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Literature Review Report on Benefit/Cost Studies and Evaluations of Transit Management Systems

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**California PATH Working Paper
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EDAPTS

Smart Transit System



Task 1 Deliverable

Literature Review Report on Benefit/Cost Studies and Evaluations of Transit Management Systems

Task Order 6401 Benefit/Cost Evaluation

Prepared for
California Partners for Advanced Transit and Highways
California Department of Transportation

Prepared by
California Polytechnic State University, San Luis Obispo
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1. INTRODUCTION

This study addresses the benefits and costs of Advanced Public Transportation Systems (APTS) applications in small and medium sized transit agencies using the research test implementation of a small transit oriented Intelligent Transportation System (ITS) on San Luis Obispo Transit as a case study. The Smart Transit System at San Luis Obispo is in a pre-commercialized state and implements the Efficient Development of Advanced Public Transportation Systems (EDAPTS) framework concept (Gerfen, 2001). The system has many potential benefits that will be identified and evaluated from a cost of service standpoint. The supporting hypothesis of this research is that small transit properties will be encouraged to deploy the EDAPTS ITS framework concept if the San Luis Obispo Smart Transit System can be shown to have a viable benefit-cost ratio.

In order to deploy ITS applications, transit properties typically look for benefits and costs information about the services they are considering as well as documented lessons learned from the experiences of others. To be most effective, these inputs should be supplemented with information that describes the context from which the data were derived.

Since the implementation of this EDAPTS Smart Transit System in 2001, only limited data analysis has been undertaken to evaluate the benefits of the system to riders, operators and the Cal Poly SLO community. A complete benefit-cost analysis is needed to provide small or medium sized transit properties with the economic justification of the EDAPTS framework deployment.

This paper documents the literature review undertaken to summarize past work on evaluation of similar APTS applications and to identify and assess the analytic methods and tools available for the complete benefit-cost evaluation of SLO Transit Smart Transit System.

2. PRINCIPAL FINDINGS FROM THE LITERATURE REVIEW

Advanced Public Transportation Systems have been increasingly developed and deployed in transit properties as a means of a) increasing the efficiency and safety of transit services, b) offering users easy access to real-time information about transit operations, and c) providing reliable customer services. In order to understand the economic justification of APTS applications, researchers have conducted a number of benefit-cost studies to assess the use of APTS technologies in transit properties (Gomez, Zhao, and Shen, 1998; Wallace, 1999; Furth and Muller, 2000; Lehtonen and Kulmala, 2002; Gillen et al 2002; Gillen and Sullivan, 2002; Daigle and Zimmerman, 2003; Peng, Zhu and Beimborn, 2005).

Our literature search found that there have been two types of research efforts relevant to APTS benefit-cost evaluation. One type of effort is centered on identifying the specific benefits and costs associated with the implementation of APTS systems as well as frameworks for evaluating these benefits and costs. The benefits and costs are normally grouped into the six categories: Safety, Mobility, Productivity, Efficiency, Energy and Environment, and User Satisfaction. The other type of effort is aimed at developing appropriate methodologies for measuring benefits and costs that are not easily quantified.

In a typical benefit-cost evaluation study, costs are usually straight forward and are more easily identified and measured while benefits are much more difficult to identify and quantify. In considering the above nature of benefit-cost evaluations, this literature review emphasized the search not only for tools and procedures to identify benefits and costs but also for methodologies that would have potential in the economic assessment of the SLO Smart Transit System.

2.1 Review of APTS Evaluation Frameworks and Applications

Economic justification and a positive return on investment are critical to the successful deployment of APTS technologies in transit properties, and especially in the small transit environment. As the economic justification often involves the evaluation of benefits and costs associated with a specific suite of APTS applications, the US Department of Transportation (DOT) has for more than a decade been actively collecting information regarding the impact of APTS implementations. Researchers also have conducted a number of benefit-cost assessment studies on APTS applications for various transportation agencies throughout the nation (FHWA, 2003; FHWA, 2005).

APTS Benefit-Cost Database

In helping justify the deployment of Intelligent Transportation Systems (ITS) applications, the ITS Joint Program Office (JPO) of the US Department of Transportation sponsored the development of the ITS Benefits and Costs Database. The databases are located at <http://www.benefitcost.its.dot.gov> and are available to the public. The databases contain the most recent data collected by the JPO and are a central repository of existing knowledge of ITS benefits and costs for transportation professionals. The databases also provide the research community with information on ITS areas where further analysis may be required. The Benefits and Costs databases website contains detailed summaries of each of the ITS evaluation reports reviewed by the JPO. In order to be reviewed, an evaluation report had to meet several acceptance criteria (see Mitretek Systems, 2000). Summaries on the web pages provide additional background on the context of the evaluations, the evaluation methodologies used and links to the source documentation.

Caltrans Guide to Benefit/Cost Analysis

In order to assist practitioners in the correct conduct of benefit-cost analysis for transportation investments, including ITS projects, the Caltrans Division of Transportation Planning, Office of Transportation Economics, recently published an on-line guide to concepts and methods in this area. The guide is located at http://www.dot.ca.gov/hq/tpp/offices/ote/Benefit_Cost/. In addition to providing useful information on the conduct of these analyses in general, the guide also provides descriptions and links to modeling software created for a range of benefit-cost applications, including software specifically designed for ITS evaluations.

Specific Benefit/Cost Applications

In their benefit-cost studies, many investigators have related the use of APTS technologies to improvements in transit operational services and found that APTS technologies can be beneficial to transit properties with large fleets; often the evaluations reveal favorable benefits for APTS deployments. There were few benefit-cost analyses of APTS applications in small or medium sized transit properties. The few publications in existence acknowledge the difficulty of measuring particular benefits of AVL systems. Some of these researchers are:

Gomez, Zhao, and Shen evaluated the benefits of transit Automatic Vehicle Location (AVL) systems and their implementation in the U.S (Gomez, Zhao, and Shen, 1998). They concluded that AVL applications in public transit systems have many benefits to transit agencies and riders, including improving on-time performance, raising productivity, enhancing security and increasing ridership. AVL can provide real-time information about bus locations, running speed and other information. Transit dispatchers could use real-time information for bus scheduling and transit planners can use real-time information for adjusting transit routes and stops. Transit users can benefit from improved on-time performance and schedule reliability, as well as real-time information to reduce waiting time and anxiety. Their research showed that transit riders are extremely sensitive to schedule reliability and the improved arrival-time reliability arising from the use of AVL could potentially increase transit ridership and improve service satisfaction.

Wallace, Richard R. et al assessed the impact of several transit safety and security enhancements based on a 1998 survey of transit riders in Ann Arbor, Michigan (Wallace, 1999). The safety and security enhancements evaluated included on-board video surveillance, emergency phones, video cameras at transit centers, enhanced lighting at transfer centers and increased police presence. Surveys were taken of riders on randomly selected routes at random times during weekday service.

They found that camera systems were the safety enhancement most often noticed by respondents. When respondents rated the degree to which improvements increased their sense of security, police presence showed the greatest influence, followed closely by increased lighting. Emergency phones and video cameras had smaller impacts.

Furth and Muller measured the effectiveness of a transit signal priority system installed in the city of Eindhoven (population 300,000), the Netherlands (Furth and Muller, 2000). The signal priority system was installed in all local transit vehicles. The adherence of the vehicle to its optimal schedule was monitored. “Early” or “late” status was communicated to the vehicle operator. Video cameras were mounted on utility poles at the busiest intersection in order to measure the impacts of the signal priority system on overall traffic delay. Also buses were equipped with onboard computers and wireless communications to track schedule adherence.

The effectiveness of the transit priority system was determined by measuring the difference in the deviation of individual vehicles from their schedule as they passed through a signalized intersection when the system was in use as compared to when the system was not in use. Performance data on schedule deviation, run times, and delay were downloaded from the computer to evaluate schedule adherence and bus delay.

This research showed that vehicular delays for traffic under conditional priority (or the priority to a bus running behind schedule) were about the same as those for traffic with no bus priority. The absolute priority (or the priority to provide a green phase to each bus regardless of whether or not it was running ahead of schedule) caused large increases in delay. This research also found a strong improvement in schedule deviation during periods with conditional priority compared to periods with no priority.

Lehtonen and Kulmala evaluated a pilot project designed to provide real-time passenger information and signal priority to tram and bus lines in the City of Helsinki, Finland (Lehtonen and Kulmala, 2002). Automated Vehicle Location (AVL) and Computer Assisted Dispatch (CAD) systems were installed in a pilot project. Their study showed that the system had positive effects on the level-of-service for tram and bus services. Based on a cross-section of test ride observations, in-vehicle studies and ticket sales information; the pilot project showed an increase in on-time performance and ridership, a reduction of travel time, fuel consumption and mobile emission and improvements in user satisfaction.

Gillen and Sullivan conducted an evaluation of the EDAPTS impacts on riders and services provided by San Luis Obispo Transit (Gillen and Sullivan, 2002). They evaluated bus operations prior to and after the deployment of the EDAPTS technologies and conducted surveys of riders. Using limited operational data they were able to identify a set of positive system benefits to the transit operator, employees, riders and to the community at large.

Daigle and Zimmerman did a Field Operational Test (FOT) on the deployment of ITS traveler information on shuttle buses at the Acadia National Park in Maine (Daigle and Zimmerman, 2003). ITS technologies evaluated included Automated Vehicle Location (AVL), real time electronic arrival signs, automated in-vehicle annunciation systems, automated in-vehicle passenger counting systems, and website and telephone traveler information services. These technologies were deployed as a way to disseminate more accurate and timely information to more than two million park visitors each year. The primary goal of the study was to measure the impact of ITS on the "quality of visitors' experience" in terms of customer satisfaction and mobility. Visitors were asked about their awareness, use and experience with ITS in the park.

The findings from their study were that ITS helped the free shuttle bus service, Island Explorer, improve shuttle bus operations, reduce parking lot congestion and improve aesthetics and safety by decreasing the number of vehicles parked alongside roads. It also enhanced the growing tourist economy through improved mobility.

Peng, Zhu and Beimborn investigated the use of AVL systems to enhance transit performance, management and customer services in two medium sized transit agencies (Peng, Zhu and Beimborn, 2005). This investigation was based on surveys conducted in Racine and Waukesha, Wisconsin before and after AVL implementation and in Manitowoc, Wisconsin, a small city without AVL. This research found that features like improving on-time performance, knowing when the bus will arrive, knowing that another bus will be dispatched in case of breakdown were valued as important to transit users. This research also observed that transit system with AVL have improved schedule adherence and on-time performance. The researchers concluded that more passenger trips (i.e. increased ridership) would be realized if better information were offered to users.

The evaluation studies described here included large, medium and small transit properties. They all showed that APTS applications provided a set of benefits including the improvement of on-time performance, the reduction of users' wait time and anxiety and the improvement of user satisfaction. However, these studies did not place their focus on the comparison of benefits to costs for APTS applications, as is generally recommended in the accepted benefit-cost analysis guidelines. Few studies measured benefits and costs in dollars and calculated benefit-cost ratios for APTS applications.

Our review of the previous APTS evaluation studies reveals that the challenges of economic evaluation of APTS applications are likely due to the lack of effective methods for placing dollar values on benefits that are not easily quantified. Quantifying benefits in dollar values requires creative assumptions and Stated Preference surveys.

2.2 Review of APTS Evaluation Methods

There are a few evaluation methods and tools that show high potential for dollar-quantified assessment of APTS applications. These methods and tools are grouped in this report into two categories: Conventional Methods and Market Study Methods.

Conventional Methods

The ITS Deployment Analysis System (IDAS) is a widely used method developed by the Federal Highway Administration (FHWA) that can be used in planning for Intelligent Transportation System (ITS) deployments. This method estimates the benefits and costs of ITS investments, including APTS applications. It can work with outputs of existing transportation planning models, compare and screen ITS deployment alternatives and estimate the impacts and traveler responses to ITS.

The IDAS method provides a set of default values for benefits and costs. These default values are the initial inputs for evaluating travel time, fuel consumption and other impacts in dollar values, making the IDAS method an effective tool for benefit-cost evaluation of ITS applications but it has limitations when used for APTS applications. A test conducted by the Chicago Area Transportation Study (CATS) in 2003 showed that IDAS uses reasonable analysis methodologies to model ITS deployments on the highway network. It therefore models highway deployments well. However, since it does not perform transit network assignments it only deals with benefits and costs of transit services at an aggregate (zonal) level. Also, a substantial level of effort required to develop all the necessary data inputs to IDAS. Consequently, although some of the IDAS default values will probably prove useful, it seems that making direct use of the IDAS model is not appropriate for the present study.

Market Study Methods

Market study method offers potential for effective evaluation of APTS applications. Two approaches described here are hedonic pricing models and contingent valuation methods. Hedonic pricing models measure imputed values in the revealed preferences of consumers. Contingent valuation methods measure Stated Preferences of consumers. In general, these two types of market study methods use information based on people's behavior, to measure their willingness to pay (WTP) when faced with situations of choice.

a) Hedonic Pricing Models

Hedonic price models are considered a potential tool for measuring benefits associated with EDAPTS because, as Williams (1991) asserts, "it can be used as a means to value indirectly non-market effects" and many of the benefits of the Smart Transit System are envisioned to be

indirect and not readily measurable. Hedonic pricing models are based on the concept that goods comprise bundles of attributes that combine to form objectively measurable characteristics or utility-affecting attributes that consumers value (Leong and Chau, 2002). For instance, in the real estate market, where much of the literature on hedonic models is published, the method uses information on people's choices to estimate their WTP for attributes related to housing location, structure or amenities and neighborhood (Diamond, 1980; Shaw, 1994; Leong and Chau, 2002). It is discernible that these attributes are both quantitative and qualitative. Even studies that specifically deal with transportation themes largely relate them to real estate location choice (Rosen, 1974; Dewees, 1976; Williams, 1991; Voith, 1991, 1993; Landis, Guhathakurta, William and Zhang 1995; Armstrong 1995; Cervero and Duncan, 2002; Heckman, 2003; Kawamura and Mahajan, 2005; Armstrong and Rodríguez, 2006). The primary effect of location choice is measured by accessibility to goods, services, activities and so on. A hedonic model allows one to infer from the model the marginal average willingness to pay for a unit of increased accessibility. Quantifying willingness to pay then becomes the basis for determining the benefit of increased accessibility or other benefits. In general the hedonic model may be stated as follows:

The market price (P) of a property can be expressed as a function (f) of housing location (L) as measured by accessibility, structure or amenities (S), and neighborhood (N):

$$P = f(L, S, N)$$

The partial derivative of this hedonic function with respect to any of the attributes, all else equal, is the implicit marginal attribute price (or benefit) of the particular attribute (Rosen, 1974). The functional relationship investigated is of the general form:

$$Y_i = \alpha + \beta X_i + \varepsilon_i$$

Where:

Y_i is a measure of market value of the i^{th} property;

α is the intercept term standing for the effect of excluded variables on the value of the property;

β is a vector with the estimated implicit marginal price for each attribute k ; X_i is a vector of measures of k property attributes; and

ε_i denotes stochastic error terms

b) Contingent Valuation Methods

Studies of existing markets are limited because only choices made by consumers can be used to infer the values of the attributes of goods. Stated Preference surveys can apply contingent valuation or ranking of attributes to estimate the benefits of actions or policies that place people beyond the range of their choice making experience (Louviere et al, 1981, 1986; Steer 1983; Kroes, 1990). For instance, transit riders may be asked to value or rank features of the Smart Transit System (or APTS features in general).

In their book on using surveys and Contingent Valuation to value public goods, Mitchell and Carson (1989) express the following:

“Economists and others have long believed that by balancing the costs of such public goods as air quality and wilderness areas against their benefits, informed policy choices can be made. But the problem of putting a dollar value on cleaner air or water and other goods not sold in the marketplace has been a major stumbling block. The authors argue that at this time the contingent valuation (CV) method offers the most promising approach for determining public willingness to pay for many public goods---an approach likely to succeed, if used carefully, where other methods may fail. Placing contingent valuation in the larger context of welfare theory, the authors examine how the CV method impels a deeper understanding of willingness-to-pay versus willingness-to-accept compensation measures, the possibility of existence values for public goods, the role of uncertainty in benefit valuation, and the question of whether a consumer goods market or a political goods market (referenda) should be emulated.”

Consider the following survey question that asks for the willingness to pay for a private good (adapted from Johannesson, Johansson, and O'Conor, 1996). Contingent valuation may be illustrated as follows:

“In the U.S., about 1 in 5000 people dies annually in traffic. A possible measure to reduce the traffic risk is to equip cars with safety equipment, such as airbags. Imagine a new type of safety equipment. If this equipment is installed in your car, the risk of dying in a traffic accident will be cut in half for you and everyone else traveling in the car. This safety equipment must be tested and serviced each year to make sure that it is working correctly. Would you choose to install this safety equipment in your car if it will cost you \$A per year?

[YES or NO]

Where \$A might take on values of \$30, \$150, \$300, \$750, \$1500, or \$3000 for each survey respondent.”

A similar question which asks for the willingness to pay for a public policy might read (again, adapted from Johannesson, et al.):

"In the U.S., about 1 in 5000 people dies annually in traffic. The number of deaths can be reduced if we devote more resources to preventing traffic accidents. We can, for example, straighten out turns, build safer crossings, and increase the supervision of traffic. Imagine a program that cuts in half the risk of your and everyone else's risk of dying in a traffic accident. Are you willing to pay \$A per year more in taxes on your car for this program?

[YES or NO]"

With both questions, the value of a statistical life is equal to the average willingness to pay divided by the reduced risk of death (dR). In this case (as is generally the case), the reduced risk of death is equal to the number of lives saved divided by the affected population). If the average WTP = \$500 and dR = .0001 (1 in 10,000), then the "benefit" or value of (a saved) statistical life (VSL) = $500/.0001 = \$5$ million.

In measuring the benefits of the Smart Transit System, Revealed Preference methods could be applicable if riders were observed to make travel-related financial decisions based on the features it provides. The readily observable factor in the Smart Transit System experiment would relate to frequency or level of rides taken. Conceptually, increases in rides, if attributable to the features of the system, would be adjudged benefits and could be indirectly assigned monetary values. However, due to the fixed nature of fares and other aspects of the experiment at hand as well as data unavailability, the usefulness of Revealed Preference methods, like hedonic modeling, is limited, and this study is more likely to benefit from the application of Stated Preference methods, using contingent valuation. In the latter case, riders may be surveyed about

- (a) The features that they would like to have (i.e. YES or NO) and
- (b) How much they might be willing to pay to have the features.

Nevertheless, as the study progresses, both revealed and stated preference methods of valuation will continue to be examined for potential application to appropriate circumstances.

3. CONCLUSIONS

This literature report summarizes the evaluation studies that were conducted to measure the benefit and costs of APTS applications. Also this report investigates hedonic pricing models and contingent valuation methods that could be useful in the economic assessment of the San Luis Obispo Smart Transit System. It is found from this literature review that very few APTS evaluation studies measured benefits and costs in dollars. This could be due to the lack of effective methods for placing dollar values on benefits that are not easily quantified. Quantifying benefits in dollar values requires creative assumptions and Stated Preference

surveys. This review found that contingent valuation methods, as compared to hedonic pricing methods, show their high potential in quantifying the benefits of the Smart Transit System.

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