic Signal Preemption Bus and
	▪ Arterial Variable Message Signs
Freeway Management	▪ Ramp Metering (pre-timed and traffic adaptive ramp metering)
	▪ Freeway Variable Message Signs
	▪ Freeway Lane Control Systems
	▪ Freeway Management Decision Support Systems Freeway Management
Transit Management	▪ Transit User Information
	▪ Automated Transit Scheduling Systems
	▪ Automated Vehicle Location
	▪ Transit Security Systems
	▪ Personalized Public Transit
Incident Management	▪ Incident Detection
	▪ Incident Verification – CCTV
	▪ Incident Response/Management – Freeway Service Patrol
Electronic Fare Payment	▪ Electronic Fare Payment Electronic Fare Payment
Electronic Toll	▪ Electronic Toll Collection Electronic Toll Collection
Railroad Grade Railroad Grade Crossings	▪ Railroad Grade Crossing R
	▪ Train Monitoring
Emergency Management Services	▪ Emergency Vehicle Control
	▪ Mayday Systems
	▪ LifeLink
	▪ Emergency Vehicle Comminications
Traveler Information	▪ Location-specific ATIS - Kiosks and Variable
	▪ In-Vehicle Information Systems
	▪ Pre-Trip Information Systems
	▪ Route Guidance Systems
	▪ Rideshare Information
Commercial Vehicle Operations	▪ Electronic Screening
	▪ Electronic Credentialing and Clearance

	▪ Safety Information Exchange
	▪ Onboard Safety Monitoring
	▪ Commercial Fleet Management
	▪ Hazardous Materials Incident Response
Advanced Vehicle Control and Safety Systems and Automated Highway systems	▪ Longitudinal and Lateral Collision Avoidance
	▪ Intersection Collision Avoidance
	▪ Vision Enhancement for Crashes
	▪ Safety Readiness
	▪ Pre-crash Restraint Deployment
	▪ Automated Highway Systems
ITS Integration Elements	▪ Freeway/Arterial Control Integration
	▪ Transit Information Integration
	▪ Integration of Arterial Traveler Information
	▪ Mayday Information Integration
	▪ Integration of Traveler Information from Various Sources

(Source: http://www-cta.ornl.gov/cta/research/idas/kickoff.PDF)

IDAS Analysis Hierarchy

IDAS is designed to help planners compare the performance of several ITS options against 'control' alternatives. Data input into IDAS is prepared by a typical regional travel demand model to construct the basic supply and demand characteristics of the system. Reading data from the travel demand model is the first step to run IDAS.

Basic components in the analysis hierarchy of IDAS are projects, alternatives, and ITS options. Unlike traditional sketch planning tools, where control alternatives refer to no-build choice, IDAS defines control alternatives as those that serve as the baseline for comparing ITS options. That is to say, the control alternative does not contain any ITS component *(5)*. Figure 6 explains how the analysis hierarchy can be used in evaluating scenarios where ITS has been incorporated into transportation planning process.

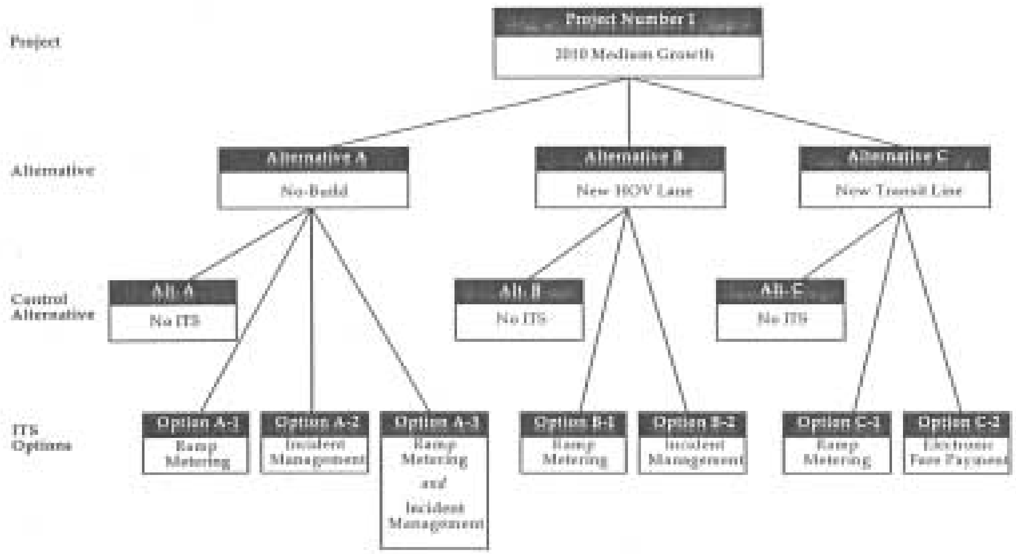

FIGURE 6 IDAS Analysis Structure

(Source: ITS Deployment Analysis System, Build 1, Cambridge Systematics, Inc. December, 1998)

Advantages of IDAS

- Users can use the deployment screen to deploy the ITS elements, examine and modify their parameters, properties and locations directly on maps.

- IDAS includes a large database describing the costs, anticipated useful life and direct benefits of a wide variety of ITS elements. This data information can also be accessed by two separate files, Equip and DirectBenefits, through Excel 97.

- The analysis hierarchy of IDAS has made itself especially suitable for evaluating projects which have incorporated ITS elements in the alternatives.

- As a sketch planning tool, IDAS has a less restrictive requirement of data input. Moreover, IDAS provides default values for the parameters. As a result, it is an inexpensive but efficient tool to help planners get a general idea of the performance of each alternative.

- The evaluation matrix produced by IDAS conforms to the requirements of the TEA-21 ITS Evaluation Guidelines. The following table lists the measures employed by IDAS for evaluating alternatives as well as the goal areas the measures are addressing to.

TABLE 9 Measures of Effectiveness in IDAS

	MOEs in IDAS	Goal areas in the TEA-21Guidelines
Annual benefits	Change in user travel time ▪ In-vehicle travel time ▪ Out-of-vehicle travel time ▪ Travel time reliability	 ▪ Mobility ▪ Mobility ▪ Mobility
	Change in costs paid by users ▪ Fuel costs ▪ Non-fuel operating costs ▪ Accidents costs (internal only)	 ▪ Energy ▪ Productivity ▪ Safety
	Change in external costs ▪ Accidents costs (external only) ▪ Emissions ▪ Noise ▪ Other mileage-based external costs	 ▪ Safety ▪ Environment ▪ Environment ▪ Productivity
	Change in public agency costs (efficiency induced)	▪ Efficiency
Annual costs	Average annual private costs Average annual public costs	▪ Productivity ▪ Productivity

(Source: ITS Deployment Analysis System, Build 1, Cambridge Systematics, Inc. December, 1998)

CONCLUSIONS

Safety, mobility, efficiency, productivity, and protection of environment and energy, are the major goal areas in ITS deployment. As a result, the evaluation team should relate the purpose of its projects to these overall goal areas and develop a table of MOEs to address them. The table of MOEs is the key to a successful evaluation of ITS deployment. The MOEs should be easy to measure and calculate, should be sensitive to the specific goals of the ITS project, and should consider the requirements by the TEA-21 Evaluation Guidelines. The index of MOEs given in this paper can be referred to start an evaluation process.

Qualitative methods are also used to evaluate ITS deployments. Surveys and interviews of project partners and travelers are major data sources to qualitative evaluation, while quantitative evaluation involves statistical tests between before- and after- the ITS deployments or between non-ITS and ITS rich alternatives that address the same problem. In most cases, a combination of the two approaches is employed to achieve a comprehensive evaluation.

Federal Register (23 CFR part 1410) emphasized the importance of incorporating ITS elements into the statewide and metropolitan planning processes. "Combination of Planning and Simulation Models" and IDAS are the two major methods used to estimate the benefits/costs of ITS alternatives in the planning processes. Both methods require input from travel demand models and make estimations in terms of traffic performance, safety, and emissions and energy. The first method is more of a microscopic level and requires more detailed and extensive data input, and hence, is expected to produce more accurate results.

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APPENDIX A *(16)*

Traffic Flow Changes At The Screenline Within The Corridor

day	period	direction	Screenline at Xerxes								
			76th St			80th St			I-494		
			1996	1999	SS	1996	1999	SS	1996	1999	SS
weekday	AM	EB	359	311	Y	276	325	N	5973	5747	Y
		WB	912	1281	Y	850	625	Y	6351	5625	Y
	Midday	EB	654	926	Y	1193	1093	Y	10198	10001	N
		WB	693	963	Y	1045	947	Y	9801	9683	N
	PM	EB	1002	1348	Y	1323	1038	Y	6258	6146	N
		WB	628	778	Y	574	634	N	5845	5666	N
Saturday	Midday	EB	567	778	Y	889	835	N	10325	10784	N
		WB	741	961	Y	708	635	N	9338	9811	Y

day	period	direction	Screenline at Nicollet											
			76th St			77th St			79th St			I-494		
			1996	1999	SS	1996	1999	SS	1996	1999	SS	1996	1999	SS
weekday	AM	EB	81	96	N	239	234	N	185	161	Y	5418	5332	N
		WB	151	186	Y	727	857	N	381	392	N	5269	4605	Y
	Midday	EB	213	192	Y	645	691	Y	526	544	N	1767	8567	Y
		WB	147	190	Y	641	747	Y	705	682	N	7708	8884	Y
	PM	EB	262	259	N	696	789	Y	319	367	Y	6415	6548	N
		WB	141	170	Y	522	560	N	408	394	N	5162	4762	N
Saturday	Midday	EB	309	264	N	739	783	N	467	529	Y	8458	9720	Y
		WB	213	286	Y	152	245	N	563	574	N	7900	8986	Y

Traffic Operations Measures of Effectiveness Adjusted for Flow Rate Changes

Frequency (travel time, number of stops, speed, and delay)												
Period	Easter Street			Northsouth Street			I-494			Corridor		
	better	worse	same	better	worse	same	better	worse	same	better	worse	same
AM	5	16	11	36	20	0	3	3	0	44	39	11
Midday	10	12	10	45	11	0	5	1	0	60	24	10
PM	13	7	12	45	11	0	4	0	2	62	18	14
Midday Sat	11	6	15	48	8	0	6	0	0	55	14	15
All	39	41	48	174	50	0	18	4	2	231	95	50
Percentage (travel time, number of stops, speed, and delay) *(%)*												
Period	Easter Street			Northsouth Street			I-494			Corridor		
	better	worse	same	better	worse	same	better	worse	same	better	worse	same
AM	16	50	34	64	36	0	50	50	0	47	41	12
Midday	31	38	31	80	20	0	83	17	0	64	26	11
PM	41	22	38	80	20	0	67	0	33	66	19	15
Midday Sat	34	19	47	86	14	0	100	0	0	69	15	16
All	30	32	38	78	22	0	75	17	8	61	25	13

APPENDIX B *(17)*

I-495 Incident Scenario MOE's

AM Peak Period - Outer Loop East of I-270 Spur with Secondary Accident West of Wisconsin Avenue

	normal recurring congestion	initial and secondary incident with no incident management	initial and secondary incident with freeway service patrols	initial incident with FSP and ATMS support
Incident duration (minutes)		40-55	30-45	25
Total vehicle hours of delay	1921	3386	2990	2210
Change in delay due to incident	-	76%	56%	15%
Incident vehicle hours delay	-	1465	1069	269
Change in delay due to CHART	-	-	-27%	-80%
Average travel speed (mph)	37.1	29.2	31.0	35.3
Travel time (minutes)	26.8	34.1	32.1	28.2
Fuel consumption (gallons)	11546	11674	11615	11640
CO emissions (kg)	1212	1390	1343	1256
HC emissions (kg)	104	123	118	109
NOx emissions (kg)	311	298	301	308
Total emissions (kg)	1627	1811	1762	1673
Vehicle miles traveled	232,316	219,641	222,536	231,783
Vehicle hours traveled	6257	7522	7174	6567
Passenger hours traveled	7506	9026	6609	7880
Passenger/Fuel Costs	$89,513	$104,853	$100,609	$93,350

I-695 Incident Scenario MOE's

PM Peak Period - Inner Loop between US 40 Loop Ramps

	normal recurring congestion	initial and secondary incident with no incident management	initial and secondary incident with freeway service patrols	initial incident with FSP and ATMS support
Incident duration (minutes)		40	30	25
Total vehicle hours of delay	1720	3516	3038	2795
Change in delay due to incident	-	+104.4%	+76.6%	+62.5%
Incident vehicle hours delay	-	1796	1318	1075
Change in delay due to CHART	-	-	-14%	-21%
Average travel speed (mph)	37.7	28.2	30.4	31.6
Travel time (minutes)	25.6	34.2	31.8	30.6
Fuel consumption (gallons)	11444	11446	11510	11526
CO emissions (kg)	1124	1347	1299	1271
HC emissions (kg)	101	124	119	116
NOx emissions (kg)	296	275	281	285
Total emissions (kg)	1521	1746	1699	1672
Vehicle miles traveled	235,377	217,887	223,775	226,339
Vehicle hours traveled	6241	7723	7323	7168
Passenger hours traveled	7490	9268	8788	8602
Passenger/Fuel Costs	$589,205	$106,990	$102,266	$100,430

I-95 Incident Scenario MOE's

AM Peak Period - Outer Loop North of MD 4 Interchange

	normal recurring congestion	initial and secondary incident with no incident management	initial and secondary incident with freeway service patrols	initial incident with FSP and ATMS support
Incident duration (minutes)		55	45	35
Total vehicle hours of delay	113	1978	1383	879
Change in delay due to incident	-	+1650%	+1106%	+678%
Incident vehicle hours delay	-	1885	1250	766
Change in delay due to CHART	-	-	-31%	-56%
Average travel speed (mph)	55.7	40.8	44.8	48.4
Travel time (minutes)	28.8	39.2	35.7	33.1
Fuel consumption (gallons)	18057	16045	15981	15939
CO emissions (kg)	1509	1690	1631	1582
HC emissions (kg)	112	135	127	121
NOx emissions (kg)	589	545	556	565
Total emissions (kg)	2210	2370	2314	2268
Vehicle miles traveled	318,664	302,721	306,319	309,593
Vehicle hours traveled	5718	7421	6843	6394
Passenger hours traveled	8862	8905	8212	7673
Passenger/Fuel Costs	$88,691	$109,106	$102,096	$96,654