A BENEFIT-COST ANALYSIS FOR THE USE OF INTELLIGENT TRANSPORTATION SYSTEMS TECHNOLOGY FOR TEMPORARY CONSTRUCTION ZONE TRAFFIC MANAGEMENT ON THE I-496 RECONSTRUCTION IN LANSING, MICHIGAN

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EXECUTIVE SUMMARY

The Michigan Department of Transportation is in the process of implementing Intelligent Transportation System technology as a temporary installation for managing traffic flow associated with the I-496 reconstruction in Lansing, Michigan. To help understand the value of such a system, a benefit/cost analysis has been conducted.

The benefit/cost analysis was based on accepted procedures and evaluation frameworks for permanent ITS systems across the United States. Data from previous studies were used to estimate benefits for the ITS system. Also, data from the Tri-County Regional Planning Commission's Travel Demand Model were used to estimate system impacts as a result of the construction project. In some cases, where data elements were missing, reasonable, yet conservative assumptions were made

The analysis indicates that the benefits of the proposed I-496 temporary ITS system outweigh the costs by a factor of two to one. With a total cost, including engineering costs, of approximately $2,500,000 for the ITS system, the analysis indicates net benefits of nearly $5,000,000. These benefits come from anticipated reductions in accidents, travel time,

environmental impacts and energy consumption. Additional benefits in terms of customer satisfaction, productivity and other factors may exist, but could not be quantified using available data.

Based on the study, the temporary application of ITS for the I-496 project is economically justified. The author recommends further evaluation of the system while in operation, to validate the results of this analysis. Additional data gathering in the form of customer satisfaction surveys is also recommended.

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CHAPTER ONE: DEFINITION OF THE PROBLEM

Introduction

The purpose of this paper is to investigate whether or not the costs associated with the application of Intelligent Transportation Systems (ITS) technology for temporary Construction Zone Traffic Management (CZTM) can be justified for the Michigan Department of Transportation's (MDOT) proposed highway reconstruction project for Interstate 496 (I-496) in Lansing, Michigan. The proposed highway construction will result in a temporary closure of the freeway, causing disruption to traffic traveling to and from downtown Lansing. In situations such as this, the use of ITS technology has promising applications for managing traffic flows. However, prior to implementation of this traffic management strategy, MDOT must know if the costs associated with such a system are warranted.

Background

The MDOT is proposing a major infrastructure improvement for the I-496 corridor through the heart of the Greater Lansing Urban Area. The project, scheduled to begin construction in 2001, represents over a $40 million investment in the corridor. It will be completed in just one construction season by closing the most work-intensive portion of the freeway.

I-496 serves as the central artery for the Greater Lansing Urban Area, providing freeway access to the downtown business district. The highway connects the urban core to the loop freeways that link Lansing to other cities in Michigan and across the nation.

Lansing is a major industrial center that is experiencing unprecedented redevelopment. This development has, in turn, spurred revitalization of the entire region's economy, from manufacturing to the service and entertainment industries. Furthermore, as the capitol of the state of Michigan, the Lansing urban area supports the functions of the executive, legislative and judicial branches of state government, including housing the administrative agencies which carry out the state's day-to-day business. Many attractions surround the capitol complex, resulting in a large number of tourists visiting the area. In addition, the region supports several major educational institutions, including Michigan State University, Lansing Community College, Cooley Law School and numerous other satellite campuses of other institutions of higher learning. The region's diversity of business, governmental, tourist and educational attractions makes it necessary for MDOT to carefully consider the impacts of this major project.

Virtually all highway construction projects result in some disruption of normal traffic flow and operations. However, over the past several years, MDOT has made great strides to reduce the impact on the motoring public by employing several traffic management strategies. These include utilizing expedited construction schedules to reduce the amount of time construction occurs within a corridor, restricting work periods to night-time or off-peak traffic hours, incorporating incentives and disincentives into construction contracts to encourage contractors to further expedite construction by making additional materials and resources available for high impact projects, and using innovative traffic control techniques and aggressive public information campaigns to alert motorists of construction activities, thereby allowing them ample opportunities to avoid construction zones if they so choose.

By applying specific strategies in the development of the I-496 project, there are several objectives which MDOT intends to achieve. One of the key objectives is to minimize overall traffic disruption during construction. MDOT has decided to close the freeway, recognizing that while the disruption may be significant, the duration of the inconvenience will be greatly reduced by giving the contractor uninterrupted use of the right-of-way. With greater flexibility, the contractor can increase the speed of construction and accordingly, the cumulative disruptive impact to the motorists should be reduced.

Among many of the strategies considered by MDOT to manage and mitigate the disruptive impact of the freeway closure is the implementation of ITS technology. ITS, in the most general sense, is simply the application of state-of-the-art technology to collect, analyze, and communicate traffic information to motorists as fast as possible. The purpose of using ITS technology is to provide motorists with real-time information such that they are able to make better travel choices. ITS is geared to have its greatest benefit during “incidents” that result in unexpected delays or backups in the traffic flow. Construction zones themselves can be considered incidents, since they create the potential for frequent traffic disruptions and back-ups. Consequently, there is intuitively a valuable application for ITS technology in construction zones. However, the public agency’s accountability to the taxpayer demands more than intuition. There must be some quantified measure of confidence that the expenditure of public funds will truly benefit the public good. Therefore, it is the purpose of this analysis to determine if the utilization of ITS technology on a temporary basis for the I-496 construction project can be so justified.

Definition of Method

In order to determine if the use of ITS technology for temporary CZTM is justified for the I-496 project, the author will utilize cost-benefit analysis. Two alternatives will be analyzed, the baseline, or “do-nothing different” approach, which will assume the construction of the project without ITS, and the second alternative, construction of the project utilizing ITS. The author intends to examine what benefits can be derived from the temporary use of ITS technology on the I-496 construction project, quantify those benefits, and then compare them to the likely costs of implementing such technology. Cost-benefit analysis is an appropriate mechanism in this case for making the justification that the proposed ITS strategy has merit for the expenditure of public funds.

Research Problems and Issues

While the subject of this cost-benefit analysis is clear, there are a number of problems and issues which must be addressed in the context of the study. The following section outlines these issues in more detail.

Permanent ITS is used for routine traffic management in metropolitan Detroit, which describes the limits of MDOT’s experience with ITS to date. No such permanent ITS system exists in the Lansing urban area to use during the construction of I-496. However, MDOT’s experience with ITS in Detroit provides optimism toward other applications, such as the one considered for the I-496 project. The author assumes that the suitability of ITS in the Lansing area for the I-496 construction project has already been determined by MDOT, based on criteria established for general

ITS applications, and is, therefore, a foregone conclusion.

Furthermore, MDOT has never used ITS solely for temporary construction zone traffic control. In fact, ITS utilization for temporary CZTM has limited application across the United States. There are only a handful of projects in which temporary ITS systems were established solely for construction projects. Despite the promising possibilities for the temporary application of ITS, the limited national experience provides little data for which justification analysis can be conducted. The author will assume that the benefits of ITS would be common to both permanent and temporary installations. Therefore, this study can reasonably draw upon the more prevalent past experience of permanent applications to forecast expected benefits of the temporary system on I-496.

Additionally, the typical products and services provided by MDOT are easily quantifiable, such as a piece of tangible infrastructure or a specific transit service. However, when trying to arrive at a justification, the expenditure of public funds for the use of high-tech devices offering no tangible benefits presents measurement challenges. The benefits are harder to measure and account for, and will evaporate at the completion of the highway construction. In this paper, the author has attempted to draw on previous research to make the case for quantifying benefits associated with such non-traditional products used by when trying to arrive at a justification a governmental transportation agency.

Finally, estimation of the costs for implementing a temporary ITS system for CZTM on I-496 is itself a variable factor. An infinite number of systems could be developed ranging in scope of capability and scale of technology from a simple traffic counting device to elaborate interactive systems spanning the entire street network in the surrounding three counties. As the basis for evaluation, the author will use the proposed system designed by a consultant hired to assist in the development of alternatives for ITS on I-496.

Definition of Terms

Capacity: The volume of vehicular traffic which an element or combination of elements of a transportation system can accommodate at normal travel speeds. Also referred to as “throughput.”

Construction Zone Traffic Management (CZTM): The system of devices and measures taken by an implementing agency to safely manage traffic flows in and around areas of construction.

Efficiency: The ability of the transportation system to move vehicles through the system.

Emissions: Molecular compounds released through the exhaust by vehicles during travel that negatively impact air quality.

Incident: An event or condition that is likely to or results in a traffic back-up.

Intelligent Transportation Systems (ITS): The application of state of the art technology to provide real time traffic information which can be used to improve transportation system operations.

Mobility: The ability of the transportation system to facilitate the movement of people, goods and services to and from desired destinations.

Productivity: The measure of output and/or cost-effectiveness associated with or facilitated by transportation infrastructure.

Safety: The relative level and nature of accidents that occur on the transportation system.

Throughput: See “Capacity.”

Travel Demand Model: A computerized model which estimates travel patterns based on infrastructure characteristics, demographics, and observed travel patterns for a given urban system of highways.

CHAPTER TWO: REVIEW OF THE LITERATURE

Introduction

Limited analysis exists on the use of ITS for temporary CZTM. Despite the fact that transportation planners and engineers continue to seek innovative ways to safely manage traffic flows in construction zones, only a handful of highway construction projects in the United States have attempted this approach. Moreover, these projects typically have an air of experimentation. The implementing agencies' main objective has been to test the applicability of temporary ITS components for construction zone use. Because transportation agencies have not extended their approach to a programmatic view of temporary construction zone ITS strategies, there are no documented economic or business analyses yet in place for this specific application of ITS technology.

Consequently, in order to examine past experience and understanding regarding the subject, the author will investigate how ITS has been justified for permanent installations in the past and what data exists relative to the determination of benefits of ITS in the general sense. From this information, the author will draw conclusions about the applicability of this data for consideration in the temporary installation proposed for I-496. The review of literature follows the path of investigating benefit/cost analysis in general, then more specifically as applied to permanent ITS by others. Issues are then illuminated as the literature review moves to descriptions of specific benefits and methods for placing value on the various benefits.

General Benefit/Cost Analysis

Benefit/Cost analysis can be a useful tool for decision makers when comparing two or more alternatives for implementation of a proposed project. Rossi and Freeman (1993) expound on the value of this technique in bringing together within one parameter both the utility and the “bottom line” of project alternatives under consideration. This evaluation method attempts to quantify all impacts, both positive and negative (benefits and costs), in the same measurement of dollars. The authors go on to explain the importance of selecting the appropriate accounting perspective for the analysis. The accounting perspectives they offer are, 1) the individual-target, 2) the program sponsor, and 3) the communal perspectives. Each has it’s own assumptions and assignment of costs and benefits, which can greatly vary between perspectives even within the context of the same project or alternative. For example, the cost for some projects, such as the I-496 project considered in this study, are borne primarily by the program sponsor (MDOT) and not the individual-target (the drivers), so comparisons of costs between the two perspectives can vary quite dramatically. Rossi and Freeman (1993) also underscore the importance of careful monetization of outcomes. For some projects, especially projects with societal outcomes, the translation of quantified impacts into monetary values can be difficult. This is a shortcoming of this otherwise common analysis procedure.

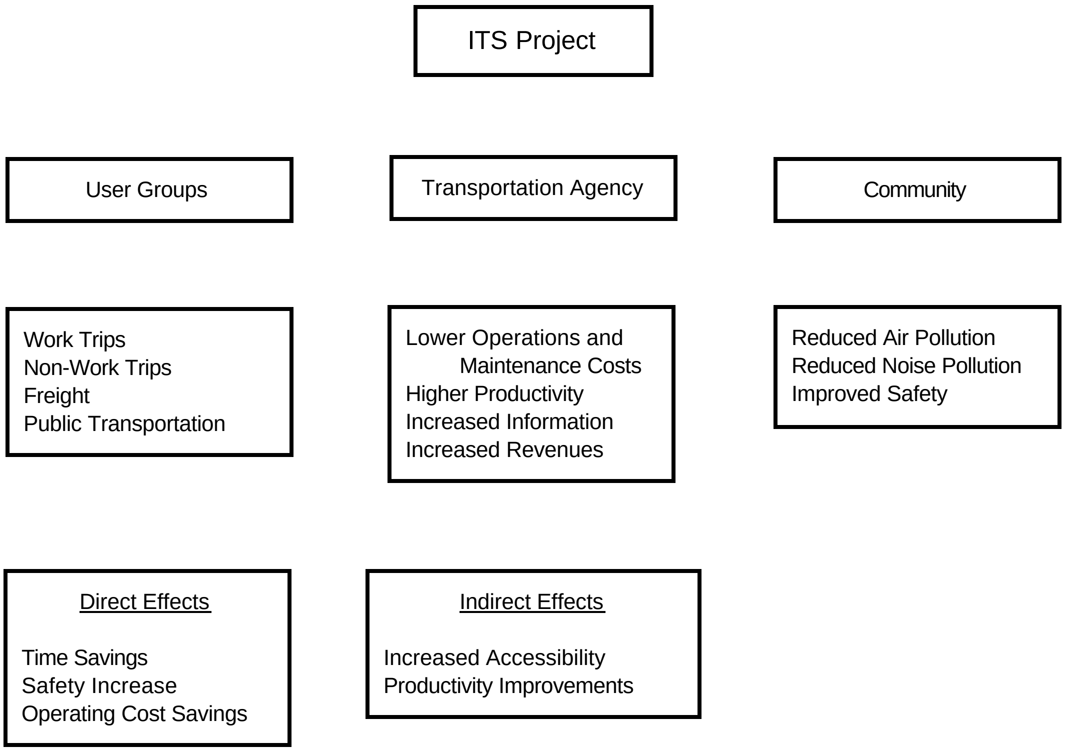
Benefit/Cost Analysis for ITS Technology

The question then must be raised, “Is benefit/cost analysis an appropriate justification tool for ITS?” Intuitively, many potential outcomes of ITS, even if not directly intended by the implementing agency, have associated societal impacts. A recent study of ITS evaluation methods (Turner, Stockton, James, Rother & Walton, 1998) cautioned policy makers against attempts to monetize all ITS benefits. The authors of the study suggest that, if some benefits are left out of the equations due to difficulties in assigning monetary values, reliance on benefit/cost analysis results may lead agencies to discard potentially valuable ITS applications.

Nevertheless, decision makers need to understand whether or not ITS applications make economic sense (Pearce, 2000). Most researchers maintain that benefit/cost analysis is a valid means of evaluation for ITS deployment. Gillen, Li, Dahlgren, and Chang (1999) reviewed this topic and concluded that benefit/cost analysis can be relevant. While comprehensive empirical data on the benefits of ITS is lacking, the authors contend that modeling techniques can effectively predict the benefits of ITS and their associated monetary values. They also argue the basic need to view ITS investment on par with other improvement projects that compete for the same scarce resources. Given that some reasonable method of quantifying impacts can be devised, the authors conclude that ITS projects do not differ substantially from other transportation improvement projects, and therefore, benefit/cost analysis is an appropriate and necessary justification tool. This position is shared by Zavergiu (1996), Brand (1993 & 1998), Li, Gillen, and Dahlgren (1999), Stamatiadis, Gartner, Winn and Bond (1998), and Ran, Lee, and Dong (1997).

Gillen, Li, Dahlgren, and Chang (1999) go further to provide an evaluation framework for ITS benefit/cost analysis. The proposed framework categorizes benefits in two different ways. The first method is to categorize benefits by the intended goals of ITS, namely 1) system efficiency, 2) mobility, 3) safety, 4) productivity, and 5) reduced environmental impacts. The second method is to categorize benefits by the recipient groups, specifically, 1) users of the facilities, 2) the providing agency, and 3) the surrounding community. This framework closely follows the methodology outlined by Rossi and Freeman (1993). Figure 1 depicts the relationships between the two categorizations of ITS benefits suggested in this study.

Figure 1. A Framework for ITS Benefit/Cost Analysis



Source: Gillen, Li, Dahlgren, and Chang (1999), p.18.

Zavergiu (1996) provides a very similar framework for evaluation of ITS benefits. He agrees with the grouping of benefits by the same goals as Gillen, Li, Dahlgren, and Chang (1999). He proposes similar beneficiary group categories, except he adds a fourth group, “potential private investors/ITS technology suppliers.” The author does this to extend his analysis beyond mere justification of ITS projects. He uses his framework to draw conclusions on who should pay for ITS investments. Tarry and Faber (1996) also suggest a framework which includes private sector interests, as private investments are becoming more critical to successful implementation efforts. MDOT has no intentions of entering into public-private partnerships for this specific project on I-496 due to it’s short duration and temporary nature. Consequently, for the purposes of this study, this perspective is dismissed by the author.

Brand (1998) also offers an ITS benefits framework model. This model categorizes benefits according to supply-side and demand-side goals. The supply-side benefits consist of measures of operational efficiency, such as improved throughput. These measures can also be translated into societal benefits in terms of reduced accidents, emissions, and fuel consumption. On the demand-side, the researcher suggests that benefit measures are related to mobility and productivity goals. This model is similar in many ways to the framework presented by Gillen, Li, Dahlgren, & Chang (1999).

Therefore, it is fairly well established that benefit/cost analysis has been accepted by researchers in the field of ITS technology as a reasonable evaluation tool for investment decisions regarding ITS projects. The framework offered by Gillen, Li, Dahlgren, and Chang (1999) provides a straightforward and comprehensive view of benefit/cost analysis for ITS projects. This framework will be the basis of the analysis performed by the author of this study. Other proposed frameworks that include impacts on private sector interests and technology suppliers, while generally having merit, will not be considered in this study, as MDOT is not contemplating any public-private partnerships in conjunction with the proposed I-496 temporary ITS project.

Defining and Quantifying ITS Benefits

With the assumption that benefit/cost analysis is a valid evaluation tool for ITS projects, the literature review now turns to issues surrounding the definition and subsequent quantifying of ITS benefits. This is perhaps the most difficult part of the analysis procedure, according to Gillen, Li, Dahlgren, and Chang (1999). Despite the challenge of estimating ITS benefit values, significant work has been done over the past decade to identify and categorize what benefits could exist and should be evaluated.

Virtually all of the literature accepts the premise reported by the ITS Joint Program Office that ITS benefits can be categorized into several major groups (ITS Benefits Database and Cost Information, 1999). These groups are centered around key goals of the transportation system and include safety, mobility, efficiency, productivity, energy and the environment and customer satisfaction. Safety is geared toward the objective of reducing both the number and severity of crashes. Mobility is focused primarily at the individual user level and refers to the user's ability to effectively travel to and from their destination.

Efficiency, on the other hand, is concerned with the macro-network or system level, and considers the capacity and throughput of the system. Productivity measures look at potential cost savings to user groups as a secondary result of efficiency and mobility effects of ITS. Other indirect benefits of ITS to society are considered in the “energy and environment” category, such as reduced fuel consumption and improvements in air quality and noise pollution. Finally, customer satisfaction measures take into account perceptions of users and managers of the ITS system, which are relevant to public and political acceptance of future project investments.

Besides these commonly accepted categories of benefits, several researchers suggest that some other positive impacts of ITS technology are being overlooked, and consequently result in undervaluation of the potential benefits of ITS investments. Eisele, Lomax and Vadali (2000) argue the case for consideration of non-typical benefits such as potentially positive impacts on land use decisions, increased access to labor, materials and markets, improved relationships between public and private agencies and expanded opportunities for mode choices. Brand (1993) recommends evaluation of elements such as the benefits from trip end opportunities which may be enhanced by ITS. He also suggests measures such as travel time reliability, user control, privacy and legal benefits, ease of implementation, community acceptance, interagency cooperation and improved data collection.

Zavergiu (1996) believes other measures such as reduced need for new right-of-way, improved transportation system management and planning and private sector business opportunities should be considered. While these additional items may in fact represent significant benefits which are traditionally overlooked in transportation benefit/cost analyses, they are also not easily determined and would rely on gross assumptions. Furthermore, in the context of the temporary condition of the proposed project at hand, many of these potential benefits have little relevance, as they primarily represent benefits that would be realized over an extended period of time. Therefore, for the purposes of this analysis, they are being disregarded by the author of this paper.

Table 1 summarizes the specific measures consistently suggested throughout the literature for assessing ITS benefits. This table, arranged by each category, also lists potential benefit values for ITS applications. The benefit value ranges are the result of both empirical data collected by other researchers and model predictions from previous studies. The empirical data has value to the extent that a correlation between the measured projects and future projects conditions can be shown. To the greatest extent possible, actual benefit measurements should be used. However, in many cases, insufficient empirical data exists (Ruthi, 1995). Therefore, several authors have addressed ways to examine benefit determination with limited, real world information.

Table 1. Benefit Measures and Values from Previous Studies.

Benefit Measures	Benefit Values	Sources
Safety:		
Injury Crash Rate	15%-18% Reduction	p. 12 (Henk, 1997); McKeever (1998), p. 11
Fatality Crash Rate	15%-18% Reduction	p. 14 (Evanco, 1996); McKeever (1998), p. 11
Mobility:		
Normal Travel Time Delay	20% Reduction	p. 17 (Inman, et al, 1996); p. 18 (Glassco, 1996)
Incident Travel Time Delay	50% Reduction	p. 19 (Meyer, 1989)
Efficiency:		
Throughput/Capacity	10% Increase	p. 25 (Van Aerde & Rakha, 1996)
Productivity:		
Increased Output	No data available	
Cost Savings	No data available	
Energy & Environment:		
Air Quality	15% Reduced Emissions	p. 38 (Van Aerde & Rakha, 1996)
Fuel Consumption	6%-13% Reduction During Normal Times 40% Reduction During Incidents	p. 40 (City of Los Angeles Department of Transportation); p. 40 (Siemens Automotive); p. 40 (Early Deployment..., 1994)
Noise	No data available	
Customer Satisfaction:		
Perceived Improvement	86% of Users	p. 37 (Henk, 1997)
Reduced Stress	63% of Users	p. 33 (Inman, et al, 1996)

Source: ITS Benefits: Continuing Successes and Operational Test Results (1997), unless otherwise noted in the table.

In their 1999 study, Gillen, Li, Dahlgren, and Chang present the concept of “willingness-to-pay”. This idea suggests that benefits should be measured by how much value an individual places on the good or service provided. How much a person actually pays is not a complete reflection of how much value that person places on the good or service. This is true since the value of each unit used will differ from the first to the last. The demand for travel is a composite of the costs for operating the vehicle and the costs of the time used. The first component is a straight-forward computation. The second reflects how much value is placed on time by the individual users. The “willingness-to-pay” measure provides an approach to consistently measure the benefit value which might normally seem very complicated due to the infinite variables impacting an individual’s valuation of time. The authors of the study contend that behavioral travel demand models can be developed to account for this “willingness-to-pay” variable. Moreover, such models are necessary for predicting the aggregate benefit value of time in the absence of credible empirical data. This theory is supported by other recent studies by Ruthi (1995), and Little, Liu, Rosenberg, Skinner, and Vance (1993).

Brand, in his 1998 study, also agrees that many ITS benefits are not accurately accounted for using strictly empirical efficiency data. He contends that the information that ITS provides may greatly change travel decisions, and therefore does not have a linear relationship between supply and demand. Consequently, the author suggests that direct measures, in the form of revealed or stated preference surveys as opposed to behavioral travel demand models, are preferred to assess the value that individuals place on ITS information. Nevertheless, he concedes the difficulty in performing such direct surveys and the need to use modeling in some instances. He also suggests that the calibration of such models is based on data from the individual user surveys.

Other studies also address the need for directly measuring user preferences and predicting user behavior. A recent review of several existing travel demand models was conducted to assess their applicability to the special circumstance of ITS projects (Ruthi, 1995). The study found that all current models lack the ability to model and assess the impacts of dynamic traveler behavior in response to information. This presents a dilemma for agency decision makers in need of supporting data for predictions on the benefits of ITS projects.

In the context of this I-496 project, the author will accept the limitations of current evaluation criteria and modeling techniques. To the extent that conditions for I-496 replicate those from previous benefit data determinations, the data in Table 1 will be used as the basis for predictions of benefits in this study. The lack of availability of behavioral and dynamic travel demand models will be addressed as a limitation on the results of this study.

Summary

Based on a review of the literature, the author has found that benefit/cost analysis is generally accepted as an appropriate evaluation technique for ITS projects. Several similar frameworks for benefit/cost analysis are offered by various researchers. The author will base the methodology for this study on the framework presented by Gillen, Li, Dahlgren and Chang (1999). The field of ITS research has defined specific categories of benefits based on generally accepted goals of transportation systems. Within these categories, specific measures are consistently considered by researchers. The author accepts the categorization and identification of benefit measures found in the literature, and will use these parameters for the determination of benefits for this study. While many other less commonly recognized benefits may exist, they are highly complex to measure and evaluate. Furthermore, these more abstract benefits are generally realized over extended periods of time. Therefore, for the temporary ITS system being evaluated in this study, they will not be considered. Benefit values, in the form of empirical measurements and model predictions, from previous research were also identified. The benefit measures and values accepted by the author are found in

Table 1. The values reported in Table 1 are included based on the relative similarity of previous studies to the context of the I-496 project.

CHAPTER THREE: METHODOLOGY

Introduction

A benefit/cost analysis will be conducted to evaluate whether or not the use of ITS technology can be justified for temporary use in construction zone traffic control for the I-496 reconstruction project in Lansing, Michigan. Literature on ITS has established that benefit/cost analysis is an acceptable tool for evaluating permanent ITS applications. The author of this study contends that the only difference between previous studies and the analysis in this paper is the duration over which benefits and costs are considered. In this case, the I-496 temporary ITS project will be implemented, operated, maintained and dissolved within the period of one year. The short duration of this project as well as other unique features in the treatment of costs have implications for the manner in which the benefit/cost analysis is conducted. This chapter will outline the methodology to be used in this study, and highlight the differences between this study and traditional benefit/cost analyses.

Design of the Method

All benefit/cost analyses follow the same basic structure, although each specific project has its own unique considerations.

First, at least two alternatives must be considered. Second, benefits and costs must be identified. Third, these benefits and costs must be measured. Fourth, the benefits and costs must be valued on the same basis, usually dollars in their net present value. Finally, the benefits and costs are compared to each other and are usually expressed as either a ratio or a net difference. Conclusions about the alternatives can then be drawn from this comparison.

A framework for benefit/cost analysis for ITS projects has been presented by Gillen, Li, Dahlgren, and Chang (1999), which is depicted in Figure 1. This framework follows the same basic pattern described above, concerning itself with identification and valuation of benefits unique to ITS projects. The author of this study has adopted this framework as the basis for the benefit/cost analysis for the I-496 temporary ITS project.

Alternatives

For the purposes of this study, two alternatives will be considered. The first alternative, the “do-nothing” or status-quo alternative, considers that the I-496 construction would occur using traditional traffic control techniques with no application of ITS technology. The second alternative , the “temporary ITS” alternative, considers the application of ITS technology in addition to traditional traffic control techniques. Both alternatives assume the same construction work occurs, the same basic construction staging, the same system of freeway closure and alternate travel routes, and the same initial traffic volumes and concentrations. By using these two alternatives, conclusions can be drawn relative to the decision on whether or not to use ITS technology on the I-496 project, since the first alternative acts as a baseline for measurement. In general, benefit and cost calculations will be computed as the difference between the “do-nothing” and the “temporary ITS” alternatives.

It should be noted that it may be possible to consider more than one temporary ITS alternative. An infinite number of variations could be created based on the types of technologies available, the number and location of devices and the type and extent of user interface with the system. For the purposes of this study, only one temporary ITS is considered. This alternative is based on a proposed plan of devices and technology proposed by a consultant retained by MDOT for designing the temporary ITS system for the I-496 project. The consultant’s proposal reflects an economical system that achieves the key objectives desired by MDOT. It is neither a “bare bones” system nor a “cadillac” system. It is a representation of the most likely system to be carried forward by MDOT, and therefore is the best basis for this analysis.

Accounting Perspective

The accounting perspective refers to the set of assumptions used to assign benefits and costs to the various inputs and outputs of the analysis (Rossi & Freeman, 1993). Researchers typically chose to analyze one or more of the three generally accepted accounting perspectives, namely, 1) the individual-target, 2) the program sponsor and 3) the communal perspectives. The assumptions inherent to each perspective for the assignment of costs and benefits can result in significant variance in the results between perspectives, even within the context of the same project or alternative. It is important to clearly define the accounting perspective used, such that benefits and costs are correctly assigned and not double-counted within a single perspective.

For this study, based on the adopted framework from Gillen, LI, Dahlgren, and Chang (1999), all three perspectives will be considered. More specifically, the alternatives will be defined in terms relative to the transportation system, the users, or drivers, of the system, the implementing agency (MDOT) and the surrounding community of the greater Lansing urban area.

User/Driver Perspective

For this accounting perspective, benefits and costs will be assigned based on their direct relationship to the individual user. For example, since the costs of the implementing the project are largely born by the agency (MDOT), the only costs of the system which can be assigned in this perspective to the user are those which the individual user must directly pay out of pocket. Benefits and costs will be summed for the aggregate number of users on the system to develop a total measure of costs and benefits for all impacted transportation users in the Lansing urban area.

Agency (MDOT) Perspective

For this set of assumptions, benefits and costs will be assigned based upon the direct impact to the agency itself. While the department’s primary objective for the temporary ITS system on I-496 is to provide benefits for the users of the system, the department also has associated benefits and costs specific to itself.

Community Perspective

In addition to benefits and costs for the direct users and the agency, all alternatives have potentially positive and negative impacts on the community at large. To completely analyze the impacts of alternatives, it is necessary to assign benefits and costs in this arena as well.

Combination of Perspectives

Typically, only one perspective is considered in a benefit/cost analysis. If more than one is considered, it is done for comparison purposes only. A comparison between perspectives will be performed in this study. The framework developed by Gillen, Li, Dahlgren, and Chang (1999) sums the benefits and costs of all perspectives into a single, total value. According to Rossi and Freeman (1993), this mixing of perspectives may result in double counting. However, the method of computation of benefits and costs to be used in this study will sufficiently isolate these benefit and cost elements, such that double counting should not be a concern. Therefore, in addition to comparison of the perspectives, the author of this study will also combine the results of the individual accounting perspectives into one, total benefit/cost figure.

Identification, Measurement and Valuation of Benefits and Costs

As the next step in the analysis, the researcher will identify, measure and place a monetary value on each benefit and cost item. This will be accomplished within the context of each accounting perspective. Table 2 identifies the benefit and cost components for this analysis by accounting perspective. The following is a description of each component and how the author intends to measure and value the component for inclusion in the final benefit/cost computations.

Table 2. Components of the Benefit/Cost Analysis by Perspective.

Users	Agency (MDOT)	Community
Benefits:		
Injury Accident Reduction Fatal Accident Reduction Normal Travel Time Delay Reduction Incident Travel Time Delay Reduction	Throughput Improvements Customer Satisfaction	Emissions Reduction Fuel Consumption Reduction
Costs:		
	ITS System Costs	Opportunity Costs

Safety Benefits

Safety benefits and costs will computed based on rates of injury and fatality types of accidents. Average injury and fatality rates will be obtained from MDOT records. These rates are typically represented in units of numbers of accidents per million vehicle miles traveled. Using the results of the Tri-County Regional Travel Demand Model (TCRTDM), an estimate of the number of vehicle miles traveled throughout the Lansing Urban area will be derived for both the “do-nothing” alternative and the temporary ITS alternative. Then applying the factor for accident rate reduction found in Table 1, the predicted change in accidents will be computed for the temporary ITS alternative. The dollar value for the difference between the alternatives will then be computed using accident cost values from a 1991 study by Miller (as cited in Gillen & Li, 1999).

Mobility Benefits

Mobility benefits will be measured in terms of user delay costs avoided by motorists as a result of the ITS system. Two components of delay will be considered. The first is normal travel time delay associated with the alternate route system. The second is travel time delay associated with incidents. Delay due to incidents is more significant, but incident delays cover only a small portion of the total time of the project.

Based on the results of TCRTDM, average normal travel time delay across the entire transportation system will be estimated for the “do-nothing” alternative in terms of vehicle-hours traveled. Using the estimate found in the literature review (see Table 1), the reduction in delay will be predicted for the ITS alternative. The respective delay reduction estimates will then be converted to dollar values using estimates from previous research for the cost of user delay in terms of dollars per vehicle-hour of delay (Walls & Smith, 1998).

For travel time during incidents, even better than expected improvements are anticipated. However, predicting incidents is an imperfect science. Therefore, the author will assume that an incident will occur five times a week, which will last, on average, one hour. An estimate of travel time associated with an incident delay will be computed, based on the normal travel time calculations and the assumptions stated above for the “do-nothing” alternative. Travel time improvement for the ITS alternative will be estimated using the data found in the literature (see Table 1). Again, the difference in travel time values between the alternatives will then be converted to dollar values using information from previous research (Walls & Smith, 1998).

Efficiency Benefits

Efficiency of the alternatives will be measured in terms of throughput of the system. Existing system capacity will be estimated using data from the TCRTDM expressed in terms of volume to capacity ratios. If volume to capacity ratios are one to one or less, this suggests that the system has adequate capacity to handle the alternate routing of traffic. Therefore, for the short-term, temporary ITS system, no benefits will be realized for capacity improvement, since sufficient capacity already exists. If this condition exists, the author will not report any benefits for the ITS system. However, if volume to capacity ratios exceed one to one, the system lacks sufficient capacity to handle traffic flows. In this condition, ITS would have beneficial impacts which should be taken into account. For the ITS alternative, an estimate of the likely improvement in throughput will be derived based on data from previous research (see Table 1). The total improvement expected in terms of volume will be converted to an equivalent length of new highway that would be otherwise required to result in the same capacity improvement. A dollar value will then be computed for this length of new highway using average construction prices from MDOT records.

Productivity Benefits

Gillen, Li, Dahlgren, and Chang (1999) suggest that productivity improvements that result from ITS systems should be accounted for in benefit estimation. The productivity with which they are concerned relates to that of specific commercial and economic sectors of the community, and is measured in terms of increased output or reduced operational and logistical costs. The author of this paper agrees with this point, however, no credible data or methodology exists from previous research to use as a basis for estimating what productivity improvements could be expected. This intuitively makes sense, since community productivity measures would generally be specific to individual sites and economic circumstances. Individual user productivity improvements should already be accounted for in the travel time benefits, since the value of individual's time takes into consideration how they might otherwise be using that time. Therefore, productivity benefits will not be estimated for this analysis.

Energy and Environmental Benefits

Energy and environmental benefits will be computed based on two measures: emissions and fuel consumption. Based on the improvement in vehicle hours traveled that were estimated in the efficiency benefits section, and using the projected impacts found in the literature (see Table 1), projected improvements in volatile compound emissions from vehicles will be determined. These values will then be converted to monetary values using information from a 1995 study by Small (as cited in Gillen & Li, 1999) on the value to society of cleaner air. Reductions in fuel consumption will be estimated using the projected reductions in vehicle miles traveled computed in the mobility benefits section. That value will be multiplied by factors for average vehicle fuel efficiency to determine fuel savings in gallons, which in turn will be converted to a dollar value based on average fuel costs.

Customer Satisfaction Benefits

Limited information exists on expected customer satisfaction measures (see Table 1). In addition, MDOT commissioned a public opinion survey in the fall of 2000. The survey, which covered many other aspects of the proposed construction project, asked only one, general question regarding public perception about the idea of ITS. The results of this study will be noted in the analysis. However, while general acceptance or appreciation of ITS may be found through customer surveys, there is little data regarding what value individuals place on their satisfaction with ITS or the value of the information that ITS can provide to them. Consequently, a reliable means for estimating a dollar value associated with customer satisfaction does not exist. Therefore, customer satisfaction benefits will not be directly accounted for in the benefit/cost analysis. However, as customer satisfaction is one of the key reasons for using the temporary ITS system for I-496, it will be considered qualitatively in the final conclusions.

ITS System Costs

ITS system costs refer to the estimated costs for designing the system, furnishing and installing the hardware and software components and operating and maintaining the system for the period of the I-496 construction. Typically, analysts must prepare estimates for each one of these elements. However, in the case of the I-496 project, MDOT intends to make the contractor responsible for all elements of the system, including the operations and maintenance, as part of one low bid price. This simplifies the system cost estimation considerably. The value will come directly from MDOT records on the tabulation of contractor bids.

Individual User Costs for ITS

In some instances on other ITS projects across the nation, part of the user interface includes in-vehicle devices which transmit information to motorists. These devices must be purchased by the individual users, and therefore, some cost for the ITS system must be attributed to the user from that accounting perspective. In the case of the I-496 temporary ITS, no personal, in-vehicle devices will be used. Therefore, no costs for the ITS system will be assigned to the user perspective.

Opportunity Costs

One final cost consideration is the opportunity cost associated with the expenditure of scarce resources on the ITS system. In other words, what benefits to the community are being foregone in order to implement the ITS alternative? Or, what is the cost of using funds that would otherwise be available for other transportation improvements? For the purposes of this analysis this will simply be estimated as the cost of the ITS system, but rather than be applied to the agency perspective it will be assigned to the community perspective.

Special Considerations for the Valuation of Benefits and Costs

A number of unique circumstances exist regarding the I-496 temporary ITS project that require special consideration when computing benefits and costs. Specifically, the issues affected are discounting, the consideration of equity and the treatment of fixed and variable costs. The following sections describe how these considerations will be managed for the purpose of this study.

Discounting

Typically in benefit/cost studies, the analyst must consider the time value of money. In cases where the benefits and costs of various alternatives are experienced over a period of several years or more, the dollar values of the impacts must be compared on a level plane. Consequently, all benefit and cost values are discounted to bring the values to their net present worth. In the case of the I-496 temporary ITS project, all costs and benefits occur within the same period of one year. Therefore, the need to discount benefit and cost values and compute net present values is not necessary and will not be computed. However, to the extent that benefit values from previous research are dated, the author will inflate the figures to current dollars using an assumed annual growth rate of three percent.

Consideration of Equity

Another consideration in many benefit/cost analyses is the accumulation of equity in the assets associated with the various alternatives over the life of the project. Another way of looking at this is that the researcher should account for the residual value of alternatives at the completion of the analysis period. In this case, the I-496 temporary ITS system components will have some residual value at the completion of the project. However, the MDOT has established the contract such that all components, hardware and software, become the property of the contractor at the completion of the contract. As such, neither the agency nor the public will receive any benefit from the residual value of the system at the end of the project. Therefore, the author will not account for the residual value or equity of the temporary ITS system for this analysis.

Fixed Versus Variable Costs

Typically in cost studies, consideration is given to the level of variability of the cost elements. In many circumstances the costs can be divided between fixed costs, which do not change regardless of the breadth of application of the project, and variable costs, which have a marginal value dependent on the number of units affected in the group being studied. For the purposes of this analysis, all cost and benefit values will be considered as fixed. While there is the potential for some variability in how the population reacts to and makes use of the temporary ITS system, there is no practical way to estimate this. Therefore, for the purposes of the benefit determination, calculations will assume a fixed number of benefactors in each accounting perspective, and therefore, values will be fixed. On the cost side, all system costs will also be fixed, as prescribed by the MDOT contract, regardless of the number of users of the system. Furthermore, all operations and maintenance costs associated with the system are part of the contractor's fixed, low bid price.

Comparison of Benefits and Costs

Finally, once the benefits and costs are estimated and valued in terms of dollars, they can be summed and compared. This will be done by each accounting perspective and as a combined total for all perspectives. The results will be tabulated as both a benefit/cost ratio and as a net benefit or cost, as the case may be. A benefit/cost ratio which exceeds a value of one indicates a favorable project. The alternative would therefore have benefits which exceed the costs. For a benefit/cost ratio less than one, the favorability of the project would have to be considered more carefully, taking into consideration the qualitative benefits that had been omitted due to difficulties in preparing realistic estimates and assigning dollar values.

Summary

This chapter has outlined the methodology of a benefit/cost analysis which will be utilized in this study to evaluate the worthiness of using temporary ITS for construction zone traffic management for the I-496 reconstruction project proposed by MDOT. The methodology follows typical guidelines for benefit/cost studies, as well as a framework established in the literature specifically for ITS projects. Benefits and costs will be compared with respect to appropriate accounting perspectives, namely the users or driver of the transportation network, the agency, MDOT and the community at large. Benefits will generally be based on data from the Tri-County Regional Travel Demand Model and projected improvements in various factors. These factors are associated with safety, mobility, efficiency, and environmental benefits which have been established in previous studies of permanent ITS systems. Due to the contractual nature of the project proposed by MDOT, certain typical economic analysis factors can be dismissed, including the need for discounting, consideration of equity and the treatment of fixed costs versus variable costs. The results of the analysis will produce benefit/cost ratios and net benefit values for each accounting perspective and for the combination of all perspectives. The author will then use this information, in conjunction with qualitative benefits which could not be readily estimated and monetized, to draw conclusions on the suitability of temporary ITS for the I-496 project.

CHAPTER FOUR: ANALYSIS OF THE DATA

Introduction

Having reviewed the literature and developed a methodology for performing a benefit/cost analysis, in this chapter the author computes the benefits and costs for the temporary ITS system for the I-496 project. First, benefits and costs will be quantified and converted to monetary values. Then, the benefits and costs will be summed and compared according to the accounting perspectives outlined in the methodology. Finally, a summary of the results will be presented.

Identification, Measurement and Valuation of Benefits and Costs

As recommended in the literature and as shown in the methodology, benefits are considered with respect to the broader categories of transportation system goals. The calculations are therefore organized in that manner. Only those benefits for which reliable estimation data was available are included here. For some benefits that could or should be considered, there exists no easily applied model or empirical data. The benefits are omitted from the computations and will be discussed qualitatively in the conclusions in Chapter 5.

Throughout the calculations, the author accounts for the fact that the I-496 project is proposed to be constructed in two phases. The first phase will close the eastern portion of the freeway for approximately 150 days. The second phase, on the western portion of the project, will maintain one lane of traffic in each direction of the freeway for an additional 60 days after the first phase is completed. One of the key sources of information throughout the calculations is the Tri-County Regional Travel Demand Model (TCRTDM). The model was run for both phase one and phase two conditions. The results of the TCRTDM are shown in Table 3. The baseline data represents the values for the Lansing urban area transportation network in its normal operating state, without any construction lane closures or detours. The computations that follow reflect the values for the two phases and will account for their respective durations.

Table 3. Tri-County Regional Travel Demand Model Results.

Model Run	Daily Vehicle Miles Traveled (VMT)	Daily Vehicle Hours Traveled (VHT)
Baseline	11,962,850	306,121
Phase 1	12,007,610	316,093
Phase 2	11,975,720	309,608

Source: Tri-County Regional Travel Demand Model (2000), Bureau of Transportation Planning, MDOT.

Also, throughout the calculations, the author assumes that the impacts of the ITS system benefits will be realized by only ten percent of the total traveling population. The proposed I-496 ITS system is temporary, and as previously mentioned, is a modest approach to ITS implementation. The breadth of coverage of the ITS system does not comprehensively address all the major routes accounted for in the TCRTDM. Therefore, it would be erroneous to assume that the benefits of the ITS would impact the entire Lansing urban area transportation network. Since, however, the temporary ITS system will affect traffic on most of the high volume arterial routes in the urban area, the assumption that only ten percent of the traffic would be affected is reasonable if not conservative.

Safety Benefits

In order to estimate the safety benefits in terms of accident reduction, the baseline accident rates must first be determined. The average total accident rate for the I-496 construction project alternate routes is 199 accidents per 100 million vehicle miles traveled (VMT). This value was computed from accident data presented in the MDOT Sufficiency Ratings (1998). It is also known that in Michigan, approximately one-third of one percent of all accidents are fatalities and approximately thirty percent of all crashes result in injuries (Michigan Transportation Facts and Figures, 1999, p. 16).

Assuming the statewide trend applies to the Lansing urban area, the fatality and injury accident rates are computed to be 0.66 accidents per 100 million VMT and 60 accidents per 100 million VMT, respectively.

To determine the actual number of accidents that would be expected to occur, should accidents follow these trends, the accident rates were multiplied by the daily VMT and by the number of days for each phase of the project, as follows:

$$\text{Number of Fatalities} = \frac{0.66 \text{ fatalities}}{100 \text{ million VMT}} \times \frac{12{,}007{,}610 \text{ VMT}}{\text{day}} \times 150 \text{ days}$$

$$+ \frac{0.66 \text{ fatalities}}{100 \text{ million VMT}} \times \frac{11{,}975{,}720 \text{ VMT}}{\text{day}} \times 60 \text{ days}$$

$$= 16.7 \text{ fatalities (for the duration of the project)}$$

Similarly, the number of anticipated injuries are computed:

$$\text{Number of Injuries} = \frac{60 \text{ injuries}}{100 \text{ million VMT}} \times \frac{12{,}007{,}610 \text{ VMT}}{\text{day}} \times 150 \text{ days}$$

$$+ \frac{60 \text{ injuries}}{100 \text{ million VMT}} \times \frac{11{,}975{,}720 \text{ VMT}}{\text{day}} \times 60 \text{ days}$$

$$= 1500 \text{ injuries (for the duration of the project)}$$

It should be noted that, typically in construction zones, accident rates increase beyond the normal accident frequency. However, in the case of the I-496 project, for the majority of the time, traffic will be utilizing alternate routes, and therefore won’t actually be in a construction zone. Consequently, the author disregards the potential for increased accidents and assumes that traffic characteristics on the alternate routes will follow normal projected trends. For the purposes of ITS benefit estimation, this assumption will produce conservative results, since potentially more accidents may occur, and consequently, more accident reduction benefits will not be accounted for.

It is anticipated that 15% to 18% of both fatal and injury accidents may be reduced as a result of the ITS placement (see Table 1). Using the lower end of this range, the total expected number of accidents would be lowered by 2.5 fatalities and by 225 injuries for the period of the construction project.

Finally, the reduced number of accidents are converted to dollar values. Miller (as cited in Gillen & Li, 1999) provides estimated values for accident costs, as shown in Table 4. These values, expressed in 1988 dollars, are then adjusted for inflation by the author, assuming a 3% annual growth rate. The author also assumes that half of the injury accidents will be “incapacitating” and the other half “evident”. Therefore, the value used in the final computations is a straight average of the two injury accident values. Multiplying the expected number of reduced accidents by the accident costs per vehicle results in a savings of approximately $10,000,000 for fatalities and $46,000,000 for injuries. As stated earlier, the author presumes that only about ten percent of the urban area will see benefits of this nature. Therefore, these values will be reduced to $1,000,000 for fatalities and $4,600,000 for injuries.

Table 4. Estimated Accident Costs Per Vehicle.

Accident Type	Estimated Cost (1988 Dollars)	Estimated Cost (2001 Dollars)
Fatality	$2,722,548	$3,998,062
Injury - Incapacitating	$228,568	$335,652
Injury - Evident	$48,333	$70,977

Source: Miller (as cited in Gillen & Li, 1999, p. 130).

Mobility Benefits

Mobility benefits are computed in terms of user delay costs that are avoided for two conditions - normal travel time delays and incident travel time delays. Normal travel time delays refer to the anticipated delay costs incurred by virtue of the construction project and alternate routes imposed on the drivers. It is expected that ITS will provide benefits to reduce the delay experienced in this situation. Incident travel time delay refers to user delays experienced as a result of a specific incident that causes congestion in the system. While similar in nature, ITS is expected to have an even greater benefit of reducing the impact of delay in response to incidents.

First, normal travel time user delay costs are computed based on the results of the TCRTDM, expressed as vehicle hours traveled (VHT), reported in Table 3. For phase one of the construction, the model estimates an increase in travel time of 9,972 VHT per day. Multiplied by the duration of phase one, 150 days, a total of approximately 1,496,000 vehicle hours of delay will be experienced during phase one. For phase two, the model estimates an increase in travel time of 3,487 VHT daily. Multiplied by the sixty day duration of phase two, this results in 209,000 vehicle hours. Therefore, in total, 1,705,000 additional vehicle hours of travel time, or delay, will result from the construction project.

Empirical data from the literature suggests that expected normal travel times will be improved by 20% (See Table 1). Therefore the expected benefit for normal travel times is 341,000 vehicle hours over the duration of the construction project. This value is converted to dollars using estimates of user delay costs. Walls & Smith (1998, p. 20) provide different values for passenger vehicles and commercial vehicles, specifically $11.58 per vehicle-hour for cars and $20.43 per vehicle-hour for trucks when adjusted for inflation. It is known that approximately five percent of the vehicle volume in the Lansing urban area is commercial traffic (MDOT Sufficiency Ratings, 1998). Therefore, ninety-five percent of the improvement in delay is converted using the car value and five percent is converted using the truck value. This results in a total anticipated savings in user delay costs of approximately $4,100,000 for normal travel time conditions. As with the safety benefits, it is assumed that the limited breadth of the ITS system will result in impacting only about ten percent of the system. Accordingly, the author reports a benefit value for normal travel time user delay cost avoided of $410,000 for the duration of the entire project.

Incident travel time prediction presents a different situation. While the literature suggests that incident situations are perhaps one of the most significant impacts for ITS applications, they are also the most difficult to model and accurately predict the outcomes. Consequently, for this analysis, the author must make some reasonable assumptions about incidents. The author assumes that five incidents will occur each week that result in additional user delay beyond the normal travel time delays. For each incident, it is assumed that, in the absence of ITS technology, the delay will add one hour to those drivers affected. Using these assumptions, over the 210 day duration of the project, it is estimated that, without the ITS system, 150 hours of incident delay will occur. It is further assumed that approximately six thousand vehicles will, on average, be impacted by the incident; that is, they will either be caught in a traffic back-up or will have to divert around a traffic back-up. Based on this assumption, the author estimates that 900,000 vehicle-hours of delay will be induced by incident throughout the life of the construction project.

The literature suggests that up to fifty percent of this sort of delay can be avoided or reduced through the application of ITS technology (see Table 1). Therefore, the benefit estimation for incident travel time is 450,000 vehicle-hours. Using the same monetary conversion values as for normal travel time delay, an amount of approximately $5,400,000 in incident related user delay cost savings is expected over the duration of the project. As with the normal travel time, this estimate will be reduced to ten percent of its value. Even though the author assumed a number of vehicles impacted by the hypothetical incidents, the computations were based on the total network system. Some incidents may not be identified due to the limited coverage of the proposed ITS system. Therefore, the reported benefit of reduction in incident travel time delay is $540,000.

Efficiency Benefits

Efficiency benefits are measured by improvements in system capacity or throughput. In the author's review of data from the TCRTDM, volume to capacity ratios across the system with the alternate routes in place were predominantly estimated as 1.0 or less. This means that even with the alternate routes and traffic diversion, the system is operating at or below capacity. Consequently, even if ITS can improve capacity, as discovered in the review of the literature, there is no real benefit if the capacity is not needed.

This is especially true for a temporary application of ITS, as is the case for the I-496 project. One perspective of the potential capacity or throughput benefit of ITS is that its application would allow the agency to defer traditional capacity enhancing improvements such as adding additional traffic lanes. Since traffic volumes generally grow over time, even if the system is currently operating at or slightly below capacity, there would exist some benefit to the agency in terms of how much longer it could maintain service levels using existing infrastructure. But this benefit is only realized if the ITS system remains in place over time. Since the ITS system for the I-496 project is temporary, no efficiency benefit is recorded with respect to capacity or throughput.

Energy and Environmental Benefits

Energy and environmental benefits are computed for the categories of emission reductions and fuel consumption reductions. Emissions reduction benefits are calculated using the results of the TCRTDM. Based on the daily estimates of vehicle miles traveled and the expected durations for each phase of the I-496 project, a total of 2,520,000,000 VMT is expected over the life of the project. Estimates of average vehicle emissions rates from the Bureau of Transportation Statistics (National Transportation Data Archive, 2001, Table 4-36 on-line) suggest that hydrocarbons

(HC) are emitted at a rate of 3.09 grams per mile, carbon monoxide (CO) is produced at a rate of 24.68 grams per mile, and nitrogen oxide (Nox) is emitted at a rate of 1.81 grams per mile. By multiplying these values through, estimates for emissions as a total for the region are as shown in Table 5. Based on the literature review (see Table 1), ITS applications, such as the system proposed for I-496, are expected to reduce emissions by fifteen percent. Table 5 also shows cost values proposed by Small and Kazimi (as cited in Gillen & Li, 1999) for the various emissions factors, adjusted for inflation to 2001 dollars, assuming a three percent growth rate.

Table 5. Estimated Emissions Reductions and Values for ITS.

Emission Type	Total Emissions Without ITS (kg)	Expected ITS Emissions Reduction Benefit (kg)	Value of Emissions Reduction	Total Emissions Reduction Benefit Value
HC	7,786,000	1,167,900	$6.19/kg	$7,230,000
CO	62,194,000	9,329,100	$1.15/kg	$10,730,000
NOx	4,561,000	684,150	$6.65/kg	$4,550,000

Source: Small and Kazimi (as cited in Gillen & Li, 1999, p. 139), adjusted for inflation at 3% per year.

As with previous benefit estimates, the emissions benefit reported is reduced to ten percent of its calculated value to reflect the fact that the ITS system does not extend across the entire transportation network. As such, the total emission reduction benefit is considered to be approximately $2,250,000 over the duration of the project.

Fuel consumption is also estimated using the results of the TCRTDM. As indicated previously, the total estimated travel during the construction period is 2,520,000,000 VMT. Using an average value of 21.5 miles per gallon for vehicle fuel economy (National Transportation Data Archive, 2001, Table 4-23 on-line), it is estimated that 117,209,000 gallons of gasoline will be consumed during the period of this project. The literature suggests that ITS will result in at least a six percent reduction in fuel consumption (see Table 1). Therefore, the projected benefit for this category is approximately 7,000,000 gallons of fuel. This is easily converted to a monetary value, using the current cost of fuel, reported as approximately $1.50 per gallon (AAA Michigan, 2000, p.1 on-line). This results in a benefit of $10,500,000. As with the other benefit values, this amount is reduced to ten percent of the computed value to account for the expected reach of the temporary ITS system. Therefore, the reported benefit for fuel consumption reduction is $1,050,000.

ITS System Costs

ITS system costs are based on data from the I-496 ITS project contract documents and bid information (Michigan

Department of Transportation Tabulation of Bids, 2001). Some elements of the ITS contract are not strictly ITS features, and would be constructed even if ITS was not implemented. These items include advanced construction zone signing, portable changeable message signs, traffic control items and a proportional amount of the mobilization costs. These items have been removed from the total contract amount to estimate the ITS system cost. As such, the total estimated construction costs are approximately $1,900,000. In addition to the construction estimate, costs for design, contract administration and construction engineering must be accounted for as well. These are estimated to be approximately $600,000, bringing the total cost for the implementing the temporary ITS system for the I-496 project to $2,500,000.

Opportunity Costs

As described in the methodology, for the purposes of this analysis, the opportunity cost of using the ITS system is simply the cost of the ITS system. In a situation of limited resources, the cost of the ITS system represents a lost opportunity to receive the benefits of other transportation facilities or services. The loss of such benefits are considered to have the same value as the cost of the ITS project, $2,500,000, but are assigned to the community accounting perspective, as opposed to the agency (MDOT) accounting perspective.

Summary of Benefit and Cost Determinations

The benefits and costs computed above are summarized in Table 6 below. These values, as described in the calculations, are based primarily on information from the TCRTDM. The estimates rely on the best available data regarding ITS benefits found in the review of previous studies. The information from the literature includes both empirical observations and simulations to predict ITS benefits. In some instances, where insufficient data was available, the author made assumptions regarding the potential benefits of the temporary ITS system for the I-496 project.

Table 6. Summary of Benefit and Cost Values.

Benefits and Costs:		
(1)	Fatality Accident Reduction (Benefit)	$1,000,000
(2)	Injury Accident Reduction (Benefit)	$4,600,000
(3)	Normal Travel Time Delay Reduction (Benefit)	$410,000
(4)	Incident Travel Time Delay Reduction (Benefit)	$540,000
(5)	Emissions Reduction (Benefit)	$2,250,000
(6)	Fuel Consumption Reduction (Benefit)	$1,050,000
(7)	ITS System Costs (Cost)	$2,500,000
(8)	Opportunity Costs (Cost)	$2,500,000

Comparison of Benefits and Costs

With the various benefits and costs estimated and converted to common dollar values, a comparison of the benefits and costs can now be conducted. Benefits and costs are summed according to accounting perspective, as prescribed in Table 2. Then the ratios of benefits to costs is computed. Finally, the net benefit, or difference between benefits and costs, is calculated. The results of these computations is shown below in Table 7.

Table 7. Benefit/Cost Calculations.

	Users	Agency (MDOT)	Community
Benefits:			
	$1,000,000 (1)		$2,250,000 (5)
	$4,600,000 (2)		$1,050,000 (6)
	$410,000 (3)		
	$564,000 (4)		
	$6,574,000	**$0**	**$3,300,000**
Costs:			
		$2,500,000 (7)	$2,500,000 (8)
	$0	**$2,500,000**	**$2,500,000**
Benefit/Cost Ratio:			
	Infinite	**0**	**1.32**
Net Benefit:			
	$6,574,000	**($2,500,000)**	**$800,000**

Note: The numbers in parentheses refer to the benefit and cost items from Table 6.

A benefit/cost ratio which exceeds a value of one indicates a worthwhile outcome of the project. From the user perspective the I-496 project is very favorable. Since the users do not directly have to pay for any part of the ITS system, nor a fee to receive the information it provides, they have no costs. Therefore, any benefits at all from the user perspective make the project worthwhile. The benefit/cost ratio is reported as "infinite", since the cost figure in the denominator is zero. It is perhaps more appropriate for the user perspective to consider the net benefit, which is $6,574,000. This amount of benefit is fairly substantial, and would in most cases justify the project.

From the agency perspective, according to the analysis, the project has no merit. Since none of the calculated benefits can be allocated to MDOT, the agency's only contribution is the cost it bears to implement the project. This results in a benefit/cost ratio of zero and a net loss of $2,500,000. However, as found in the literature, there are benefits which could be allocated to the agency in this case. One such example is customer satisfaction. For this project, no readily available data existed to measure or monetize the value of customer satisfaction for the I-496 temporary ITS project. Yet customer satisfaction, or rather minimizing driver dis-satisfaction, is one of the key objectives for MDOT in pursuing temporary ITS for construction zone traffic management. In a pubic opinion survey commissioned by MDOT in November, 2000, 83% of those surveyed said they thought the ITS system would be helpful (Survey on I-496, 2000, p. 15).

Considering this, it is reasonable to suggest that, should the system produce the expected results, some benefit to the department would be realized. Therefore, conclusions about the result of the benefit/cost analysis from the agency perspective should not be made without consideration of the qualitative benefits that could not be reasonably included.

Looking at the community perspective, there is a benefit/cost ratio of 1.32 and a net benefit of $800,000. These results suggest that the project is favorable for the community at large. Despite the lost opportunity of some other transportation project that might benefit the community, enough benefits are realized in terms of energy savings and reduced environmental impacts to justify spending scarce resources on the ITS project.

Using a combination of all three accounting perspectives, the total of benefits is $9,874,000 and the total of all costs is $5,000,000. This yields a benefit/cost ratio of 1.97 and a net benefit of $4,874,000. While Rossi and Freeman (1993) caution against combining perspectives, in this case none of the benefits or costs are computed in such a way as to result in double counting. Given the fact that there are no reported costs in the user perspective and no reported benefits for the agency perspective, the combination of all perspectives gives a more accurate picture of the benefit/cost ratio for the project overall. By nearly a two to one margin, the temporary ITS project for I-496 is justified using the benefit/costs analysis.

Summary

In this chapter, the benefits and costs have been estimated and monetized for the temporary ITS system proposed for managing construction zone traffic on MDOT’s I-496 reconstruction project. The TCRTDM was used as the basis for many of the calculations. The estimates rely on both empirical data and the results of simulations regarding ITS benefits found in the previous studies. Where insufficient data was available, the author made assumptions regarding the potential benefits of the temporary ITS system for the I-496 project.

Comparing the benefits and costs, the project, generally speaking, is a favorable one. From the user perspective, there are no costs, so the presence of any benefits results in a positive outcome. In this case, the net benefit is estimated to be $6,574,000. From the agency perspective, the analysis reports no benefits. However, this is due to the lack of reliable information on which to base computations. It is predicted, for example, that customer satisfaction benefits will be realized by the agency. Therefore, despite the net cost of $2,500,000 reported in the analysis, some qualitative benefits should also be considered. From the community perspective, energy and environmental benefits outweigh the opportunity cost of not having another cost comparable transportation improvement by approximately thirty percent. Combining all three perspectives, the benefit/cost ratio is nearly two to one with net benefits of $4,874,000. Based on the analysis, the expenditure of public funds on the temporary ITS project for the I-496 reconstruction can be justified.

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The Michigan Department of Transportation is about to embark on the application of ITS technology for temporary CZTM for the first time in it's history. This specific application of ITS will be used to help manage traffic flows as a result of the reconstruction of the I-496 corridor through the central business district of Lansing. Successful management of traffic is essential, since the urban area of Lansing serves as the seat of state government as well as an industrial, educational and tourist center.

MDOT has experience using permanent ITS installations in the metropolitan Detroit area, and the department is encouraged by the prospects for expanding applications to other situations, such as the temporary application being considered for the I-496 project. But, as a government agency, MDOT is accountable to the public for ensuring that it uses tax-payer funds in cost-effective ways. Therefore, some sort of economic analysis must be completed to assist in the decision making process for the agency. The purpose of this study was to evaluate whether or not the costs associated with the temporary application of ITS technology by MDOT for their proposed highway reconstruction project for I-496 in Lansing, Michigan can be economically justified.

The author found that little research has been conducted on temporary ITS applications. However, previous studies have determined that benefit/cost analysis is an appropriate evaluation technique for ITS projects in general. Gillen, Li, Dahlgren, & Chang (1999), Zavergiu (1996), Brand (1993 & 1998), Li, Gillen, and Dahlgren (1999), Stamatiadis, Gartner, Winn and Bond (1998), and Ran, Lee, and Dong (1997) all arrived at this conclusion. But Turner, Stockton, James, Rother, and Walton (1998) cautioned against reliance on benefit/cost analysis, as many good ITS projects might be dismissed based on faulty economic analysis as a result of incomplete data or poor modeling and analysis techniques. The author of this study accepted the argument that benefit/cost analysis is an acceptable mechanism for conducting an economic analysis for ITS projects.

The field of ITS research has defined specific evaluation frameworks and categories of benefits based on generally accepted goals of transportation systems, such as safety, mobility, efficiency, productivity, environmental impacts, and customer satisfaction. One specific framework proposed by Gillen, Li, Dahlgren, & Chang (1999) was accepted by the author to be used as the basis for the analysis contained herein (see Figure 1). This framework sorts the various benefit categories among three primary recipients, the users of the system, the implementing agency, and the surrounding community. This framework closely follows the general principles of benefit/cost analysis outlined by Rossi &

Freeman (1993), which the author of this study recognized as an important feature of the framework.

Still, other frameworks and benefit data categories have been proposed in the literature (Zavergiu, 1996), (Tarry & Faber, 1996), (Brand, 1993 & 1998), and (Eisele, Lomax & Vadali, 2000). The proposals range from inclusion of private sector and supplier accounting perspectives to new benefit categories such as impacts on land use, mode choice, public-private relationships and other more abstract concepts. While the author conceded that these factors should generally be considered, for this specific project they were not included. Due to the lack of reliable data for estimating such benefits, many of the factors are simply impractical to consider here. Furthermore, many of these benefits are of the sort that would only be realized over extended periods of time. Since the project under consideration in this study is temporary, with a duration of less than one calendar year, these benefits were disregarded.

Ruthi (1995) also expounded on the lack of reliable data and good modeling tools. The author of this study, based on his research of the literature, concurs with this claim, and considered this as a limitation to this study. Nevertheless, a sufficient number of reliable data values were discovered that made a general benefit/costs analysis still feasible for this project. In some cases, however, the author made assumptions or simply had to omit potential benefits, due to the lack of acceptable data.

One specific area of data deficiency is the body of information on how users value their time and the information they receive from ITS applications (Gillen, Li, Dahlgren, & Chang, 1999), (Ruthi, 1995), (Little, Liu, Rosenberg, Skinner, & Vance, 1993), and (Brand, 1998). This information is best gathered using revealed or stated preference surveys. While MDOT conducted a survey in the fall of 2000, it was not detailed enough to provide this information which is critical to dynamic behavior modeling and estimation of customer satisfaction benefits. The author of this study agrees that more data collection needs to be done along these lines.

Given all this, the author proceeded to outline a methodology which essentially followed the framework from Gillen, Li, Dahlgren and Chang (1999). Benefits and costs were then computed and evaluated using both empirical data and the results of model simulations found in the literature. Benefits and costs were arranged and summed from the perspectives of the user, the agency, and the community at large, as well as a combination of all three of these perspectives. Benefit/cost ratios and net benefits were then computed for each perspective and for the combination of perspectives.

The analysis of the data indicated generally positive results. For the user perspective, the benefit/cost ratio was reported as “infinite”, since there were no costs to assign to the users, and the denominator of the ratio is zero. For the agency perspective, due to the inability to estimate some benefit types, no benefits were reported, causing a benefit/cost ratio of zero. For the community perspective, the benefits of energy savings and environmental improvements outweighed the opportunity cost of implementing ITS. Using the combination of perspectives, the total benefit/cost ratio is almost two to one, with net benefits of nearly $5,000,000.

Conclusions

Based on the analysis in this report, the author concludes that the temporary ITS project for construction zone traffic management on I-496 is justified. Generally, the benefits of the ITS system outweigh the costs, regardless of the perspective of the analysis. The one exception to this is the agency perspective. In this case, no benefits were allocated to the agency. This is due to the lack of reliable data upon which to base estimates. However, it is expected that, as a result of the ITS system, the agency will accrue benefits, especially in terms of customer satisfaction. Despite the lack of some benefit data, the analysis of the combination of perspectives indicates a benefit/cost ratio of approximately two to one, with net benefits of nearly $5,000,000. Therefore, investment in the ITS project can be justified.

The author of this paper agrees with the contention raised by Turner, Stockton, James, Rother, and Walton (1998) that, due to the difficulty in estimation, many benefits are going to be overlooked. The implications of this became apparent in the computations for the agency perspective, as noted above. If MDOT was strictly limited to this accounting perspective, decision makers would be faced with an economic analysis that appears very dismal. Presumably, economic justifications will continue to be the norm in this era of increased governmental accountability for public expenditures. Therefore, abandonment of benefit/cost analyses or other cost based evaluations is not an option. Researchers in the future must simply address the limitations of this technique for ITS applications and attempt to interject qualitative measures in the discussion of the results of quantitative analysis.

The author also agrees with the ideas presented by Zavergiu (1996), Tarry & Faber (1996), Brand (1993), and Eisele, Lomax & Vadali (2000). Many other types of benefits can and should be considered when performing benefit/cost analyses for ITS projects. However, careful consideration must be made when evaluating temporary installations such as the I-496 project, as some ITS benefits may only accrue over extended periods of time, and therefore the benefits would not materialize for short term applications. Perhaps if more types of benefits were considered in this study, the zero values for benefits and costs for the agency and user accounting perspectives would not have occurred.

In particular, data is lacking regarding customer satisfaction and customer valuation of travel time and the information received from ITS. The author agrees with Gillen, Li, Dahlgren, & Chang (1999), Ruthi (1995), Little, Liu, Rosenberg, Skinner, & Vance (1993), and Brand (1998) that more needs to be done to collect information using revealed and stated preference surveys to determine the benefits associated with customer perceptions. The author further believes that the I-496 project presents a good opportunity to collect this data, since users will have before and after perceptions which can be measured to note the impact ITS has on their valuation of time and information.

Still, as Ruthi (1995) remarks, the lack of comprehensive data and dynamic behavioral modeling tools to perform the analyses will remain as obstacles to thorough benefit/cost analysis. To be practical, decision makers will need easy-to-use tools to perform economic analyses that incorporate the many other potential benefit factors. In the absence of such tools, many potentially viable ITS projects might be cast aside based on incomplete economic evaluation.

Recommendations

Based on the favorable results of the benefit/cost analysis, the author puts forward the following recommendations.

1) The author recommends implementation of the temporary ITS system for Construction Zone Traffic Management for the I-496 reconstruction in Lansing, Michigan. The project is justified based on the benefits expected relative to the costs of the proposed ITS applications by a factor of two to one.

2) The author recommends further traffic data collection of the Lansing urban area transportation network before and during the operation of the temporary ITS system. This will allow the MDOT to measure actual benefits and verify the assumptions of this study. Information measuring traffic diversion, accident rates and user delay should be gathered. This data collection effort will not only benefit the analysis of the I-496 project; it will also aid in the accumulation of new information regarding ITS, thus furthering the collective research effort in the field of ITS technology. As potential ITS applications surface in the future, having complete, reliable data will be critical to the evaluation of future projects.

3) The author recommends that MDOT conduct additional public opinion surveys to gather more specific data on customer satisfaction regarding ITS. The survey should include questions that allow researchers to establish what value

people put on the information they receive from the ITS system. Such information would significantly add to the field of ITS research.

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