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Research Project: Evaluating Intelligent Transportation System Impacts: A Framework for Broader Analysis

16. Abstract

The evaluation of the impacts of Intelligent Transportation System (ITS) treatments is at an early, but important stage. The national-level focus on a “few good measures” provides a standard, systematic method for understanding a variety of programs and projects. This report presents an expanded process and measures for considering the effect of ITS investments. A series of questions are proposed to bring out the potential effects of ITS programs that may not be analyzed due to relatively little data or complex relationships. This particularly relates to subject areas unfamiliar to the public sector transport agencies that typically are in charge of ITS deployment. These groups have little experience with logistics, supply chains, or business restructuring concepts.

The report also recommends expanding one goal and adding another. It suggests that local goals be identified and studied as a way of exploring important attributes and developing future plans. The important factors might be better analyzed and incorporated with a multi-criteria analysis approach, rather than the traditional benefit/cost analysis. This approach will also allow the local concerns to be addressed in a more “customized” process and produce the statistics needed to compare local projects with national standards and results.

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EVALUATING INTELLIGENT TRANSPORTATION SYSTEM IMPACTS:

A Framework for Broader Analyses

by

Tim Lomax
Research Engineer
Texas Transportation Institute

Sharada Vadali
Assistant Research Scientist
Texas Transportation Institute

and

William Eisele
Assistant Research Engineer
Texas Transportation Institute

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TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, TX 77843-3135

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SUMMARY

The study of impacts from intelligent transportation system (ITS) treatments has generally focused on elements that are easily quantifiable with existing or "traditional" data. Many of the effects and significant benefits of ITS, however, are not quantitative or included in typical traffic studies. Most measurement schemes focus on obtaining data similar to the traffic monitoring programs that served the transportation profession in the era when added capacity was the usual solution to mobility concerns. And yet if broader analyses had been conducted during past eras, there may have been less reliance on freeway frontage roads and less frequent driveway access to major arterials.

This report discusses a conceptual ITS impacts assessment framework that addresses the potential myriad effects of ITS improvements. It should be noted that when the word "framework" is used in this report it does not refer to a methodology for a specific impact analysis, but rather as an aid for evaluators to understand what impacts or effects should be considered. The real need appears to be for more evaluators to address a wider range of factors than for traditional projects. Reaching out to the private sector, in particular, should yield better understanding of the broader societal consequences and potentially economically justify a much greater set of actions than traditional studies will.

The framework allows planners and concerned agencies to recognize that some ITS investments are different from conventional transportation improvements. The greatest benefits of some ITS projects may accrue to private companies, or may be reflected in changes to business practices or commuting behavior. A different framework, one that looks beyond conventional benefit/cost analysis to multi-criteria analysis, is needed to identify all these benefits.

To provide this insight, the framework:

- recognizes that there are multiple measures of the same benefit criteria and recommends ways to minimize problems that stem from this multiplicity,
- is sensitive to differences between ITS investments and traditional transportation improvements,
- includes qualitative as well as quantitative aspects of ITS benefits,
- includes user-related impacts as well as non-user impacts, and

- includes the different manifestations of the same benefit criteria depending on the length of the time period being observed.

The framework is divided into four major elements:

- a series of questions designed to help evaluators determine a comprehensive set of impacts,
- a process to evaluate which impacts and measures are most important and the best method to obtain the information,
- additional measures to augment those already identified for ITS evaluations, and
- recommendations for improved models and broader case studies that can assist with the estimation of ITS project impacts until better project level information becomes available.

The analytical theory used in this framework is similar to others in practice. The differences are in the treatment of the goals and in the process for identifying which goals and impacts should be studied.

Most importantly, this report identifies a comprehensive typology of issues. Potential positive and negative impacts of each issue are identified, they are linked to the broad ITS goals, and measures are suggested for each. This typology of gross impacts can be a useful guide for businesses, government, and other interested parties who wish to evaluate the link between measurable impacts of ITS projects or programs and user impacts including productivity, economic development, ITS deployment, and other qualitative impacts.

The report identifies several potential areas for expanded ITS impact analyses. These include broader assessments of current ITS program goals, as well as an expansion of the goals themselves. The following are key aspects of the report:

- Private sector impacts must be emphasized in more studies. Economic development and productivity are discussed as goals in many documents, but relatively few measures are used.
- Some impacts are not easily quantified and, therefore, they have not been included. Moving toward a multi-criteria analysis where quantitative and qualitative factors can be included will improve the breadth of the impact assessment. This approach also

allows many of the local stakeholder concerns to be included with the national ITS program assessments.

- A twin improvement strategy of performing case studies in the near term while better project level analyses are being conducted in the long term appears to be a way to improve the information available to project planners and engineers. The long-term analyses can take advantage of automated data collection technologies.
- Equity and privacy are two issues that have been discussed in the literature, but rarely addressed in any comprehensive manner. These are important impacts to some affected groups.
- Impact estimation has not suffered from an extensive double-counting problem yet, but as more data become available this will affect the validity of the analyses. The improved data access, for example, can lead to some mobility benefits being added to land value increases; part of the land value increase is the result of the improved mobility for trips to and from the site. The report suggests that this issue be monitored as evaluation techniques evolve.

INTRODUCTION – WHAT IS THE GOAL?

ITS applications can have significant benefits for users of the transportation system. The benefits can also extend to the operation of the roads, bridges, public transportation systems, and other elements of the system. The benefits may also manifest themselves in private businesses and public sector agency operational efficiencies. To date, however, relatively little is known about the long-term benefits due to the few years of many ITS operations.

When compared to the amount of information available about other transportation systems elements, the lack of information available on ITS improvements provides both positive and negative aspects. The negative side is that the lack of information may slow down implementation; some cities will wait to see the results before they invest the time and money installing operational improvements. The current state of knowledge on ITS impacts also makes it difficult to estimate ITS impacts with any degree of confidence. The positive side, however, relates to the potential improved benefit studies.

This report suggests that for a range of public and private sector information needs, there should be a broader study of ITS project impacts. These impacts can be included in future impact studies to provide ITS designers with a better idea of how their projects will be used.

THE ITS GOALS

The USDOT has established six goals for ITS implementations (1). The achievement of these goals will measure the success of ITS applications, and the impact assessment should provide information about each:

- Goal 1. Increase Transportation System Efficiency and Capacity
- Goal 2. Enhance Mobility
- Goal 3. Improve Safety
- Goal 4. Reduce Energy Consumption and Environmental Costs
- Goal 5. Increase Economic Productivity
- Goal 6. Create an Environment for an ITS Market

DESCRIBING ITS

The ITS Architecture effort has grouped the techniques, technologies and institutional arrangements designed to achieve these goals into six "user service bundles" (Table 1). These groups provide some structure and focus to a wide-ranging set of goals, objectives, needs, and projects. The projects and programs commonly thought of as ITS improvements are grouped into systems that perform functions satisfying the user service needs. The initial set of "systems" defined near the beginning of the ITS program in the early 1990s (Table 2) have been further described with a combination of market packages and equipment packages aimed at ensuring useful products.

THE IMPACT ASSESSMENT ISSUE

Intelligent transportation systems include a broad variety of subsystems that result in diverse and complex impacts. The complexity lies in the diverse technological reach of basic ITS infrastructure across all modes of transportation. This impacts an entire spectrum of stakeholders ranging from the economy and society as a whole, to infrastructure operators and fleet managers, to individual travelers. This also makes the evaluation of ITS a challenging prospect. Like traditional transportation improvements, ITS can impact both the users of the facility (often described as operational benefits) as well as non-users. The study of ITS impacts has traditionally focused on the user side and on effects that are more easily measurable with existing or quantifiable data. Many of the impacts of ITS, however, are qualitative and may defy measurement. Reports by Apogee Research, Inc. and Wilbur Smith Associates provide a comprehensive summary of both existing and ongoing studies (2,3,4,5) that document many of the impacts of ITS investments.

A comprehensive evaluation framework should:

- identify the process needed to specify the goals, objectives, and potential impacts in whatever form they appear and
- develop measures to estimate those impacts.

The framework should also assist in the difficult issue of causation – frequently ITS improvements are accomplished along with several other traditional improvements, which may mask the effect of ITS projects.

This report is an overview of an evaluation process that explores some of the less studied effects of ITS treatments. The framework resulting from this effort identifies a broader set of factors and measures to be tracked for a complete assessment of ITS impacts:

- It focuses on a different set of stakeholders for a more complete impact assessment.
- It identifies the importance of investigating the impact distribution for different user groups.

Table 1. ITS User Service "Bundles"

User Service "Bundle" Name	Services Included in "Bundle"
Travel and Traffic Management	Pre-Trip Travel Information En-Route Driver Information Route Guidance Ride Matching and Reservation Traveler Services Information Traffic Control Incident Management Travel Demand Management Emissions Testing and Mitigation Highway-Rail Intersection Archived Data
Public Transportation Management	Public Transportation Management En-Route Transit Information Personalized Public Transit Public Travel Security
Electronic Payment	Electronic Payment Services
Commercial Vehicle Operations	Commercial Vehicle Electronic Clearance Automated Roadside Safety Inspection On-Board Safety Monitoring Commercial Vehicle Administrative Processes Hazardous Material Incident Response Commercial Fleet Management
Emergency Management	Emergency Notification and Personal Security Emergency Vehicle Management
Advanced Vehicle Safety Systems	Longitudinal Collision Avoidance Lateral Collision Avoidance Intersection Collision Avoidance Vision Enhancement for Crash Avoidance Safety Readiness Pre-Crash Restraint Deployment Automated Vehicle Operation

Source: (1)

Table 2. Intelligent Transportation Systems, Circa 1996

System	Description
Advanced Traveler Information Systems (ATIS)	These systems include real-time route guidance, pre-trip information, and notifications of incidents to the driver.
Advanced Traffic Management Systems (ATMS)	Systems of this sort monitor traffic throughout the transportation system. Traffic management centers (TMCs) are being developed throughout the nation to manage freeway and street operations in regions and intercity corridors. These centers generally include placing many service agency representatives (e.g., state DOT, emergency services, transit agency) in one building for ease of communication and coordination.
Advanced Public Transportation Systems (APTS)	These technologies enhance the operation and safety of public transportation systems to encourage their use. Traveler information, electronic fare payment, and fleet management are examples of ITS technologies that are applicable to APTS.
Advanced Rural Transportation Systems (ARTS)	These systems apply several technologies including crash avoidance, hazard warning systems, and routing information for rural travelers.
Commercial Vehicle Operations (CVO)	These systems are aimed at improving the operation of trucks and buses. These applications include monitoring and evaluating vehicle performance, fleet management, and traveler information. Other applications include communicating inspection and compliance information to regulatory agencies.
Advanced Vehicle Control and Safety Systems (AVCSS)	These applications improve vehicle control and crash avoidance. Examples of these systems include assisted braking and collision warning.

Source: (1)

THE CURRENT SITUATION
WHAT IS MEASURED AND HOW?

ITS impact evaluations typically measure elements that are easily quantifiable with traditional types of traffic data. These data may include easily obtained traffic parameters, cost estimates, and accident information. The result is that ITS evaluations are not complete assessments of the project implementation impacts. In many cases, this will not present a problem because the individual treatment effects are limited to traffic engineering types of impacts. Larger, or more diverse ITS implementations, however, may effect more of the travel patterns and economic activity in a region and the impacts, therefore, may be more far-reaching. The performance indicators shown in Table 3 are typical of those used in traditional ITS benefit evaluations and are matched to the USDOT ITS goals they typically measure. The USDOT approach is to evaluate a "few good measures" that can be replicated, are relatively easily to obtain, and can be used to evaluate a range of ITS programs and projects.

The "few good measures" are designed to provide some basic consistency between evaluations and offer information on the progress of ITS efforts each year. The list (6) includes the following measures:

- travel time,
- throughput,
- crashes,
- fatalities,
- user satisfaction or user acceptance, and
- cost.

The approach is generally sound, and the need for extensive data can seriously harm project budgets, as well as disrupt the focus of implementing and operating agencies. Focusing the analysis on a few important measures ensures that data requirements are reasonable and specific. Not all of the performance measures listed in Table 3 therefore, are collected to assess a particular goal on every project. For example, only one or two of the measures (e.g., number of trips taken, travel time) may be used to evaluate the goal of enhancing mobility. Unfortunately, other impacts of ITS implementations may be overlooked. These "other impacts" are the motivation for this report.

Table 3. Performance Measures for Evaluating the Goals of ITS as Defined by the USDOT

ITS Goal	Related Performance Measure
Goal 1: ▪ Increase transportation system efficiency and capacity	▪ Traffic flows / volumes / # of vehicles* ▪ Intermodal transfer time* ▪ Infrastructure operating costs* ▪ Lane carrying capacity ▪ Volume to capacity ratio ▪ Vehicle hours of delay ▪ Queue length ▪ Number of stops ▪ Incident-related capacity restrictions ▪ Average vehicle occupancy ▪ Use of transit and HOV modes
Goal 2: ▪ Enhance mobility	▪ Travel cost* ▪ Number of trips taken ▪ Individual travel time ▪ Individual travel time reliability ▪ Congestion and incident-related delay ▪ Vehicle miles traveled (VMT) ▪ Number of trip end opportunities ▪ Number of accidents ▪ Number of security incidents ▪ Exposure to accidents and incidents
Goal 3: ▪ Improve safety	▪ Number of accidents* ▪ Number of fatalities* ▪ Number of incidents ▪ Number of injuries ▪ Time between incident and notification ▪ Time between notification and response ▪ Time between arrival and clearance ▪ Medical costs ▪ Property damage ▪ Insurance costs
Goal 4: ▪ Reduce energy consumption and environmental costs	▪ NO_x emissions ▪ SO_x emissions ▪ CO emissions ▪ VOC emissions ▪ Liters of fuel consumed ▪ Vehicle fuel efficiency
Goal 5: ▪ Increased economic productivity	▪ Travel time savings* ▪ Operating cost savings* ▪ Administrative and regulatory cost savings ▪ Manpower savings ▪ Vehicle maintenance and depreciation ▪ Information-gathering costs
Goal 6: ▪ Create an environment for an ITS market	▪ ITS sector jobs ▪ ITS sector output ▪ ITS sector exports

Note: Goal numbers added for clarity in this report.
*Included in USDOT's "few good measures" list.
(Adapted from 6)

Goals 1 through 4 are what could be called "conventional transport engineering goals." Most evaluation plans include some way of considering these effects, primarily because it is traditionally "the way it has always been done." Focusing on Goals 1 through 4 leads to the use of traditional approaches using direct user benefits within a benefit/cost framework. This approach is good for evaluating the marginal value of changes to standard technologies, but tends to become less valuable for the evaluation of new modes or new technologies. It is also not as useful in evaluating changes in total system effects for ITS investments—which have both improved and new technologies. ITS deployments require an alternative framework and approaches which could completely identify all facets of deployment-oriented questions.

Goals 5 and 6 go beyond traditional user benefits to cover the potential impacts of ITS technologies on, for example, private sector company logistics, productivity, and employment. Some of these measurements, even when recognized during the evaluation program design phase, are not included due to their complexity.

ISSUES WITH CURRENT APPROACH

Performance measures and evaluation techniques for the goals in Table 3 have several similarities and a few key differences. It is useful to outline these as a way to illustrate any evaluation framework.

Assessment of Micro-Level and Macro-Level Impacts

All of the goals in Table 3 can be assessed at both the macro (national) level as well as at the relatively micro level (e.g., state, local community, private company, or individual traveler). However, for a particular issue of interest some indicators may be more meaningful at one level than the other. For example, at the macro level, one of the indicators of Goal 5 (increased productivity) is enhanced competitiveness. This is more meaningful at the national level for assessments of the ITS Program. Individual firms may wish to evaluate the contribution of their ITS investments to their profit/loss, but that is not typically the issue with program evaluations. In other words, how well a single firm performs is much less important than the success or competitiveness of a whole industry for evaluations performed at the macro level.

Brand developed a framework that could be used for the evaluation and selection of ITS projects based on their site-specific user benefits and costs rather than desired results (7). He also acknowledges that the use of the latter is justifiable in the context of planning for a research program whose payoff is mostly uncertain. The framework was designed to evaluate mobility and mobility-induced impacts at the micro level of the individual tripmaker instead of relying on aggregate measures of flow volumes and travel times on the network.

Brand extends the framework developed in 1993 to propose criteria and evaluation methods for ITS plans and operational tests (8). The criteria proposed are stratified by 1) supply-side versus demand-side impacts, and 2) time scale of impact (short-, medium- or long-term impact). Increased operational efficiency was classified as supply-side efficiency while increased output was treated as a demand adjustment. This separation enables the evaluator to separate ITS technology benefits from individual and corporate demand responses to ITS that actually induce an increase in output over and above those produced by the technology alone, while also enabling an evaluation of induced travel impacts. This framework has two additional features. First, it extends the original framework to include a consideration of possible non-user impacts through the stratification scheme, and second, implementation criteria are elucidated. Non-user impacts include economic development criteria while implementation criteria include agency cooperation, technological flexibility, and ease of implementation. However, the framework is essentially focused on potential user-centered criteria and micro-level impacts of ITS.

Underwood and Gehring present an evaluation framework for ITS for four different kinds of benefits: current, future, expected, and potential (9). In the framework, current benefits may be measured empirically through evaluation of operational field tests and other direct approaches. Prescriptive evaluation is the suggested approach for evaluating future benefits. These are more formal mathematical models and include forecast models, optimization models, and descriptive models. The work of Underwood and Gehring also recognizes that accounting for indirect effects could be important for institutional-type issues but that this would also increase uncertainty of forecasts. However, no methodology framework for consideration of institutional impacts is provided nor are links between impacts discussed.

Addressing Quantitative and Qualitative Impacts

All USDOT goals share both quantitative and qualitative elements. Quantitative impacts are measurable impacts for specific issues that can be expressed and analyzed numerically. A number of techniques can be used to estimate these impacts. They range from simulation, statistical, and econometric modeling to operational field tests and case studies. The technique used depends upon the specific impact being measured and the time frame being considered (e.g., current, future). From a theoretical standpoint, these quantitative estimates can be converted into dollars and used in an overall benefit/cost (B/C) ratio (assuming that no benefits have been double counted).

All goals also have qualitative elements, however, and these are typically more difficult to include analytically. The qualitative elements can be subdivided into two categories—qualitative assessments and qualitative impacts. Impacts refer to elements which are measurable (but not in a wholly numerical manner).

For example, the fact that increased safety, improved mobility, and reduced pollution will improve quality of life is a qualitative impact. These types of impacts are critical for addressing societal implications inherent within Goals 2, 3, and 4. These also bring ITS goals directly into the realm of sustainability, particularly those related to sustainable communities.

A qualitative impact related to Goal 5 is the statement that businesses and the private sector will value improvements in their material and capacity utilization (i.e., they can more efficiently use elements such as space and capital). The reduction in logistics costs can enhance their individual productivity which will, in turn, affect their analysis of their ITS investments. These impacts may not be easily measured, but some of them can be simulated.

Qualitative assessments, on the other hand, are used when some aspects cannot be currently measured due to various limitations such as the time factor (i.e., the extent of ITS saturation in society and, therefore, an inadequate database). Some of these impacts may be amenable to simulation modeling, but if the extent of ITS saturation is not large enough (i.e., actual measurement of the impacts are not possible) a qualitative assessment is sometimes all one can perform. However, a qualitative assessment can provide a good estimate of anticipated impacts especially when no other way exists for measurement. For example, the assumption that in-vehicle guidance systems will reduce traveler fatigue and increase traveler convenience is a qualitative assessment of benefits. The statement that ITS investments will lead to increased productivity (Goal 5) at the national level is another (2,3,4,5).

Table 3 includes many performance measures that quantify the benefits of ITS for Goals 1 through 4. These factors are often based upon data that are relatively easy to collect and/or are modeled with analysis packages. Goals 2 through 4 also contain societal implications including quality-of-life and the value of ITS improvements at all levels from national to individual. Typical ITS impact evaluations often do not consider these quantifiable, but not easily measured, aspects.

Some of the performance measures for Goals 5 and 6 are more difficult to quantify and often lead to the use of qualitative measures. Qualitative evaluation and/or simulation modeling are extremely helpful for practitioners and decision-makers because the potential for some relatively new technologies within ITS is rather uncertain. Therefore, being aware of these potential impacts, and including them when possible, is critical to a complete assessment.

Decision-makers have traditionally considered the user benefits embodied in Goals 2 through 4. McGurrin and Shank write, "knowing that ITS investments have a high benefit/cost ratio (based on user aspects alone) is not enough—ITS competes with other solutions that are good investments and ITS will most likely be adopted only if planners think that it is the best solution to an existing problem" (10). If this is true, then it is important for ITS investments to consider all possible ways in which benefits can accrue. In particular, it is important to evaluate the societal impacts of ITS investments. Goals 5 and 6 are socio-economic goals that address some non-transport issues that concern the general public.

The question then is: "Should impact measures under Goals 5 and 6 be evaluated for incorporation into a benefit/cost analysis?" The answer to this question is uncertain at present. There are many commonalities, linkages, and potential correlations between goals that may measure the same effect. Some of these impact measures should not be incorporated directly into an integrated benefit/cost measure for decision-making purposes because it could lead to an overestimation of true benefits. However, decision makers may value or weight different manifestations of the same impact differently and, ultimately, they must decide which manifestation of the benefit is the one that may represent the true "value added" to society and the community. Other impacts or measures can be eliminated from the decision-making process.

The specific type of ITS improvements being considered should also guide the composition of the analysis. If a commercially viable or effective improvement such as a commercial vehicle treatment or an information dissemination technology is considered, private sector impacts are important. These also may lead to equity-related impacts. Other treatment analyses may not be as encompassing.

Including Direct and Indirect Impacts

Goals 1 through 6 can be manifested either directly (primary impacts) or indirectly (secondary, tertiary, or also referred to as higher-order impacts). As has been noted by previous research, it is rather straightforward to conceptually draw inferences from the deployment of specific ITS technologies and the resulting impacts. These are the direct impacts.

Indirect impacts, however, are a consequence or result of direct impacts and are, therefore, important to examine. For instance, increased productivity (Goal 5) could be the consequence of Goal 2 and/or Goal 4 when it is measured as increased output or cost savings per unit of input. The enhanced mobility (Goal 2) could be reflected in higher land or property values. Similarly, Goal 4 could also eventually impact land/property values. Travelers using ATIS could definitely benefit from travel time savings and improved speeds; however, theoretical research has shown that even non-users could be impacted by the improved system efficiency. Many socio-economic types of impacts can be considered to be higher-order impacts. Changes in employment (mostly construction employment), however, can be a direct manifestation of Goal 5.

Most higher-order impacts tend to be long-term. Yet other indirect impacts due to improvements in congestion, air pollution, and travel time still present a challenge for valuation purposes. It is hard to conceptualize the link between indirect or higher-order impacts and ITS investments. It is even harder to establish a cause-and-effect relationship between these events. However, it is important to consider them in any long-range forecast because they tend to feed back to the transportation sector eventually by causing shifts in travel demand.

Measuring Long-Term and Short-Term Impacts

The measurement, or estimation, of impacts from ITS implementation is a direct result of the amount of information available. The extent of ITS deployment and type of service or technology being deployed will determine the source of measurement information—collected, modeled, or estimated—but it should also determine which performance metrics are used in the evaluation.

Both long-term and short-term impacts will result from major ITS investments, but Goals 1, 2, 3, and 4 are more likely to have substantial effect over the short term. These are easier to observe and measure; there is often data available to quantify the impact or at least calibrate a model and the short-term and long-term impacts can be measured/estimated with the same metrics.

Longer term impacts, which include those from Goals 1 through 6, will probably include more qualitative information and more simulation modeling, especially early in the implementation phase. The "quality-of-life" effects of projects aimed at Goals 2, 3, and 4 will obviously be longer term issues, as will most of the effects of Goals 5 and 6. Long-term effects are important features of the feasibility and cost effectiveness studies; ignoring them may underestimate both positive and negative impacts of a project. Issues as wide ranging as environmental impacts, user benefits, private sector investment, and tolling potential rely on long-term effect analysis. The analysis should be conducted even if the level of detail is only at the qualitative assessment or computer modeling level.

Counting Some Benefits Twice and Others Not at All

In the near term, there are impacts that will be considered to be related to Goals 1 through 4 that, in the long-term, will be easier to identify as a Goal 5 impact. This will lead to double counting of these impacts. For example, double counting may occur in mode choice when transportation efficiency and capacity is increased, mobility is enhanced, and safety is improved. Commuters may feel that they can comfortably live further from employment and activity centers with ITS applications (e.g., in-vehicle traveler information) that reduce the travel time to the same as they experienced living closer to the activity centers without ITS in place. This phenomenon may lead to more purchase of property on the fringe areas, thus leading to an increase in property values in those areas over time. Therefore, there would be double counting to the extent that indicators on urban form and development patterns are included in an analysis, especially at the project level.

The impacts on property values are a result of the safety, travel time, and reliability improvements already accounted for in the analysis in Goals 1, 2, and 3. The potential for double counting and areas in which it may become a problem will become clearer as ITS is deployed more extensively into a given area. Double counting also becomes an issue when selecting among alternative investment strategies or ITS technologies. The problem can be evaluated over the course of deployment if the issue is recognized.

Examining the impacts measured in an evaluation program also allows the analyst to determine if any impacts are not represented. To the extent that the analysis is based on traditional traffic engineering principles, some of the broader impacts will be missed. These may become more important as ITS investments eventually compete with other equally viable alternatives for funding. Market-type forces will eventually push ITS project designers to consider a broader range of impacts. A method is needed that will quantify these issues in the form that they can be included with the more traditional, and readily quantifiable, aspects of several goals. These measures could possibly be integrated into a benefit/cost ratio or a scoring/weighting procedure. Sensitivity analyses that test the impact of a range of estimated values (rather than relying on a single estimate) can assist in the evaluation of ITS projects by identifying the most important factors.

Data Availability and Appropriateness

In some analytical and institutional processes, the issue of data availability is paramount. The information threshold is difficult to overcome for some issues, some data items, and some project impacts—this has the effect of altering the perception of the professionals involved in analyzing the project. Impacts that are difficult to estimate may be marginalized if the focus on data availability overcomes the goal measurement orientation. Using a sensitivity analysis approach to identify a range of demand and other effects, a range of estimated costs will inform the project evaluations until better data are available. This approach also recognizes the great knowledge uncertainty in some ITS subject areas.

This issue relates to the relatively small amount of experience with ITS programs—a problem that may only be addressed by time. The local and national "multipliers" or estimation techniques that are familiar for basic traffic engineering projects have not been developed for ITS. There is no consensus on the magnitude (or even positive/negative direction) of impact to the private sector. The lack of literature and quantitative studies extends to congestion-related impacts.

In addition, certain ITS impacts are correlated, or linked, with other impacts. Consider, for example, the relationship between private sector productivity goals, and shipper or traveler information—a relationship including Goals 1, 2, and 5. If ITS improvements enable the same number of vehicles to ship more goods, there is a potential for the firm's transportation costs to decrease and its profit margins to increase. Productivity is likely to increase as well. Therefore, the private sector's productivity goals and shipper/traveler information are linked. This must be considered when developing a data collection plan and when performing the evaluation.

WHAT CAN BE IMPROVED?

The measures in Table 3 for Goals 1 through 4 are appropriate for quantifying ITS project impacts. These are traditional transportation engineering and planning measures improved by recent advancements in data collection. This especially extends to travel time and speed data collection through the traffic management centers. There are several issues related to collecting and analyzing the data, but the quantitative measures are appropriate.

Quality-of-Life Indicators

Survey-based approaches appear to be the best ways to measure quality-of-life indicators. It may be best to use the before-and-after case study method to measure such ITS impacts. This would be performed by comparing a location before and after the implementation of ITS with a similar control site in which ITS is not deployed. This type of technique can aid the measurement of any marginal changes there might be in quality-of-life indicators such as neighborhood quality for residents and businesses.

Recent research also indicates that there are ways to incorporate these kinds of measures into the overall decision-making framework. These approaches could involve multi-attribute utility theory or other variants of this approach. These methods quantify various qualitative measures based upon the value that individuals place upon them (i.e., the utility). Qualitative considerations can be quantified in a survey form (i.e., with a 5-point scale) to indicate their relative weight. This quantified information can then be integrated into the decision-making framework. The analyst must still be aware of the potential effects of double-counting when integrating this information with the results of measures in other goals.

Willingness-to-Pay Information

Cost effectiveness indicators for transportation improvements may be increasingly related to the amount of money that users are willing to contribute for the service. This may be for each use, as on toll facilities or at commercial vehicle inspection stations, or on the investment that private companies are willing to make in ITS infrastructure or systems.

Several approaches to measuring this "willingness-to-pay" have been advocated in the literature. Some of these approaches are survey-based, but current research in this area is developing new ways of addressing this question using a combination of surveys and other approaches (e.g., travel cost approaches). One implication of considering safety, energy, and environmental goals or non-market goods as impact factors is that measuring these will mean that the willingness-to-pay has to be measured. This might be illustrated over the long term in property values, or a variety of business decisions, but in almost all cases, they will not be easily measured from the roadway.

Societal Goals and Equity Considerations

While not specifically designed to address these issues, ITS improvements will be graded on them, as all transport programs ultimately are. Including measures in the evaluation process will give ITS designers and evaluators an "early reading" of the potential public opinion of ITS treatments. This may be very valuable in the design and early operating phases when changes can be made more easily. ITS is still generally viewed as in the experimentation phase when change is expected; this can be used to great advantage if the changes can be informed by the range of concerns.

Social goals and equity-related issues—who gains, who loses, and where the spatial distribution of effects from specific ITS projects—are not well covered in the current ITS goal set. Many of the factors cannot be converted into dollar terms. One way to approach this is to consider the issues within the framework of multi-criteria analysis (MCA). Traditional benefit/cost analyses cloud the assessment of equity issues. MCA evaluations can supplement benefit/cost analyses to account for intangible impacts and those for which it is difficult or impossible to place a dollar value upon. This multi-attribute approach is one way in which concepts of sustainability can be operationalized as well.

Some implementation decisions may involve equity considerations as a product of the operation mode. Information generated from ITS programs, for example, can be sold and some groups may not be able to pay for that. Privacy concerns are not typically part of an evaluation or performance audit, but are usually addressed during planning and design. They might be productively included in an evaluation framework as another element of "are ITS projects achieving societal goals?"

Shipping and Transport

Shippers should experience the same transportation efficiency and capacity increases, mobility enhancements, and safety improvements, with shorter, and more reliable, travel times that motorists realize. As mentioned in the section on linkages, this operating environment would reduce transportation costs, as well, and allow for better capacity utilization of businesses. These impacts are reflected in Goals 5 and 6 and, clearly, there is a strong link here to Goals 1 through 4 resulting in the potential for double-counting.

Technological Spin-Offs

Estimating the potential technological spin-offs from ITS is challenging. It may be possible to estimate technological spin-offs attributable to ITS using market estimates for the magnitude of the technological development directly attributed to ITS-related research and development for existing technologies. It will be very difficult to separate the impacts of ITS-related research and development with information technology (IT)-related research and development. Disregarding this relationship, however, can lead to inaccurate measurements. These developments would be reflected in Goals 5 and 6.

A SET OF QUESTIONS TO INFORM IMPACT EVALUATIONS

In both general and specific terms, evaluating ITS programs and projects is not too different than other public works improvements. What is different is the analytical and social environment that exists and the substantial process changes that are taking place in transportation.

For construction projects or maintenance activities many issues have been "settled" on the subject of how to conduct evaluations. The goals are reasonably well understood and accommodated in the evaluation frameworks; the performance measures are changing, but only to more accurately reflect already well-understood traveler reactions; and the data are available, or simulation models can predict the effects.

What has received more discussion lately, however, is some of the basic premises behind the justification of transportation improvements as a whole. Evaluation programs should address a wide range of effects previously thought to be secondary. These may include a variety of social or business practice impacts. Part of the problem is that the goals of transport improvement programs in general are not as clear as they used to be.

A generic evaluation framework can still be applied to ITS improvements, but it seems useful to point out locations in the process where enhancements can provide a broader set of answers. This chapter begins with a set of questions that ITS evaluators and designers might use to discover other key issues that could be addressed during an evaluation period or for a project feasibility analysis. An ITS impact evaluation framework designed to answer the key questions has a much greater chance of successfully identifying the data needed to justify past actions and support future recommendations for improvements.

GENERIC FRAMEWORK

As described in both performance-based planning literature (11) and evaluation steps for mobility improvements (12,13), the *goals and objectives* for transport systems should be the focus of the analysis. The evaluation *measures* should indicate the impacts and level of achievement of those goals and objectives. And the *data* should be collected or estimated according to the needs of the measures. This framework, as illustrated in Figure 1, is a good base to start with because of the "primacy of goals" feature. To a significant extent, the goals and measures in Table 3 and Figure 1 illustrate the successful application of this framework.

The general process recommended in this report is summarized in Figure 2; it closely mirrors the performance-based planning process of Figure 1. The goals and objectives lead to assessments of the impacts. The impacts may be qualitative or quantitative in nature, may vary in a temporal or spatial context or may affect groups of people or businesses differently. A benefit/cost analysis can be one portion of the assessment, but a sensitivity analysis and some refinement similar to multi-criteria analysis will be useful to obtain the truly broad-based impact assessment recommended in this report.

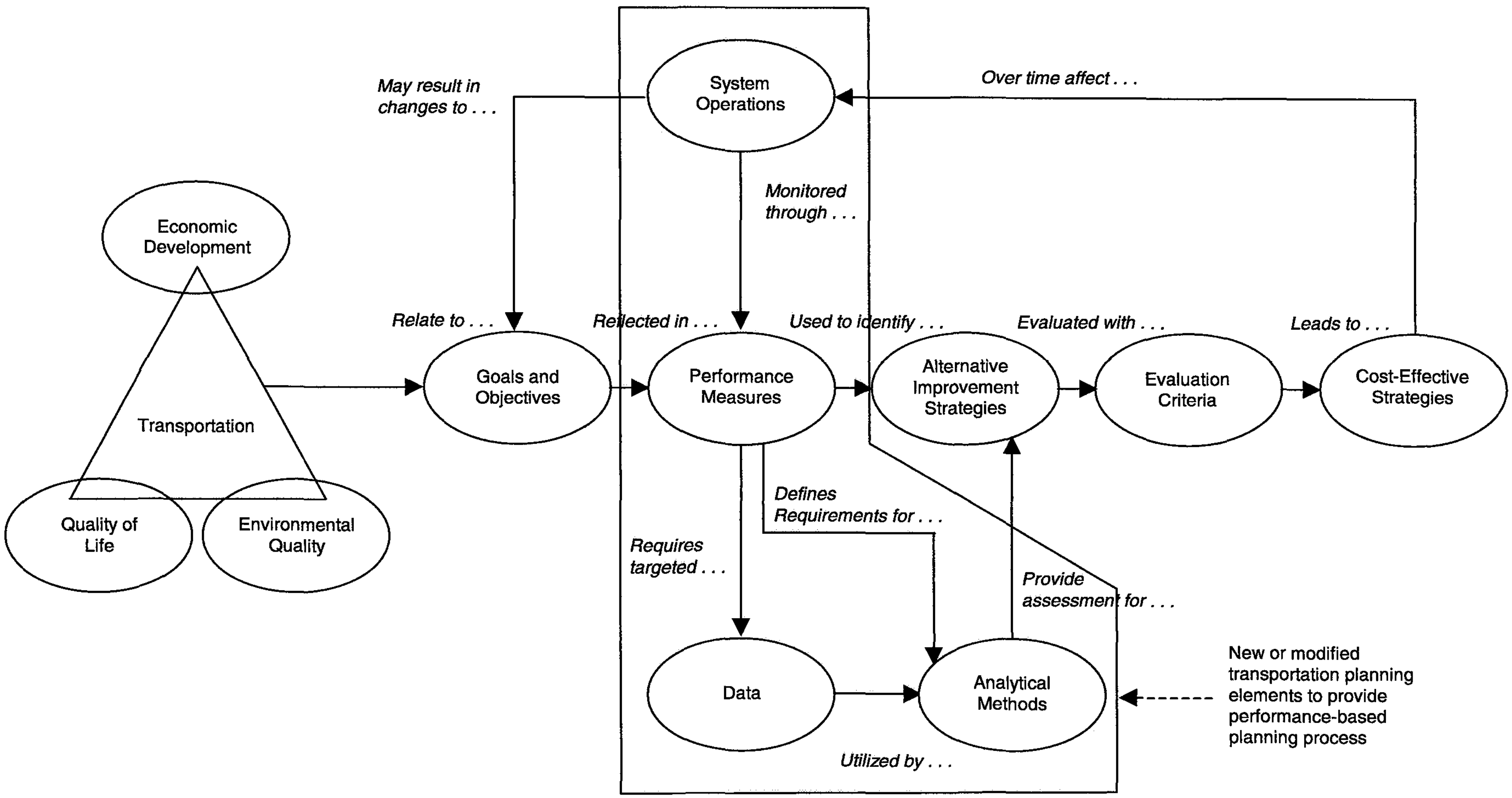
A SET OF RELEVANT QUESTIONS

Moving from existing practice to a more comprehensive set of measures will require practitioners to either recognize existing deficiencies or recognize opportunities. This process might be assisted by a list of questions that lead the practitioner to re-examine their current evaluation plan or feasibility study. These questions, and some suggestions concerning what answers might be found, are discussed below.

Question 1: What is the ITS project trying to accomplish?

This is another way of stating the goals and objectives of the project, but this phrasing allows consideration of any desired effect rather than simply two or three officially published goals. This should be a relatively detailed list but not to the level of individual site or time impacts.

Some examples of these targets are presented in Table 4. They are generally organized from broad impacts or difficult to estimate issues, to more specific or focused impacts. The aim of this question is not to decide if the issue can be measured, but rather to think broadly about potential outcomes from the implementation. The comprehensiveness of the analysis will be determined in later steps. These targets and their potential impacts are discussed in the appendix.



Source: 11

Figure 1. Elements of a Performance-Based Planning Process

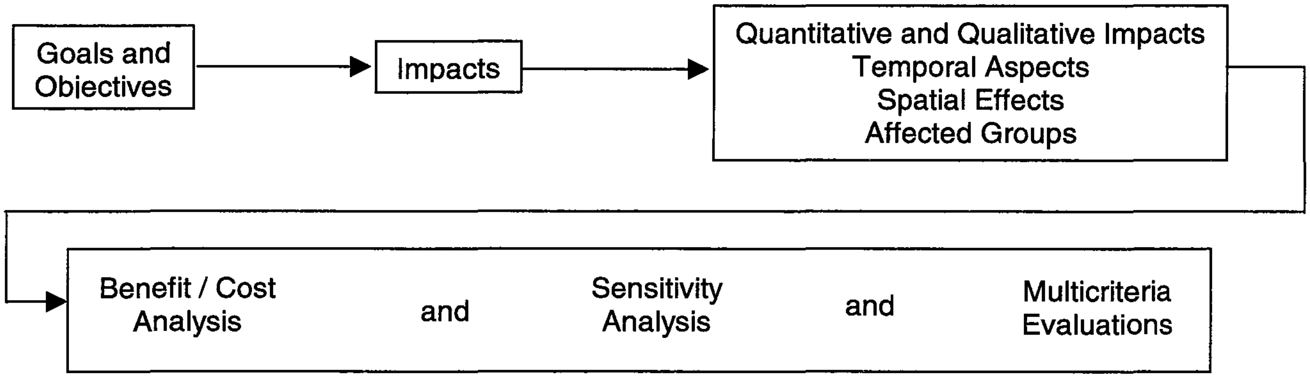


Figure 2. General Schematic of ITS Evaluation Framework

Table 4. Examples of Potential ITS Accomplishments

	Potential Accomplishment	ITS Goal[1]
Broad Impacts	Land Use Changes	NR
	Improved Access to Labor, Materials, and Markets	2
	Relationship Building Within and Between Public and Private Organizations	NR
	Ensure an Equitable System	NR
	Ensure Privacy	NR
	Air Quality and Fuel Consumption Changes	4
	Mode Choice Changes	1,2
	Shipping Effects	1,2
	Future Demand Increases	1,2
	Motor Vehicle Standards and Changes	5
	Reduce Motorist Workload and Improve Comfort	2,3
Focused Impacts	Improved Emergency Medical Service Response	3
	Develop Compatible Systems, Specifications, and Architecture	6

[1]See Table 3 for list of Goals.
NR – not currently referred to in one of the USDOT Goals.

Question 2: What are the possible effects?

More specific than outcomes are the possible secondary effects of an ITS project. These include the actions, events, or change in status that might result from the outcomes listed in Question 1. It may be logical to think of these as potential positive and negative effects but the direction of change is not as important as the type of impact. A proper set of measures can only be developed if the analyst knows what to look for. Table 5 lists sample impacts for the issues listed in Table 4. The Appendix includes more discussion about the targets and the potential impacts.

Table 5. Potential Positive and Negative Impacts for Issues Related to ITS Implementation

Potential Positive Impact(s)	Potential Negative Impact(s)
Land Use Changes	
▪ Makes land more valuable in fringe areas	▪ Contribution to urban sprawl ▪ Reduced farm land, reduced crop production ▪ Encroachment on small towns ▪ Deterioration of ecosystems ▪ Loss of access to jobs in inner cities
Improved Access to Labor, Materials, and Markets	
▪ Increased output ▪ Decreased costs ▪ Increased competition ▪ Increased opportunity for innovation ▪ Increased opportunity for public/private partnerships	▪ Increased relocations of businesses
Relationship Building Within and Between Public and Private Organizations	
▪ May lead to cheaper contracts ▪ May lead to more efficient construction ▪ May lead to lower maintenance costs due to designs that include all agencies ▪ Creation of new ideas	▪ Potentially introduces too many individuals/agencies into the planning, design, and/or construction project phases that may cause difficulty in decision making
Ensure an Equitable System	
▪ Builds trust between transportation professionals and agencies, decision-makers, and the public ▪ Eliminates sense of "haves" and "have nots"	▪ Increased effort needed to analyze equity
Ensure Privacy	
▪ Builds trust between transportation professionals and agencies, decision-makers, and the public	▪ Increased staff time for interviews ▪ More complex analysis
Air Quality and Fuel Consumption Changes	
▪ Reduced fuel consumption and emissions due to "smoother" traffic (i.e., decreased hard accelerations)	▪ Does ITS-related traffic improvement encourage more private vehicle travel and less transit or carpooling?
Mode Choice Changes	
▪ Added convenience since one can travel anytime to anywhere in personal vehicle	▪ Reduced incentive for public transportation ▪ Reduced incentive for TDM strategies ▪ Increases in fuel consumption ▪ Reduced air quality

Table 5 (continued). Potential Positive and Negative Impacts for Issues Related to ITS Implementation

Potential Positive Impact(s)	Potential Negative Impact(s)
Shipping Effects	
▪ Same number of vehicles ship more ▪ Quicker and more reliable delivery ▪ Increased market share ▪ Possible to work into real-time coordination with TMC	▪ Increased need for information creates more employees at private firms ▪ Truck drivers feel closely monitored
Future Demand Increases	
▪ Not applicable	▪ Latent demand and demand due to new economic development take the place of additional capacity created by ITS strategies
Motor Vehicle Standards and Changes	
▪ Reduced insurance for some features (e.g., daylight running lights, four-wheel anti-lock brakes, air bags, automatic seat belts) ▪ Provides incentive for continued safety improvements	▪ Increased vehicle costs
Reduce Motorist Workload and Improve Comfort	
▪ Less stressful driving experience	▪ Potential for driver distraction by new systems increasing accident potential ▪ Additional education and training of motorists to operate systems
Improved Emergency Medical Service Response	
▪ Improved emergency medical response ▪ More in-tact families ▪ Potentially reduce number of EMS, fire, and police vehicles necessary ▪ ALERT vehicle--reduces clerks needed and video images aid criminal action and prosecution process ▪ Reduced health care costs	▪ Not applicable
Develop Compatible Systems, Specifications, and Architecture	
▪ Creation of new ideas and companies ▪ ITS can be "packaged" and sold ▪ Necessary hardware and software become standard ▪ Customer benefits from new strategies and company increases revenue ▪ Provides data in a standard format for quantifying benefits	▪ Reinforce bias against technology due to system failures or unreliability

Several of the impacts in Table 5 are expressed as relatively subjective events, or as items that would be difficult to measure. Some issues are assigned to a category (positive or negative) that could be a point of contention. Again, if it assists the analyst in identifying measurement needs, the process is successful. The analysis process should be constructed as a way to look for the positive and negative aspects—the process should not attempt to replicate these ideas of positive and negative outcomes.

Question 3: How can the impact be measured?

This step begins the process of separating the impacts into groups according to the level of detail and specificity that might be used in the measurement process. The measures can be quantitative, qualitative or merely conceptual ideas. The information used in the measurement methodology can be data collected from operations, estimates from limited or preliminary operational studies, models or estimated results, surveys, or case study results applied to a different situation.

Table 6 illustrates some potential performance measures related to the issues and impacts discussed in Questions 1 and 2 (Tables 4 and 5). Many of the quantitative measures are included in the list of measures prepared by USDOT, but the survey information and other qualitative measures or assessments are not typically included. Some of the changes are not easily "assignable" to one improvement, or even to any action, as opposed to general economic improvement or decline.

A range of detail and precision level will be required to address the questions in this step. Policy analyses or system-wide planning studies may not require the same level of detail or the same type of measures that are needed in the system design phase. And some issues or impacts will become more important over time as they become more fully visible. Direct impacts of travel time saved, for example, will become obvious very quickly. Business practice changes, however, may eventually be larger than travel time savings but they are not typically evident for several years.

Question 4: Are there other goals for the project that should be measured?

Each ITS program or project has a local component to the activity. These local constraints or opportunities arise as a product of the variation in sites, policies, and public opinion. Rather than trying to fit all of these local expectations into one of six USDOT goals, a better approach may be to have an additional list of goals that appear to be outside of the typical goal list. Some of these may not be measurable, there may not be any data or models to support an analysis, and it is possible that there would not be agreement on all the goals. The objective of this question, however, is to develop an understanding of how the project will be perceived by the professionals and the public. The list of issues in the "Current Situation" chapter may also provide several ideas for non-traditional goals.

Table 6. Possible Performance Measures for ITS Impacts

Potential Positive Impact(s)	Potential Negative Impact(s)	Related Performance Measure(s)
Land Use Changes		
▪ Makes land more valuable in fringe areas	▪ Contribution to urban sprawl ▪ Reduced farm land, reduced crop production ▪ Encroachment on small towns ▪ Deterioration of ecosystems ▪ Loss of access to jobs in inner cities	▪ Change in developed land ▪ Change in population density ▪ Surveys with travelers about the ease of travel and changes in travel behavior ▪ Other quantitative measures shown in Table 1
Improved Access to Labor, Materials, and Markets		
▪ Increased output ▪ Decreased costs ▪ Increased competition ▪ Increased opportunity for innovation ▪ Increased opportunity for public/private partnerships	▪ Increased relocations of businesses	▪ Productivity and cost measures ▪ Market share and competition ▪ Changes in employment patterns of businesses and/or changes in business relations ▪ Public/private partnerships
Relationship Building Within and Between Public and Private Organizations		
▪ May lead to cheaper contracts ▪ May lead to more efficient construction ▪ May lead to lower maintenance costs due to designs that include all agencies ▪ Creation of new ideas	▪ Potentially introduces too many individuals/agencies into the planning, design, and/or construction project phases that may cause difficulty in decision making	▪ Interviews with public and private personnel ▪ Savings attributable to contracts and relationships at agencies
Ensure an Equitable System		
▪ Builds trust between transportation professionals and agencies, decision-makers, and the public ▪ Eliminates sense of "haves" and "have nots"	▪ Increased effort needed to analyze equity	▪ Interviews with system users and non-users regarding equity ▪ Market research of ITS customers ▪ Willingness-to-pay
Ensure Privacy		
▪ Builds trust between transportation professionals and agencies, decision-makers, and the public	▪ Increased staff time for interviews ▪ More complex analysis	• Interviews with general public about the perceived privacy of the system • Evaluation of system security
Air Quality and Fuel Consumption Changes		
▪ Reduced fuel consumption and emissions due to "smoother" traffic (i.e., decreased hard accelerations)	▪ Does ITS-related traffic improvement encourage more private vehicle travel and less transit or carpooling?	▪ Changes in air quality and fuel consumption
Mode Choice Changes		
▪ Added convenience since one can travel anytime to anywhere in personal vehicle	▪ Reduced incentive for public transportation ▪ Reduced incentive for TDM strategies ▪ Increases in fuel consumption ▪ Reduced air quality	▪ Changes in air quality and fuel consumption ▪ Surveys with motorists about the ease of travel and changes in travel behavior ▪ Other quantitative measures shown in Table 1

Note: See Appendix A for description of measures.

Table 6 (continued). Possible Performance Measures for ITS Impacts

Potential Positive Impact(s)	Potential Negative Impacts(s)	Related Performance Measure(s)
Shipping Effects		
▪ Same number of vehicles ship more ▪ Quicker and more reliable delivery ▪ Increased market share ▪ Possible to work into real-time coordination with TMC	▪ Increased need for information creates more employees at private firms ▪ Truck drivers feel closely monitored	▪ Changes in travel time and reliability ▪ Savings attributable to reduced travel time and improved reliability ▪ Increased economic productivity or increased market share ▪ Other quantitative measures shown in Table 1
Future Demand Increases		
▪ Not applicable	▪ Latent demand and demand due to new economic development take the place of additional capacity created by ITS strategies	▪ Surveys with motorists regarding travel behavior before and after system implementation ▪ Other quantitative measures shown in Table 1
Motor Vehicle Standards and Changes		
▪ Reduced insurance for some features (e.g., daylight running lights, four-wheel anti-lock brakes, air bags, automatic seat belts) ▪ Provides incentive for continued safety improvements	▪ Increased vehicle costs	▪ Dollar savings attributable to having such features ▪ Additional measures shown for "improve safety" goal in Table 1
Reduce Motorist Workload and Improve Comfort		
▪ Less stressful driving experience	▪ Potential for driver distraction by new systems increasing accident potential ▪ Additional education and training of motorists to operate systems	▪ Savings attributable to having such systems ▪ Interviews with system users regarding extent of workload and fatigue ▪ Additional measures shown for "improve safety" goal in Table 1
Improved Emergency Medical Service Response		
▪ Improved emergency medical response ▪ More in tact families ▪ Potentially reduce number of EMS, fire, and police vehicles necessary ▪ ALERT vehicle—reduces clerks needed and video images aid criminal action and prosecution process ▪ Reduced health care costs	▪ Not applicable	▪ Lower response time ▪ More predictable and reliable response time ▪ Personnel and equipment reductions ▪ Additional measures shown for "improve safety" goal in Table 1
Develop Compatible Systems, Specifications, and Architecture		
▪ Creation of new ideas and companies ▪ ITS can be "packaged" and sold ▪ Necessary hardware and software become standard ▪ Customer benefits from new strategies and company increases revenue ▪ Provides data in a standard format for quantifying benefits	▪ Reinforce bias against technology due to system failures or unreliability	▪ Surveys with transportation professionals utilizing system to evaluate if equipment and architecture are standardized, practical, and understandable ▪ Surveys with those using or not using "packaged" materials (e.g., software, hardware) ▪ Savings attributable to having such standards and procedures ▪ Additional measures for ITS market goal in Table 1

Note: See Appendix A for description of measures.

This step is intentionally placed late in the order of the questions to reflect the way that most ITS projects and programs will be implemented. In almost every case, the easy and probably fastest approach will be to allow the traditional (e.g., ITS architecture) process to be used to develop the initial list of standard goals, measures, and data. Project developers will feel comfortable with this process, and the steps should go quickly. Question 4 is a good place to begin the outreach process to a wider range of travelers, shippers, other agencies, and community leaders. Their questions might be more comprehensively addressed if traditional measures are already "in the list."

Question 5: Are there other impacts that should be measured?

As a result of Question 4, and other input, the list of impacts might be expanded. As with other questions, the impacts should not be limited to those that can be measured by traffic data or similar quantitative information. A broad assessment of items and issues that might need analysis can lead to more informed decisions about where to focus resources.

Question 6: How should the other impacts be measured?

The new goals from Question 5 should be examined from the perspective of generating measures and finding data or estimates to support the measures. The focus of this question is similar to Question 3, but it is more likely that the answers to Question 6 will be qualitative, from an atypical quantitative source or from a simulation analysis. Pursuing these data sources will uncover other information that may be useful in describing how non-technical audiences will relate to the ITS improvements.

Question 7: What is the relevant time frame for impact assessment?

Both near-term and long-term impacts will be interesting to project evaluators. Some project or program impacts may become evident only in the longer term. Near-term impacts may also be more amenable to estimation using relatively simple procedures where longer term impacts may require simulation modeling and a greater degree of sensitivity evaluation.

Question 8: From whose perspective are the impacts viewed?

The multiple user groups and affected communities have different views on the impacts and effects of ITS programs, just as they do with other transportation improvements. These potential differences should be accommodated within the impact assessment.

AN ENHANCED EVALUATION FRAMEWORK

Applying the set of questions in the previous chapter will lead ITS professionals to several conclusions about the project or program they are evaluating. This chapter summarizes some of the significant findings that might result from such an investigation. The process of evaluation should not be an onerous or expensive task, although it can appear costly. The framework applied here is one that can identify the trade-offs between time, staff or consultant resources, and funding on one side and the information communicated or knowledge gained on the other side. This identification of effects, analyses of improvement ideas, and assistance for future projects is the basis for comprehensive impact assessments. Some elements of an evaluation package may be more expensive or extensive than appears necessary, but the questions should be asked. The chapter includes several suggestions for enhancing ITS project impact analyses presented in a framework that includes impacts beyond those typically measured.

REVISIONS TO USDOT GOALS

The USDOT goals accomplish the objective of focusing ITS projects and programs on issues important to businesses and citizens. Two changes could improve the goals, without significantly increasing the data collection or analysis efforts necessary to support impact evaluations.

REVISING THE SCOPE OF GOAL 5

The scope of Goal 5 should be increased to include economic development criteria. The restated goal will read "*increase productivity and economic development.*" This is recommended because economic development is also an indirect economic impact of any transportation investment, and it is not necessarily implied by "increased productivity." Increases in economic development can ensue with or without increases in productivity. It is also relatively easy to quantify economic development impacts (in comparison to productivity increases) due to ITS investments at the individual, state, or regional level. Productivity improvements are more meaningful and important at the national, and possibly state or regional, level. At the local level, there are too many confounding issues (e.g., the "spillover effect" that makes it difficult to isolate the impact of any single action) to make "productivity" a truly valuable component at the local level. Economic development indicators can, however, be measured at any level of disaggregation, even to the local or project level, but the redistributive issue should be addressed. Economic development that would have occurred somewhere else, but was moved due to an ITS project should, for example, be accounted for differently than one that was the result of an ITS improvement. Several of the issues listed in Table 5 can be connected to an economic development impact.

Add a Goal for Implementation of ITS Systems

A Goal 7 entitled, "*Ensure equity and privacy in ITS implementation*" is recommended. An implementation-oriented goal is important, especially in the planning stages of ITS deployment. Recent research done in the area of equity has indicated that this concern is important because it can impact how costs can be allocated for specific ITS technologies and how projects are evaluated by the public. This can affect impact funding decisions (7). More specifically, the "willingness-to-pay" issue arises when there is a concern of whether an ITS strategy is equitable and from what source funding will come. The inclusion of this criterion as a separate goal should also have a lasting impact on the trust between the public, decision makers, and transportation professionals and agencies.

Public privacy is an issue associated with many of the "travel tracking" technologies. These may provide an extensive database of information to travelers, but they often rely on data collected about travelers—by monitoring the travel patterns of system users. Even though the information is presented in aggregate form and the individual readings are not typically listed by name, there are some concerns about retaining travel pattern data. Ensuring that any of this type of information remains private should be an expressed goal of ITS programs.

It may be the position of transportation agencies and operators that such a goal is either outside their area of concern, an element that the general public is not worried about, a relatively simple step in a complicated process, or only an outcome of implementation. Any of these findings might influence an agency to look at the suggested Goal 7 as a result or an issue, rather than a goal. It is likely that in at least some areas, however, the concern over this issue may be more effectively dealt with by raising the subject to the "Goal" level.

Summary of ITS Goal Revisions

Understanding the evaluation targets is the first step to identifying a framework. The revised Goal 5 and new Goal 7 are incorporated in the recommended list of Goals below:

- ✯ Goal 1. Increase Transportation System Efficiency and Capacity,
- ✯ Goal 2. Enhance Mobility,
- ✯ Goal 3. Improve Safety,
- ✯ Goal 4. Reduce Energy Consumption and Environmental Costs,
- ✯ Goal 5. Increase Productivity and Economic Development,
- ✯ Goal 6. Create an Environment for an ITS Market, and
- ✯ Goal 7. Ensure Equity and Privacy in ITS Implementation.

The issues identified in Tables 5 and 6 are "mapped" to this new set of goals and presented in Table 7. The goals and issues will provide better information for ITS impact studies. They address a broader range of concerns and a broader constituency of stakeholders than many current procedures. Not every ITS project will require a significant set of additional issues, but each project should consider them.

Table 7. ITS Goals Defined in the Framework and Corresponding Related Issues from Table 6

ITS Goal as Defined in Framework	Corresponding Related Issue(s) from Table 6
Goal 1: Increase Transportation System Efficiency and Capacity	▪ Mode Choice Changes ▪ Shipping Aspects ▪ Land Use Changes ▪ Improved Emergency Medical Service Response ▪ Future Demand Increases ▪ Develop Compatible Systems, Specifications, and Architecture
Goal 2: Enhance Mobility	▪ Mode Choice Changes ▪ Shipping Aspects ▪ Land Use Changes ▪ Future Demand Increases ▪ Improved Access to Labor, Materials, and Markets
Goal 3: Improve Safety	▪ Shipping Aspects ▪ Improved Emergency Medical Service Response ▪ Motor Vehicle Standards Changes ▪ Reduce Motorist Workload and Improve Comfort
Goal 4: Reduce Energy Consumption and Environmental Costs	▪ Mode Choice Changes ▪ Shipping Aspects ▪ Land Use Changes ▪ Future Demand Increases ▪ Air Quality and Fuel Consumption Changes
Goal 5: Increase Productivity and Economic Development	▪ Shipping Aspects ▪ Future Demand Increases ▪ Improved Access to Labor, Materials, and Markets
Goal 6: Create an Environment for an ITS Market	▪ Develop Compatible Systems, Specifications, and Architecture ▪ Shipping and Transport Aspects ▪ Improved Emergency Medical Service Response ▪ Improved Access to Labor, Materials, and Markets ▪ Relationship Building Within and Between Public and Private Organizations
Goal 7: Ensure Equity and Privacy in ITS Implementation	▪ Ensure Privacy ▪ Ensure an Equitable System

EVALUATING GOALS 1, 2, 3, AND 4

Several enhancements have already been made to the evaluation concepts used for Goals 1 through 4 relative to the way they would have been evaluated 10 years ago. Travel-time related measures and data are used more often. Automated data collection is more achievable with management centers and there is more appreciation for the importance of reliable transportation service to a wide range of transport users. Simulation models can also be used to estimate travel-related aspects. Two additional enhancements specific to Goals 1 through 4 are mentioned here.

Expanding Data Collection Activities

One of the methods of obtaining data for evaluating the achievement of the goals shown in Table 7 is through the use of surveys. Surveys can help evaluate such factors as "user satisfaction" and "user acceptance" of ITS. For example, these factors can be evaluated with a five-point scale for users of a route guidance system. Surveys also provide valuable insight into the perception of individuals, which may be much different than the reality of the situation. Decisions are often based upon these perceptions.

The surveys can also be used to evaluate the perception of non-users, as well as a variety of non-transport impacts. Perhaps one of the most useful survey activities will be to connect modeling statistics and transport system data with more qualitative information. Developing a connection between user satisfaction and modeled or collected statistics allows user and non-user input to be a part of feasibility studies. The expected reaction to potential future conditions can be developed from measured reactions to current conditions.

Modeling and System Data Collection

The factors that are relatively more quantifiable in Tables 5 and 6 can be calculated relatively easily by comparing the system performance when the ITS application is being used to conditions prior to the installation of the ITS applications. Comparisons are often made at both a corridor and/or network level over which the ITS strategies are applied. Benefits from these projects (e.g., travel time savings, reduced delay) are then converted to monetary benefits for use by transport professionals and decision-makers at all levels and in the public and private sector.

The ideas and the framework presented in this report can provide a more comprehensive approach to measuring impacts. They can also encourage and inform the development of better simulation models and estimation techniques. As impact evaluations are performed, there will be an important link back to the modeling and estimating procedures. Identifying productive ways to apply the ITS technologies will greatly benefit from operating experiences, but the simulation and estimation process can also be improved with this information.

EVALUATION METHODS FOR GOAL 5 AND 6 IMPACT MEASURES

Table 8 attempts to show what type of evaluation technique could be most appropriate for components of Goals 5 and 6 for evaluations on state, regional and local levels. The three components are:

- productivity indicators (e.g., cost savings, market share, profitability, competitiveness, increased productivity),
- development indicators (e.g., property values, employment, land use), and
- ITS environment indicators (e.g., ITS jobs, ITS market share) at the state and local levels.

Case studies and surveys are approaches that can only be conducted after a substantial amount of time has lapsed after ITS deployment. They hold the most promise as potential evaluation tools, however, for ITS impacts associated with Goals 5 and 6. Case studies could employ a number of statistical approaches to estimate the impacts. Simulation models are good for prediction purposes; however, there are some implicit problems with these models which need to be addressed. Regardless, simulation modeling may be the route adopted, especially for productivity-related impacts.

Table 8. Evaluation Approaches for Goals 5 and 6 Components

Method	Productivity Indicators	Development Indicators	ITS Environment
Literature and subject debriefing	③	③	③
Case studies	①	①	①
Extrapolation using demographic and simulation models and other forecasting approaches	③	③	③
Surveys	②	②	④

① most appropriate; ② often appropriate; ③ occasionally appropriate; ④ inappropriate approach

Using and Modifying Existing Impact Models

Implicit in regional and simulation models are multipliers which may not really be appropriate for ITS investments. The basis for the multipliers are important to consider when evaluating national-, state-, or regional-level economies. Multiplier effects are important to consider when evaluating economic impacts since the multiplier aims to capture the potential indirect impacts that may otherwise go unnoticed or unaccounted for in addition to the direct effects. Therefore, regional and simulation models do hold considerable potential for prediction purposes, depending on the types of indicators.

These models are, however, rather costly, and the multipliers almost certainly will need to be calibrated for ITS impacts. Case studies can only be concluded after substantial deployment experience has been gathered, but they hold the most promise as potential evaluation tools for impacts associated with Goals 5 and 6. Literature and subject debriefing can only be potentially helpful for a macro-level analysis, but may be inappropriate for even that use at the state level because there may be very few state-level impacts.

Case studies can employ a number of statistical approaches to estimate these impacts. Econometric and statistical analysis of indicators is ruled out in the short-term because many impact indicators such as productivity, competitiveness, land use, and property values listed under Goals 5 and 6 take a long time to manifest themselves. A number of issues pertaining to measurement also need to be solved before such an analysis can be accomplished. In other words, it is beyond the current state-of-the-art to address all of these impacts. This *does not* imply that such impacts can be ignored. It only implies that, in time, researchers will be in a better position to assess these impacts as well as to address the link between cause and effect. For the time being, it is still possible and desirable to identify and estimate some of these impacts. Once quantified, regardless of the technique, they can provide a wealth of information to businesses about how they could potentially benefit from ITS investments. This should further the creation of a suitable "environment for ITS" in ways that reliance on public sector funding never will.

Improving the Decision-Making Process

The final issue to be addressed for Goals 5 and 6 is how these measures shall be integrated into the decision-making framework. A method is needed that will quantify these issues in the form that they can be included with the more tradition, and readily quantifiable, aspects of these, and other, goals. These measures could possibly be integrated into a benefit/ cost analysis or a scoring/weighting procedure. However, the concern for double counting of benefits will likely arise.

A conservative approach would be to group the impact measures into similar effects, and to include only those impacts that are close to the users. Unfortunately, this approach leaves out the group that most needs to be included—the private sector. A combination of case studies to identify the amount of double counting that results from a broader impact estimate, and specific local data collection to calibrate national averages and focus local attention can provide quantitative and qualitative support to ITS programs. The potential for double counting and areas in which it may become a problem will become clearer as ITS is deployed more extensively into a given area and can be evaluated.

The process should also recognize the different aspects of impacts – temporal and spatial variations and the variety of user groups and stakeholders. This should facilitate comparisons between groups, as well as within groups, and improve decision-making.

OTHER IMPACT EVALUATION ISSUES

In addition to comments on the specific goals and measures, there are two issues that distinguish themselves in terms of importance to evaluations. They both relate to "who" benefits rather than the more familiar "what are the" or "how much" benefits.

Most of the high-speed, high-capacity road and transit infrastructure has been built with public funds. Private funding, however, may be a more frequent option for ITS programs and technologies, as will more direct user payment options.

Role of the Public and Private Sector

The public sector has traditionally assumed the responsibility for transportation infrastructure investment because of the "public goods" nature of the facilities and services provided. However, since ITS investments are large-scale investments involving extensive traffic surveillance and communication systems, the benefits provided would not be limited to the public sector alone. In fact, some early research indicates that some elements of ITS such as traveler information should be provided by the private sector because there may be significant benefits for the private sector.

The evaluation framework presented in this paper suggests that there is a great potential for the private sector to participate in the deployment of ITS technology. The ideas presented in this report are from the perspective that the public sector may have to bear a greater share of the initial investment on ITS because of the uncertainty of impacts shrouding these investments. The private sector should play an increasingly important role in the future funding of ITS technology based on the following aspects:

- approximation of the potential long run impacts to the private sector,
- linkages suggesting real long-term impacts and qualitative assessments of impacts in the short-term,
- computation of these impacts over the long-term as inherent problems with measurement and modeling are addressed, and
- deregulation of the telecommunications industry.

The private sector issues include impacts such as industrial restructuring (changed business organization structures), altered procedures, new opportunities for products, new products to address new or different customer requirements, and a range of other issues relating to the information and communication improvements. The proprietary nature of this information may make case studies difficult to conduct. Business analysis procedures, information and process mapping, and logistics studies can, however, provide a wealth of information. And business performance measures and impact procedures are appropriate for measuring the impacts of ITS strategies.

In other words, the initial public investment in ITS could eventually have an immense leveraging potential for additional investment from the private sector. A report by Apogee Research, Inc. suggests that the present value of some of these approximated benefits to the private sector can be very substantial at the national level (3).

What About User Benefits?

A direct consequence of the analytical framework adopted in the report is the economic implications for measurement of user benefits as embodied by travel time savings. From a simple economic theory perspective, every individual is unique and, therefore, how individual A values travel time will vary from the value of individual B. User benefits are typically difficult to measure, and little data currently exists on user benefits associated with specific ITS technologies due to the limited long-term deployment.

User benefits are usually measured using economic valuation techniques such as contingent valuation or travel cost valuation which require willingness-to-pay information for users and the consequent impact on demand. Willingness-to-pay information for particular ITS-related services, however, is also not widely available at the present time. When willingness-to-pay research has been conducted on ITS issues, user benefit evaluation can be used to relate benefits such as travel time savings, safety improvements, and reductions in vehicle emissions to actual dollar values.

The concept of users paying more directly for their transportation services, however, is not necessarily consistent with previous approaches used to measure and value travel time savings. Standard techniques typically based on simple averages may have to be reconsidered so that they represent a wide range of situations and include a value of time distribution. Early experimentation with some of these concepts will help identify the data to collect and the estimation procedures needed.

Estimates of user benefits should, until more investigation is accomplished, describe completely the data and assumptions and the potential linkages with other impact assessment issues. As more benefits are identified and as more can be measured, there will be a risk of double-counting the benefits. If the benefit assumptions and methods are captured, the simulation model or estimation technique will be easy to check. Benefits that cross over subjects may be particularly difficult to identify. If the evaluators and the modelers are familiar with the issues, the decision-makers can be alerted to possible problems. A process that identifies and removes double-counted benefits is the goal, and a conservative approach to inclusion of benefits is prudent in the near-term.

Where Does the Data Come From?

The traditional sources of transport information will remain useful for estimating the impact of ITS treatments. The huge improvement that is possible, however, is in the area of "free" data—statistics that can be compiled from system monitoring efforts that are accomplishing other tasks. There will be an additional need for models and estimating procedures that illustrate the effects of the treatments and programs that are being developed.

Using Traditional Data

Traffic counts, travel time and delay studies, crash statistics, and other "usual" sources of data represent the background information that is available during the planning and design phases of ITS improvements. Collecting more detailed data leading up to ITS deployments allows before/after studies to more rigorously show the benefits of improvement projects. It can also help improve the estimating techniques used to identify the operating conditions in alternative scenarios.

Using Operations Monitoring Data

Many of the large urban area ITS deployment programs have an operations monitoring component. The ability to identify conditions and communicate to travelers is key to the success of many types of ITS services. As these technologies are installed, there is very often a data collection component. These data are usually collected for the purposes of monitoring the roadway and transit system and providing information to operating agencies. There may also be reporting activity from automobiles and trucks that can be used to identify the travel conditions.

The significant advantage that all of these techniques provide is the continuous or at least significant data flow. Travel time and speed information is obtainable by a number of methods, but the real-time monitoring equipment can provide information about travel patterns and travel time variability. Crash rate information is available on an historic basis, but automated tracking programs can collect data on the location and duration of each crash or vehicle breakdown and the response and clearance performance of incident management patrols.

Survey Data

Survey approaches may be needed more extensively early in the deployment process and might be less necessary as automated monitoring processes are installed. Surveys of user perception, however, cannot be replaced by system monitoring equipment. They represent an important element of the "how are we doing?" sort of questions. And a range of alternative construction and operation scenarios might be informed by a survey process that estimates the reactions of users and non-users.

As the systems are installed, the travelers will "vote with their feet" and move toward more desirable "products" of ITS implementation. This may mean increased transit ridership, shift in travel patterns toward ITS-equipped routes or modes, increased purchase and use of ITS technologies to improve business operations or increased use of communication tools such as phone lines and Internet websites.

Case Studies

An important element of a broader approach to ITS impacts is the use of representative case studies to supplement local information. Case studies can be used to investigate issues such as business, social, or environmental effects of ITS improvements. These non-traditional transportation impact studies may be very important in moving the ITS program toward the private sector. Some companies are discovering ways to use ITS treatments to their advantage. Public sector agencies, however, are still in control of much of the ITS infrastructure implementation. Identifying the range of impacts beyond traffic volumes and speed effects will help bridge the traditional gap between public sector measures and private sector concerns.

ITS project implementers can also benefit from case studies of previous projects. Operating and construction costs and the lessons that come from new projects and programs are very valuable for the implementing area, as well as other cities.

Case studies can be conducted in a few locations and the results can be documented and publicized. Local applications of similar programs or user services can use the case studies as a starting point. Decision-makers—from political, business, and public agency perspectives—will need evidence that the case studies are relevant and will need confirmation that operating experience in their area will be monitored so that local lessons can be uncovered as well.

It is important, then, that the case studies be used as a technique to guide implementation and evaluation at the local level. National case studies need the local investigations to supplement the database and to identify the linkage between national case studies and local experience. This suggests a two-element approach to some of the broader ITS impact evaluations—use of national case studies and local analyses aimed at relating national and local experience.

WHAT DOES THE PROCESS LOOK LIKE?

The questions and issues identified in previous sections can be arranged in a process to consider the important measurement steps in a systematic way. The term "framework" may not be entirely appropriate in some cases, but it is a useful way to think about how to proceed. The resulting measures and data elements may not be the same, even when the deployed ITS strategies are similar. Local situations, public input, or funding differences may lead the analyst to use a variety of measurement techniques or metrics. But the steps that lead to the final evaluation program should include the features discussed in this report.

Responses to questions in the steps should be informed by the impact issues raised in this report and elsewhere. The relatively narrow transportation focus and vehicle travel performance measures used in some studies may be acceptable in the near term, but may not best serve the long-term viability of some ITS projects. Just as the computer has changed the way many businesses operate, some ITS strategies will have effects far beyond transportation systems. It is not necessary that every project investigate each possible effect, but the evaluation scheme should include consideration of them. All of the impacts cannot be anticipated, but many of them can be uncovered by some "outside the box" thinking—some consultation with the affected groups and stakeholders may identify impacts in areas beyond the expertise and knowledge of local ITS program designers.

The Process

Based on the analysis and evaluation needs identified in this report, the following questions should provide a useful framework for a range of ITS impact evaluations. A re-examination step (Step 8) is included in the framework to assist in the selection of a set of measures. This step gives the analyst an opportunity to go beyond the relatively easy measures and ideas that are often the first items considered, and therefore the focus of measurement programs.

Step 1. What are the goals and expectations of the improvement program?

The official set of goals is an important start, but at some point the evaluation needs to include other goals, and perhaps more importantly, the accomplishments that people believe the ITS treatment will achieve. Initial perception is a very important part of determining ultimate success of a program. This step involves asking questions such as the following from the point of view of the stakeholders and the general public:

- What is the program trying to accomplish?
- What do people expect from the ITS treatments?

There are many opinions and ideas about ITS programs when they are introduced, and it is important to understand those in advance of the program. This allows the evaluation program to identify which goals or expectations might be met, and which may be the product of misunderstanding or miscommunication. This type of information can be found in opinion polls, public meeting comments, media coverage, and citizen input from a variety of sources (e.g., web sites, letters).

Step 2. What are the problems or opportunities the ITS treatment is addressing?

The step should identify some of the "environment" within which the improvements are being undertaken. ITS programs are often part of a package of treatments that address mobility problems. It is important that the effects of the ITS treatments be isolated, if possible, from these other treatments. These solutions may be motivated by a problem or by an opportunity; in either case, questions such as the following are appropriate:

- What are the targets?
- Why is the program being pursued?
- What else is being (or may be) implemented in the same area?

Information on this typically comes from project feasibility studies, but public input is also useful for the same reasons as noted in Step 1—perception is important in evaluating unfamiliar or new technologies and programs.

Step 3. What are the possible solutions/treatments and their effects?

The possible remedies to problems or ways to capitalize on opportunities should be examined to identify the attributes that might need to be measured. At this point, it is not necessary to decide which treatment(s) will be implemented. If the evaluation process is to function effectively, however, it must include measures of the effects of each treatment; this process starts during the feasibility portion of the analysis. The basic question to ask is "if this treatment were implemented, would the effect that it has be illustrated in the measures?" The measures developed in the FHWA guidance are a good start and other locally designed measures may add to the information derived from basic measures. Local transport professionals will be able to assess the need for more measures during this and subsequent steps.

Step 4. What is known about the effects of the ITS treatments?

This is a data collection step in a broad use of that phrase. The key questions here do not all have to be answered initially, but they include:

- Where are other similar treatments?
- What were the basic design and operating situations in those implementations?
- Why were the implemented treatments chosen?
- What were the results? How much and what kind of effect did the treatment have?

The usefulness of the answers to these questions lies in the development of an evaluation program and a feasibility assessment that reacts to previously developed information. The effects can include quantitative and qualitative information. The iterative approach can be used to develop a basic understanding and calibrate simulation models initially and then more specific data collection when the project feasibility analysis is being conducted.

Step 5. Who and what will be affected?

The effects should be "mapped" by identifying which stakeholder groups or features of the transport system and the environment they affect. For the purposes of evaluation, the location of the impacts is often a good indication of a measurement need, as well as an observable effect that can be used to explain the measurement concept. The effects may occur in such places as:

- geographic locations;
- time of day, month, year;
- business practices; and
- roadway or transit system operations.

The "who" question could be answered by a variety of responses ranging from individuals, groups of individuals, agencies or private firms, industrial categories, or groups of businesses characterized by similar operations or locations.

Step 6. What type of evaluation will be conducted?

There will frequently be several answers to this question, all of which may have similar measurement needs, but thinking about the range of analyses before they begin can assist the evaluator in describing the needs. The analyses may be grouped by time—current situation, before/after, or future year condition—or by phase of the analysis—concept feasibility, cost effectiveness study, design effort, or operational analysis—or by other characteristics that are appropriate.

Step 7. What are the measures to investigate the effects?

When the criteria and needs for measurements are described, the measures represent the way to satisfy the need for information. The analytical time, precision requirements, and data requirement sensitivities need to be recognized. The output of this step is a set of measures that inform the process, but do not unduly harm the efforts of the planners, designers, operators, and users of the systems. Cost and effort considerations that determine the ultimate set of performance measures to be used for a given analysis are determined in a later step.

Step 8. Re-consider Steps 1 to 7, especially to identify non-traditional elements.

This step, more than any other, is a key recommendation of this framework study. Many efforts follow the general guidance in this section, but they do not approach the task with the broad view of the effect of ITS on society. Many of the impacts that ITS could receive credit, as well as blame, for are not investigated. The evaluation "field" is thus left open to those with an initial point of view, rather than those who are interested in learning the lessons and how to improve operating systems and the travel conditions for the public.

Step 9. What data items are needed to support each measure?

A weakness of ITS case studies and analyses is that the monitoring equipment that is needed to conduct the study is installed during the construction period. The before data is thus, not substantial enough, or is collected with different methods that cause the before /after analysis to be colored by several changed data conditions. Developing a good set of data to characterize the before condition should be a part of each implementation project. The first step in this process is to ensure that the data items throughout the process are proper and the data burden is not too great.

Step 10. Develop decision criteria to evaluate the set of measures.

A set of decision criteria based on the needs of the analysis, the agencies, and the stakeholders can be used to identify the most important metrics. The importance of each factor will be different depending on where in the process the analysis is being conducted and what information is being developed, but the set of criteria may not change significantly from project to project. The key part of this step is to examine the analytical needs and develop a set of criteria that will meet those needs.

Step 11. How can the data be collected?

Collecting the information necessary to support the analyses is an important aspect of the process, but data concerns should not be the driving force behind measure selection. ITS treatments are a source of significant improvement in data availability for many purposes. The travel time, travel speed, and travel reliability information that is so important for mobility analyses have been difficult to collect. With many ITS projects, this information is relatively easily obtained.

The most frequently used data collection methods are the direct data collection methods, typically by special data collection activities in the before period and by automated methods after the ITS treatment has been installed. National experience is another source of information that is frequently used. Estimation techniques or simulation models are also becoming more useful as the information needed to develop and calibrate them becomes available. These traditional "public agency" sources can increasingly be supplemented with private sector sources to provide a richer data source and more user-focused information for planning and operating decisions. This information can also be used to improve the simulation models and estimation techniques.

Step 12. How much will the data collection options cost?

Cost is a factor in data collection decisions and can make simulation models and "passive" (or automated) data collection processes attractive options. Accuracy concerns will enter into the decision about the most cost-effective data collection strategy, but even automated collection methods have costs. Agency budgets should accommodate the financial needs of the analysis.

Step 13. How important is it that all the impacts get measured?

This "reality check" step is a very useful consideration before the final set of measures is selected. It is at this step that the "we cannot afford this" or "this is not very important to our program" decision should be made. At this step there is much more information on the potential benefits of collecting and analyzing a particular data item or measure. A decision at this step will more closely resemble the product of a benefit/cost analysis rather than simply a cost decision. Understanding the benefits is particularly appropriate for an analysis of newer improvement types—decisions about further expenditures on those improvements will be better informed with a broader set of information early in the product evolution cycle.

Step 14. Select the measures and a data collection scheme that provides timely and complete information at an affordable cost.

While this is much easier to say than it is to do, selecting measures is easier to do with the proper level of information. If a process similar to Steps 1 to 13 is followed, the information will be available to make decisions about the measures and data necessary to have a good evaluation program as well as information for planning, design, and operations purposes.

CONCLUSIONS AND RECOMMENDATIONS

After undertaking a review of the relevant literature and examining ITS benefit estimation and impact studies, this report proposes a conceptual ITS impacts assessment framework. The framework is similar to two other frameworks developed in the literature in the analytical theory adopted. This analytical approach was thought to be appropriate for partitioning impacts and detecting correlation between potential impact measures. The framework in this report is also consistent with the ideas included in the FHWA approach to measuring ITS impacts.

The biggest need is not for more frameworks or performance measures, but rather for more extensive evaluations of any kind. Evaluators grew relatively complacent over the years before operational improvements became so widespread. Impacts that were once considered secondary may be the primary benefit and justification for doing an ITS project, but the factors were not typically analyzed in construction projects.

The framework presented here allows planners and other concerned agencies to:

- recognize that some ITS investments are different from conventional transportation improvements in the way they affect the transportation system and business processes;
- examine local goals and issues within the framework of a national evaluation program;
- recognize that there is a need to look beyond conventional benefit-to-cost ratios based on direct user benefits and examine the private sector benefits and the qualitative aspects of ITS strategies;
- demonstrate the benefits of large-scale ITS deployments and specific ITS technology purchases to the private sector;
- show project planners and other implementers how their individual project goals fit with the overall strategy, what other factors they should be looking for, and how they can better compete for ITS funding by considering all potential ITS impacts;
- recognize that ITS impact assessments in the near-term can be improved through the use of select case studies to utilize empirical information about unknown impacts; and

- continue utilizing the appropriate performance measures for very quantifiable goals, but consider the less-quantifiable impacts to the extent possible.

There are, however, a number of differences between the framework described in this report and others proposed in the literature. The differences include:

- An additional goal pertaining to equity and privacy in the implementation of ITS programs should be considered. The earlier literature ignores this aspect, but recent legislation and public concern indicates the importance of examining this issue.
- One of the USDOT goals is revised. The goal of increasing economic productivity is expanded to include increased economic development to recognize that ITS strategies may do more than improve the efficiency of existing private sector operations.
- Both qualitative and quantitative impacts are considered in the framework. Some of these impacts present a challenge for evaluation purposes because of the number of complex issues that need to be addressed. Some of these impacts can be approximated, and better estimation procedures will be developed from case studies, real-time monitoring systems, and simulation tools. Some potential methods for incorporating these impacts are also suggested.
- Other potential ITS accomplishments are suggested which could further enhance the scope of ITS impact assessments. On a local level, these goals may be important considerations at the project feasibility and cost effectiveness analysis stages. Demonstrating that ITS strategies respond to local problems and opportunities may be at least as important in the long term as the satisfaction of national goals.

GOAL-RELATED FINDINGS

The USDOT goals were found to encompass most of the significant issues and provided an excellent basic framework. The "few good measures" approach to measuring these goals (see subsequent section) was also found to provide some very useful information. This report suggests the need for one revision and one additional goal.

New Goal

The new goal would be "ensure equity and privacy in ITS implementation." While not a specific concern of some project designers, issues like this arise on almost every project. Raising this to the level of a goal might highlight some shortcomings or raise problems for project developers. Many projects, however, appear to address this goal in some specific way. Identifying the issues as a goal allows designers to deal with equity and privacy concerns in an open and direct manner that illustrates their importance.

Revised Goal

A revision to USDOT Goal 5, so that it includes economic development will point to the need for measures and data that examine the impact on expansion activities. The current focus on productivity does not specifically identify the effects beyond making existing practices more efficient. The history of technological and information systems development has been one of expanding opportunities for business activity—there is no reason to expect ITS to be different.

MEASURE-RELATED FINDINGS

The new and revised goals plus the outcome of the investigation into issues that should be included in the framework led to the development of several suggested new measures. One overarching measurement concept that may change the manner in which measures are prepared is the need to tailor the statistics to a variety of stakeholders and societal values.

More Detailed Measures

With better data gathering activities and improved simulation models, evaluators can estimate much more detailed project effects. The measures, for example, might be sensitive to travel delay by user group so that emergency vehicle, rush delivery, commute, and vacation travel can be valued differently for cost effectiveness analyses. Varying the value of trips (setting aside the difficult issue of deciding on those values for a moment) will require a more detailed accounting process than currently exists. This need is already evident in toll highway and value pricing projects that rely on the values of time and willingness to pay for transport services being spread across a range so that price can hold demand at an acceptable level.

More Qualitative Measures

Many of the suggested additions to the list of measures include some form of citizen survey or other somewhat qualitative technique. The initial focus of the ITS program on "hard" data and statistics may have been important to ensure the responsible expenditure of funds. But it should also be noted that much of the initial funding was from public sources, and the taxpayer concerns extend beyond creating an efficient transport system. Using qualitative measures to calibrate the objective statistics creates a powerful argument that ITS projects are meeting the needs of the customers.

Qualitative measures can also be used in combination with more traditional benefit/cost information to create multicriteria analysis tools that provide direct input to the question, "Are the goals being met?" This report suggests that the goals for ITS projects be expanded to include the accomplishments that the public expects—many of these cannot be measured by benefit/cost assessments.

Expanded Private Sector Measures

Investigating private sector concerns and issues is increasingly common in ITS program evaluations. These important stakeholders represent a significant market for ITS-derived information and services. The private sector can also be counted on to help develop products based on ITS attributes. One element of ITS impacts that has not been fully explored is their effect on business practices and organizational structure. Case studies and long-term analyses can be effective tools to identify any efficiency gains or business opportunities that might occur. Many private entities are investing in ITS technologies and services. Businesses involved in freight movement are particularly active at incorporating ITS technologies into their operations. It should be interesting to see how the improved information and other benefits alter the structure and operating plans of these firms.

Basic Measurement Principles

One hazard of expanding the factors and impacts that are measured is the risk of double-counting benefits. This is often the case, for example, when travel time benefits and increased land values are included without regard for the fact that some of the land value increase is related to the improved travel time. The source of particular benefits and their relationship to other elements in the equation should be carefully checked.

Tracking the impact from cause to effect is another principle that should be guarded. The temptation to assign condition improvements to the most recent treatment or the technology under investigation can lead to significant overestimation of the benefits.

Sensitivity analyses can be used to test a range of estimated values in impact assessments. The range of input values should be based on experience; the output statistics can be checked to identify which variables are most important. These can be studied further and data collection efforts re-focused if necessary.

DATA-RELATED FINDINGS

Much more transport systems performance information is available now than just a few years ago. Somewhat paradoxically this has created a "problem" in the mind of many analysts and system operators. The effort that has gone into addressing the "what to do with all this data" question would have been unthinkable less than 10 years ago—the assumption was that more data is better. Even with a significant amount of data coming from some systems, not all of the data issues have been resolved.

Need for Local Studies

The national impact evaluations provide a significant source of information, but they cannot substitute for some local needs. Citizens, elected officials, the business community, and a variety of transport professionals need evaluation statistics on local ITS treatments. Some of the data needs can be satisfied by using analogies and relationships to the national studies. A variety of specific needs from future planning for the local system to public information will cause local evaluations to be conducted.

National level studies can develop evaluation methodologies and can be used to address national level information needs. They can also lead investigations of complicated issues. Local non-technical leaders will often ask questions such as, "How is our system performing for our citizens?," and evaluation programs should anticipate these.

Need for Simulation Models

Not all of the "what if" feasibility questions can be answered with current system data. This data can, however, be used to develop simulation models, among its many uses. Current traffic simulation models have to varying degrees incorporated some ITS treatments in the effects that they measure. Much more improvement should be made, however, as the results of detailed impact studies become available. Detailed computer simulations are an ideal environment for examining the effect of ITS treatments. The effect of similar deployments or technologies may be quite different in cities with different base conditions or with different system characteristics.

CONCLUSIONS

The USDOT ITS evaluation framework has taken a relatively conservative approach to benefit estimation. This is not inappropriate given the initial scrutiny of the ITS program and the relatively limited deployment of truly effective systems (as opposed to the more numerous tests of individual technologies). The "few good measures" approach will limit the amount of double-counted benefits and allow analysts to focus their efforts on a few elements that might be measured more accurately.

This report suggests an expansion of this approach with the goal of improving ITS strategy implementation. A typical result of measurement programs is stated as "what you measure is what you get." This saying has a corollary in "if you do not measure it, you will not design for it." Missing some of the project effects may lead to systems that do not take full advantage of the opportunities to serve all the customers of the transportation system.

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APPENDIX

Additional Discussion on
Potential ITS Project Impacts

Background Information for Tables 4, 5, and 6

This Appendix describes in more detail the issues presented in Tables 5 and 6 that are related to the goals shown in Table 4. The discussion highlights the points made in Tables 5 and 6 to provide the reader more insight into the potential positive and negative impacts. The discussion generally centers on travel time and travel reliability improvements that may be achieved from ITS strategies. This illustrates the considerations associated with each issue and how those may be applied in certain situations.

LAND USE CHANGES

The shorter, and more reliable, travel times that motorists realize with ITS strategies may encourage land use changes (e.g., suburban sprawl). Commuters may feel that they can comfortably live further from employment and activity centers since ITS applications (e.g., in-vehicle traveler information) may reduce the travel time to near that for individuals living closer to the activity centers without ITS in place. Therefore, the increased mobility and accessibility provided by ITS may continue to feed the sprawl of communities. Although this may make land more valuable in the fringe areas, it may reduce the amount of farm land available for crop production, and it will likely cause the encroachment of development on small towns. Whether these are desired or not is not the issue, rather the ITS impact evaluation should consider the measurement of this market reaction.

Measure Descriptions

- change in developed land—the amount of urbanized area; may also compare rate of change by corridor if there are significant differences in regional ITS deployment;
- change in population density—compares population growth to growth in developed area; and
- traveler surveys—examine user reactions to total system; examines reactions to system performance and user behavior.

IMPROVED ACCESS TO LABOR, MATERIALS, AND MARKETS

Transportation access to cost-effective labor, materials, and markets are critical for many industries, services, and manufacturing industries. Should transport facilities not exist, the costs of hiring skilled labor, for example, may increase and businesses would be forced to relocate to other areas. As the economy is becoming increasingly service-oriented, this access is a very important issue. To the extent that ITS can improve such conditions by moving businesses closer (e.g., as measured in travel time) to markets, an improvement in productivity measures as well as increasing opportunities for new products, services, innovations, and public/private partnerships should be observed.

Measure Descriptions

- productivity and cost—examine the changes in productivity (output per worker, per foot of space, per dollar invested) and cost of production or cost per unit of service for "ITS-rich" companies;
- market share and competition—change in the percentage of market held by "ITS-rich" companies; measures of competition might include number of new companies or percent of market held by new companies in a particular field; examine barriers to entry for new companies to see if ITS has reduced them;
- employment and business patterns—internal operating changes as a result of ITS; how have business practices changed?; what ITS products are highly valued?; what type of workers are needed?; and
- public/private partnerships—number, type, subject areas, products or programs developed all need to be studied.

RELATIONSHIP BUILDING WITHIN AND BETWEEN PUBLIC AND PRIVATE ORGANIZATIONS

The inherent complexity of developing ITS applications and strategies must involve the experience of individuals from public and private sectors. Important public sector participants include the state department of transportation, transit agency, metropolitan planning organizations, emergency services, and local transportation officials. Public industry includes both transportation consultants and vendors of software and hardware necessary for the implementation of ITS applications. Relationship building within public and private organizations is imperative for facing the future challenges of ensuring urban mobility and accessibility. It is critical that agencies establish good working relationships since extensive communication and planning is necessary for implementing such systems. The increasing number of transportation management centers (TMCs) that locate many public agencies into a central location, often a central building, promote the development of such relationships by allowing different agencies to work closely with one another. It is difficult to quantify the benefit of these relationships and how they may contribute to further benefit in the development of ITS technologies, but they are undoubtedly very important.

One potential positive impact to developing such relationships is that it may lead to cheaper contracts. It may also lead to more efficient construction since all the necessary agencies and individuals are communicating openly. This may also lead to lower maintenance costs since the design process will include all agencies. One potential caution to establishing working relationships with all individuals is that it may introduce too many individuals or agencies into the planning, design, and/or construction project phases. While this may cause decision-making difficulty, in the long-term these relationships will be a benefit.

With the increased communication between the agencies described above, comes the increased opportunity for the creation of new ideas. Planners, designers, engineers, and professionals at every level of the implementation of such systems may become more open to new ideas and solutions as they work together to establish such systems. This may become a more obvious benefit if private companies begin to work together in designing compatible systems, specifications, and architecture rather than striving solely for competitive advantage in the ITS market. Further, there may be many technological "spin-offs" and by-products from ITS applications.

Measure Descriptions

- interviews—attitudes, work activities, and effects on other projects due to interaction facilitated by ITS programs; and
- savings—funding and personnel allocated to particular tasks or subject areas; role of automation in creating efficiencies.

ENSURE AN EQUITABLE SYSTEM

The concern for equity in the development of ITS applications is expressed in questions such as, "for whom are we building these ITS strategies?" or "who is paying, or should be paying, for ITS?" The answers to questions of this sort are very important when planning ITS applications. It is likely that not everyone is going to benefit from the ITS strategies that may be implemented. ITS strategies may, to some degree, simply be widening the gap between the "haves" and "have-nots." Further, the equity issue and distinction can vary between geographic lines, over time, between populations, communities, or groups, or by income categories.

Decision-makers must be conscious of these equity concerns when implementing ITS improvements since these impacts can be socially significant. Ensuring that the issue of equity is considered will build trust between transportation professionals and agencies, decision-makers, and the public.

Measure Descriptions

- interviews—evaluate citizen approach and reaction to transport services; evaluate ability to convey message—both from agency and user point of view—about what is important;
- market research—who is using ITS services and why?; and
- willingness to pay—how much are users paying and who is paying for services?; has this changed due to ITS?

ENSURE PRIVACY

Ensuring that privacy concerns are addressed will build trust between transportation professionals and agencies, decision-makers, and the public. ITS strategies are generally data intensive and track vehicles and persons with video cameras, route guidance technologies, smart cards, automatic vehicle identification (AVI), and automatic vehicle location (AVL) technologies, to name a few. Transportation professionals implementing such systems must ensure that these systems ensure the privacy of the motoring public.

For example, consider smart cards for improving fare payment and commercial vehicle operations. They may contain very personal information about the card holder including anything from their name and address to savings account information. Their use in the future will likely increase since they provide many benefits including eliminating transfer slips, reducing data collection costs, and providing revenue with unused value on cards when used for paying tolls. However, if this information is accidentally released, an individual's privacy can be violated or money stolen. The future of ITS implementation may be severely endangered if misuse of such private information occurs. It is imperative that those individuals and agencies planning ITS for future implementation seriously consider the privacy issue.

Measure Descriptions

- interviews—is privacy an issue of concern or have implementers successfully addressed the issues?; and
- evaluation of system security—operational integrity, reliability, and information security; are these issues successfully considered?; number of unauthorized accesses to the system.

AIR QUALITY AND FUEL CONSUMPTION CHANGES

With improvements in travel time and travel time reliability, there may be decreased fuel consumption and emissions. Generally, fuel consumption and mobile source emissions are increased when vehicles are exposed to situations in which they have consistent accelerations or stop-and-go travel. ITS strategies may help to "smooth" the speed profile of a given trip or an entire transportation network. In theory, these affects are quantifiable by evaluating reductions in major emissions (e.g., CO, NO_x, HC) and increases in fuel economy. However, the simulation and modeling tools have not been very accurate since they tend to consider average speeds only. Although the average-based models may be useful for some comparative analysis, their results should be used with caution and are sometimes not included in benefit analyses. However, improvements in air quality are a very important impact of ITS strategies, and newer microsimulation models that measure the effect of every vehicle's performance can significantly increase the confidence in modeling information.

Measure Descriptions

- changes in air quality and fuel consumption—examines trends in environmental impacts; can also examine these on a per capita basis.

MODE CHOICE CHANGES

One benefit of ITS applications that is often reported is the reduction in travel time. For example, a time savings may be realized due to improved route guidance and traveler information in a passenger vehicle. This provides added convenience since one can travel to more places in a convenient time in their personal vehicle if the travel time savings is significant. Further, if ITS applications provide a substantial travel time benefit to those driving passenger vehicles, there may be an increased difficulty in attracting choice transit riders to public transportation. In addition, these systems may produce a reliable travel time to motorists with in-vehicle traveler information.

Travel time savings and reliability are often major promotional tools when planning for enhancements to public transportation. For example, high-occupancy vehicle (HOV) lane facilities may look less attractive if travel via single-occupant vehicle can result in similar reliable travel time savings with an ITS application. Further, there may not be as much support for other travel demand management (TDM) strategies such as telecommuting or flextime if ITS applications are already providing a reliable travel time savings. Such an influence on individual mode choice may have far-reaching impacts on travel patterns, emissions, and fuel consumption.

These effects may degrade air quality and increase the reliance on fossil fuel, thereby contributing to global warming.

Measure Descriptions

- changes in air quality and fuel consumption—examines trends in environmental impacts; can also examine these on a per capita basis; and
- surveys—examine the ways in which ITS has improved use of transportation services; information availability, quicker transport times, transfers and access time, ease of travel, willingness to make a trip.

SHIPPING EFFECTS

Shipping and transport companies will likely benefit from a more reliable travel time. This may allow for more efficient shipping of goods on the transportation system. This may occur in a number of ways including allowing the same number of vehicles to ship more goods, providing a quicker and more reliable delivery, and increasing the market share. This can have a potential impact on all types of businesses by enhancing operational efficiency and just-in-time delivery logistics. The increased transport efficiency would likely enhance local, national, or even global competitiveness of the businesses taking advantage of ITS.

Businesses can utilize such an integrated system in a number of ways. For example, real-time traffic information about roadway demand can be transferred to trucking companies for route decision making. Load content, size, and weight information may also be integrated into deciding upon a particular route, especially if a particular route facilitates processing more efficiently (i.e., with a weight-in-motion and transponder system). Businesses may also be able to alert a traffic management center (TMC) when vehicles are leaving warehouses to provide insight into when and where the roadway system will be impacted. This type of information would be especially useful for groups of vehicles traveling together or for wide loads. The information would not only allow transportation professionals and agencies to utilize the transportation system more efficiently during times of heavy use, but it would also likely aid in the logistics and business restructuring of the shipping and transport business.

Measure Descriptions

- changes in travel time and reliability—shipping time, transfer time, schedule reliability; ability to quickly respond to changes in demand or "taste;" knowledge of product location "in-transit;"
- savings attributable to reduced travel time and improved reliability—cost, personnel, equipment, inventory impacts; and
- increased economic productivity or increased market share—improvements in business position; changes to supply chain or business operations

FUTURE DEMAND INCREASES

Two concerns that are often not addressed in the prediction of ITS benefits are latent demand and the demand due to new development. Latent demand refers to the demand that exists in a transportation system that does not currently use a particular route because travel speeds are low; this demand would like to use the facility. Additional demand may also be induced due to new economic development. When capacity improvements are made, this demand may fill the new capacity. Consideration is not always given to latent demand, or demand from new economic development, when ITS benefits are evaluated. If demand in a corridor is anticipated to be high, the improvements in capacity provided by the ITS improvements may be quickly filled. The demand may make some of the potential benefits (e.g., air quality improvements, travel time savings, and reliability) more difficult to measure. If the impact assessment understands the likely source of these confounding elements, the evaluation can be modified to address the issues.

Measure Descriptions

- surveys—reaction to improved information; number, type, and mode of trips; time (of day) of travel; amount of time spent in travel.

MOTOR VEHICLE STANDARDS AND CHANGES

Many advances in vehicle safety are being created with advanced vehicle control technologies. These applications include crash avoidance, collision warning, assisted braking, or vehicle control, to name a few. Clearly, there are some quantifiable benefits such as accident and injury reductions that may be produced with these technologies. However, as these systems become more common, other impacts may be realized. In the future, automobile companies may offer such systems as standard equipment on vehicles. In the short-term, this may cause the cost of vehicles to increase. Currently, many automobile insurance companies offer reduced insurance rates for features such as daylight running lights, four-wheel anti-lock brakes, air bags, and automatic seat belts.

The reduced accidents attributable to these applications and the support of insurance companies in recognizing the safety benefits of these systems will provide incentive for continued safety improvements in vehicles. Further, similar impacts may be found in commercial vehicles. It should be noted that although these impacts are shown in Table 5, and are relatively quantifiable, they are often not included in typical cost-effectiveness evaluations of ITS.

Paradoxically, some of these safety innovations may lead to more "risky" behavior. The capacity of a freeway lane, as measured in the number of vehicles per hour per lane, has increased over the last few decades. This measures the willingness of drivers to travel closer to other vehicles at relatively high speeds. This appears to be, at least partly, a reaction to the improved safety and performance of individual vehicles. As ITS safety improvements are implemented, there may be similar reactions by drivers.

Measure Descriptions

- dollar savings—insurance rates, out of pocket expenditures for operations and repair, new car costs, optional and after-market purchases of ITS-related equipment and services.

REDUCE MOTORIST WORKLOAD AND IMPROVE COMFORT

One common concern about ITS technologies is the potential for increasing the motorist workload. Consider a vehicle containing traveler information and advanced control technologies. While these systems are aimed at reducing the driver workload, the motorist still must process the information that is often coming to them via a new medium (e.g., in-vehicle computer screen, audio/visual cues). These systems may actually take the driver's attention away from the driving task and could distract the driver. The increased information may increase accident potential. In addition, there will likely be education and training needs to allow motorists to operate the systems. As such systems become more commonplace in vehicles, and motorists become more comfortable with them, they may provide the motorist with a reduced workload and less fatigue.

Measure Descriptions

- savings—crash repair costs, number, type and severity of crashes; and
- interviews—compare user reactions and market response to statistics on driver performance and trip making; number of long-distance auto trips; number of trips to unfamiliar destinations.

IMPROVED EMERGENCY MEDICAL SERVICE RESPONSE

One very obvious benefit to ITS applications is their ability to improve emergency medical service (EMS) response. Positioning systems, in-vehicle navigation, traveler information, and advanced incident response systems likely have the most impact upon EMS response to emergency situations. These changes cannot necessarily be measured in the number or intensity of accidents. One potential positive impact of such strategies is the fact that more families will stay intact as a result of the savings of life. There is also the potential for a reduction in the number of EMS, fire, and police vehicles necessary. Finally, new technologies in law enforcement, such as the Advanced Law Enforcement and Response Technology (ALERT) vehicle allow a reduction in the officer workload and the number of clerks needed to process citations. The video images derived from the system aid in criminal action and prosecution due to advanced technologies on the vehicle that automate or organize many of the procedures.

Measure Descriptions

- personnel and equipment reductions—number, type, and cost of emergency operations personnel and equipment;
- lower response time—the time from receipt of call to arrival of responding EMS unit; and
- more predictable and reliable travel time—the certainty with which agencies can predict travel time and the variation in travel time from day-to-day.

DEVELOP COMPATIBLE SYSTEMS, SPECIFICATIONS, AND ARCHITECTURE

One common consideration that often surfaces in the literature with respect to ITS strategies is their need to be integrated. Efforts by the USDOT to establish architecture requirements for ITS are providing the foundation for such integration and related standards. ITS strategies encompass many different aspects and markets in the transportation system. Software and hardware systems must be compatible between applications for data management and information exchange. Further, due to the scope of ITS, integration of systems will likely be beneficial. For example, a route guidance system may provide significant travel time savings to a motorist; however, if the vehicle is equipped with technologies such as collision avoidance, the vehicle will likely be even safer. The integration of ITS applications into all modes of transportation will likely magnify the potential impacts at both the corridor and network level.

An integrated system would also likely increase economic productivity and create an environment for an ITS market through the creation of new ideas and companies since ITS can be more easily "packaged" and sold as the necessary hardware and software becomes standard. Since the customer would likely benefit from such systems (i.e., travel time savings due to a route guidance system), companies could increase revenue due to sales. It is also important to note that these systems can provide data for quantifying their own benefit. It is often overlooked that advanced ITS applications themselves provide more reliable, and often real-time, data that can be used for their own evaluation. Many of the "traditional" performance measures outlined in Table 3 can be computed with the data that ITS can provide. An integrated system will help to ensure that such data are in a standard format, are easier to collect and obtain, and are potentially easier to analyze. The reduced data collection and analysis time from data in a standard form obtained through advanced ITS techniques itself may be a very significant benefit of an integrated system.

Measure Descriptions

- transport professional surveys—system user evaluations of ITS equipment and programs;
- surveys of users and non-users—to identify causes of behavior-reaction to products or initial bias; degree to which negative bias has been overcome; and
- savings—cost, equipment, procedural, regulatory, operational, personnel and training.