October 2000

Benefit-Cost Evaluation of ITS Projects:

Benefit-Cost Summary

Prepared for the FHWA/FTA Joint Program Office, US DOT

Abstract: Over 60 individual ITS projects were defined in four "model" cities for purposes of conducting benefit-cost evaluations of deployments under the USDOT's Metropolitan Model Deployment Initiative (MMDI). The federal government provided funds for deployment, and in return requested participation in the evaluation of the projects. Benefit-cost was one of several approaches to evaluation, the others including customer satisfaction, safety, efficiency and throughput, institutional benefits, and integration of ITS components.

Keywords: benefit-cost, ITS, MMDI

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ITS Components:	Traveler Information Electronic Toll Collection Electronic Fare Payment Emergency Systems Management Incident Management Railroad Grade Crossing Safety Transit Management Traffic Signal Control Freeway Management
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Summary

Project Descriptions

Some 65 individual ITS projects were defined for purposes of benefit-cost evaluation across the four MMDI sites: New York, Phoenix, San Antonio, and Seattle. Not all of the projects selected for benefit-cost evaluation received funding from the MMDI program, and several were unrelated to the MMDI.

These projects spanned all of the nine ITS "components," although almost half were in the single category of traveler information. The benefit-cost task sought to ensure that all categories were represented, and to conduct at least one in-depth study in every component category, but most of these studies are still incomplete in terms of measurable deployment and adequate data.

Evaluation Results

Benefit-cost analysis is project-oriented, and summarization of a program (ITS, in this case) cannot be anything more than a summary of all the projects that make up the program. Moreover, generalizations about subcategories (e.g., traffic signal coordination) are inevitably both yes and no; it depends upon the specific case. Some of the specific cases are included as appendices to this report. Some conclusions that can be offered from this study are:

(1) All of the technologies appear to have conditions under which they can generate net benefits. Even when the benefits per vehicle or per user are small, large volumes of usage can make the costs look quite reasonable.

(2) The data with which to conduct benefit-cost evaluations of these projects are lacking. Some data were collected specifically for the MMDI, and large amounts of data are routinely collected by automatic detectors and the like, but little of it has applicability to benefit-cost, at least in its present form.

(3) Some of the projects were not implemented within the time frame for evaluation, or were implemented on a small scale. Some attrition is both inevitable and healthy, but it is desirable to weed out weak projects as early as possible.

(4) The concepts of benefit-cost evaluation are not well understood among ITS planners, and the potentially useful application of *prospective* evaluation (conducting benefit-cost *before* deployment) is rarely considered.

(5) There does not appears to be any systematic or rational process for evaluating ITS projects or for distinguishing good projects from weak ones, either before implementation or after.

A brief summary report follows, providing a limited number of generalizations about the intent and strategy of the benefit-cost study, and is in turn followed by a series of 12 individual project reports. Each project report provides a description of the project, an analytic framework for evaluation, and often a spreadsheet analytic tool for projects of the particular type.

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Acronyms used in this report:

Acronym	Full Name
AADT	annual average daily traffic volume
BCR	benefit-cost ratio
CMS	changeable message sign
MMDI	metropolitan model deployment initiative
TOC	traffic operations center
VMT	vehicle miles of travel

Project Descriptions

Benefit-cost analysis is applied to decisions or actions, whose consequences are distinguished from what would have happened without the actions. For each evaluation, then, benefit-cost requires a "base case" or counterfactual representing the state of the world at each point in time after the actions were or are taken, a "project" representing the actions, and measurements that allow for the estimation of the differences between the two states of the world. For retrospective evaluations—the present purpose—the base case is entirely hypothetical because the project has been implemented, so the state of the world without the project is unobservable. Whether the evaluation is retrospective or prospective, the future states of the world with and without the project must always be estimated.

Definitions of Projects for Benefit-Cost

To qualify as a "project" for benefit-cost evaluation, an ITS deployment should consist of a set of actions having the following characteristics:

(1) the actions are intended to have an impact on travelers and the transportation system;

(2) the expected impacts are relatively direct;

(3) the project is "complete" in that all the mechanisms for causing impacts are included in the project; and

(4) the project is self-contained, in that the impacts can be plausibly separated—at least analytically—from the impacts of other projects or actions.

These criteria are aimed at avoiding several pitfalls. If the results of the evaluation are to be of use to other cities considering implementation, then all of the costs required to reach a set of benefits should be included. For an evaluation to look only at "incremental" costs (meaning partial costs, in this context), but count all of the incremental benefits (which hadn't previously occurred because the project wasn't complete) would be misleading. Carried to extreme, the only cost would be turning on the switch.

Consequently, projects defined for benefit-cost evaluation tended to encompass the whole system, or a major generational upgrade to a system that resulted in a qualitative change in the amount of information available. Usually this meant something larger than the scope of the MMDI projects.

Process

Projects were defined in collaboration with the local evaluation team, consisting of agency personnel, consultants, and planners. These discussions took place initially on-site, and refinements were made subsequently via site visits, quarterly workshops, and teleconferences.

The final list did not change a great deal from the initial list. Some projects were defined solely for purposes of demonstrating "integration," and these quickly fell by the wayside. Others stemmed from the locals' tendency to think of a facility—an operations center, an information network, a server—as a project, which is a reasonable orientation for purposes of accomplishing the deployment, but not useful for benefit-cost. Both of these types of projects have been deleted from the list of projects below.

Because the benefit-cost evaluation was sponsored by the MMDI program, there was a natural expectation that the evaluation would focus on MMDI expenditures and benefits associated with them. This might have been suitable if the subject of evaluation were the MMDI program, but the orientation of the benefit-cost task was on ITS, rather than the MMDI "vehicle." Thus not only were projects defined to include previously installed components not funded by the MMDI, but several projects were included, in the interests of breadth, that were unrelated to MMDI.

List of Projects

An individual summary of each of the projects is given in Table 1. Projects are grouped according to ITS component, and within component by city. Status indicates the deployment status as of approximately the end of the MMDI evaluation period, or the end of calendar year 1999. Comments provide information on which individual project reports are applicable to the technology or component, in those cases where the project does not have its own report. Projects selected for prototype evaluations, with their own reports, are highlighted. In most cases, if an analytic tool was developed for the prototype project, it is applicable to the candidate project if the relevant data are collected. For example, the traveler information spreadsheet model can be used for kiosks, web sites, in-vehicle navigation devices, cable TV, or any of the other traveler information services that can be widely disseminated. Narrowly focused information services, such as variable message signs, may be better modeled using the freeway management analytic tool.

Table 1: MMDI projects for benefit-cost evaluation

Project Number	Project Name	ITS Component	Status	Comments
NY-1	Personalized Traveler Information	ATIS	not deployed within evaluation time frame	similar to SE26
NY-2	Multimodal Call-in Traveler Information	ATIS	not deployed within evaluation time frame	similar to SE26
NY-3	Multimodal Traveler Web Site	ATIS	not deployed within evaluation time frame	similar to SE26
NY-4	Transit Trip Planner Web Site	ATIS	not deployed within evaluation time frame	similar to SE26
NY-5	Call-in Transit Trip Planner	ATIS	not deployed within evaluation time frame	similar to SE26

Table 1: MMDI projects for benefit-cost evaluation

Project Number	Project Name	ITS Component	Status	Comments
NY-6	Transcom “Satin” Kiosks	ATIS	not deployed within evaluation time frame	similar to SE26
PH-9	Cable TV	ATIS	deployed; CS report	similar to SE26
PH-10	Kiosks	ATIS	small scale deployment	similar to SE26
PH-11	In-Vehicle Navigator	ATIS	cancelled	similar to SE26
PH-12	Fastline PCD	ATIS	deployed; small market	similar to SE26
PH-13	Personalized Pager	ATIS	not deployed or small scale	similar to SE26
PH-14	Web Page	ATIS	AZTech web page deployed	similar to SE26
PH-15	Transit Status Information	ATIS	small scale deployment?	similar to SE26
PH-18	Highway Closure System (HCRS)	ATIS	page on web site	similar to SE26
SA-5	**AWARD RR Grade Crossing Info**	**ATIS**	**deployed; rarely used**	**see project report**
SA-6	Kiosks	ATIS	some deployment, but kiosks not functional	similar to SE26
SA-8	Web Page	ATIS	deployed; low level of usage	similar to SE26
SE-17	MS “Traffic View” Web Site	ATIS	cancelled	similar to SE26
SE-18	ETAK/Metro Networks/Seiko Personalized Traveler Information	ATIS	deployed; low level of usage	similar to SE26
SE-19	Fastline Handheld Personal Computer (PCD)	ATIS	service offered, but little demand	similar to SE26
SE-20	Cable TV Traffic Channel	ATIS	deployed	similar to SE26
SE-21	Washington Information Network (WIN) Kiosks	ATIS	cancelled	similar to SE26
SE-22	Seattle Center Advanced Parking Information System	ATIS	not deployed within evaluation time frame	similar to SE26?
SE-23	King County Web Page	ATIS	deployed, well used	similar to SE26
SE-24	King County Transit Center Displays	ATIS	deployed, well received	similar to SE26
SE-25	Washington State Ferry Service Web Site	ATIS	not deployed within evaluation time frame	similar to SE26
SE-26	**Enhanced WSDOT FLOW Map Web Site**	**ATIS**	**deployed, successful**	**see project report**
SE-27	Traffic Hotline Phone	ATIS	deployed, low usage	similar to SE26
SE-28	Metro Transit RiderLink Web Site	ATIS	regional transit information deployed	similar to SE26
NY-7	**NY Thruway EZPass**	**AVI/ETC**	**previously deployed**	**see project report**
NY-9	Transmit AVI probes	AVI	deployed and expanding	see NY7 project report
SA-10	**Traffic Speed Data Sources**	**AVI**	**deployed**	**see project report**
PH-8	**Valley Transit Electronic Fare Payment**	**EFP**	**previously deployed**	**see project report**
SA-3	**Lifelink**	**EMS**	**deployed; little used**	**see project report**
SA-7	In-Vehicle Navigation	EMS	partially deployed in public vehicles	
SE-10	Bartizan Mayday Services	EMS	cancelled	
SE-11	XYPoint Mayday	EMS	cancelled	
SE-14	Emergency Operations Centers	EMS	unknown	

Table 1: MMDI projects for benefit-cost evaluation

Project Number	Project Name	ITS Component	Status	Comments
PH-4	**Accident Investigation**	**IM**	**deployed**	**see project report**
SE-12	Incident Capture and Processing	IM	unknown	
SE-13	Improved Incident Video	IM	unknown	
NY-10	**LIRR Intermodal Control System**	**RRX**	**not deployed within evaluation time frame; awaiting FOT**	**see project report; no quantitative analysis**
PH-5	**AVL Transit Vehicle Dispatch**	**TM**	**deployed**	**see project report**
PH-6	Paratransit AVL	TM	deployed?	similar to PH5
PH-7	AVL Service Vehicle Dispatch	TM	unknown	similar to PH5
SA-4	Bus Incident Management System (BIMS)	TM	not deployed within evaluation time frame	
SA-9	Paratransit IVN	TM	deployed, may not be sustained	similar to PH5
SE-15	King County Metro AVL System	TM	deployed	similar to PH5
SE-16	AVI Bus Signal Priority	TM	not deployed within evaluation time frame	similar to PH5
PH-1	Southern-Baseline Corridor	TS	not deployed within evaluation time frame	similar to PH3
PH-2	Bell Road Corridor	TS	not deployed within evaluation time frame	similar to PH3
PH-3	**Scottsdale/Rural Road Corridor**	**TS**	**deployed; evaluated**	**see project report**
SE-1	North Seattle ATMS	TS	not deployed within evaluation time frame	similar to PH3
SE-2	Eastside ATMS	TS	not deployed within evaluation time frame	similar to PH3
SE-3	Southside ATMS	TS	not deployed within evaluation time frame	similar to PH3
SE-4	Seattle ATMS	TS	not deployed within evaluation time frame	similar to PH3
SE-5	SeaTac ATMS	TS	not deployed within evaluation time frame	
SE-6	Bellevue Traffic Operations Center	TS	not deployed within evaluation time frame	similar to PH3
SE-7	WSDOT Northwest Region Traffic Systems Management Center	TS/FM	not deployed within evaluation time frame	similar to SA2
SE-8	WSDOT Olympic Region TSMC	TS	not deployed within evaluation time frame	similar to PH3
SA-1	**Medical Corridor Traffic Control**	**TS/FM**	**not deployed within evaluation time frame**	**see project report**
SA-2	**Expanded ATMS**	**FM**	**deployed**	**see project report**
SE-9	Regional Video	FM	not deployed within evaluation time frame	

Criteria for Inclusion

Although an evaluation of all projects might have been desirable, time and resource constraints precluded anything on that scale. It not have been acceptable, however, to select only successful projects, or only failed projects, if the results were to have any meaning beyond the selected deployments.

Breadth

With a focus on ITS evaluation rather than the MMDI per se, the objective of the benefit-cost task was to be broadly inclusive, at least to the extent of ensuring at least a few examples in every category of the nine ITS components. Because the initial MMDI RFP featured traveler information, almost half the projects fell in that category. At the other extreme, there were no MMDI-stimulated projects in electronic toll collection or electronic fare payment, and the only project involving a railroad grade crossing consisted purely of traveler information.

Thus the evaluations of the EZPass, the Phoenix credit card, and the LIRR train control system were included entirely at the initiative of the benefit-cost task. Also, most if not all of the transit management projects would have been dropped were it not for the efforts of the benefit-cost task (there still would have been transit traveler information projects). Although these projects were not supported by any significant data collection efforts, some potentially useful analytic tools and evaluation frameworks were developed.

Integration

The MMDI project office placed a great deal of emphasis on something called "integration," which embodied the notion that ITS technology is at a state of development whereby large benefits can be obtained from integrating different ITS components (e.g., freeway management and signal coordination). Because the ITS technologies typically involve communications, integration meant exchange of information collected for one purpose that could fruitfully be used for another as well. This has been referred to as "the whole is greater than the sum of its parts."

The problem with this idea for benefit-cost was two-fold: the actual integrations taking place meeting the above definition were modest in scale, and, more importantly, the data needed to measure integration effects was lacking. With not even enough information to be able to evaluate basic projects, the possibility of measuring the impacts of two or more together—as distinct from the impacts of each one separately—was negligible. Some efforts were made to describe and quantify various types of "integration" benefits, but not as part of the benefit-cost task.

Prototype Projects

An objective of the benefit-cost task was to have as wide a range of projects as possible in terms of their analytic structure. To a large extent, this was accomplished by ensuring breadth across ITS components, but not all cases fit the standard analytic framework for the component. A general traveler information system called for a tool that considered all the possible behavioral choices a traveler might make, but some contexts (VMS, for example) allow for so few options that the broader model is superfluous.

Perhaps it should not be surprising that a lot of the non-ATIS projects often contain some kind of deterministic queuing model within their analytic frameworks. By "deterministic" is meant, in this instance, a queue—a stopped block of traffic—whose characteristics are calculated by analytic formulas and always give the same answer for the same inputs, versus a Monte Carlo simulation in which vehicles behave probabilistically and the state of the queue (e.g., its length) varies within some distributional range, for the same conditions. Delay—whatever the source—often can be modeled as some form of queuing.

All of the analytic tools that were developed utilize a variety of fairly simple algorithms in flexible ways. Those studies that did not proceed so far as to produce an analytic tool still yielded framework that could be implemented quantitatively using algorithms the same as or similar to those that were developed for other projects.

Parameterization

Another essential part of the benefit-cost strategy was to design analytic tools that contained appropriate parameters. "Appropriate" in this case has several interpretations. One, the essential attributes of the deployment (number of VMS, percent who divert) and the environment into which it is placed (traffic volumes, market segments, capacity) needed to be captured in numbers that could reasonably be obtained from data or other studies. Two, the parameters could be varied within realistic ranges to assess the robustness of the quantitative results (delay time from stopping, benefit-cost ratio). Three, the parameterization needed to allow for possible future refinement of the model, if that should prove to be desirable and feasible (results highly sensitive to the parameter, better data become available). Network effects, for example, are accommodated through elasticities.

Results of Evaluation

Without thorough knowledge of the specifics of the deployment, and relying only on its general description and expressed intent, not much can be said about a project's costs and benefits. A few patterns, however, can be commented upon and causes speculated upon.

ITS Components

Traveler Information

Most of the survey research effort under the customer satisfaction task was directed at actual or potential users of the information. In many cases, the level of usage and the refinement of the deployment were such that opinions could be gathered but behavioral impacts on travel choices could not be obtained. The prime exception to this pattern is the Seattle WSDOT Web Site (SE26), for which a regional survey had been conducted prior to MMDI and an MMDI survey was mounted afterward.

Detailed surveys were conducted of viewers of two cable TV channels (Phoenix and Seattle) which were providing highway congestion reports. While there are avid users, market penetration is low. Among ATIS methods, however, the low-tech TV is relatively successful.[1] Several of the web pages are heavily utilized, and Seattle's WSDOT site is among the most popular (see the report for SE26).

Electronic Toll Collection and AVI

ETC is, in many ways, one of the most successful forms of ITS. It is being rapidly adopted by toll facility owners, after initial stimulus provided by USDOT seed money. The technology is not without problems however, notably in the areas of toll plaza configuration, slow speeds in mixed (ETC and manual) traffic, and violators (see the NY7 report on EZPass). The same AVI technology is used for estimating traffic speeds (see the SA10 report on probes).

Electronic Fare Payment

Only one project involving electronic fare payment was designed, some information was obtained for the Phoenix credit card feature implemented prior to MMDI, and a project report was prepared (see report PH8). There seems to be room for beneficial application of this technology to transit fare collection, even in a low-tech form.

Emergency Services Management

Several projects fell into this category. The video communications capability added to ambulances in San Antonio and referred to as "LifeLink" was implemented, and a quantitative evaluation conducted, but most of the parameters could not be confirmed and the system appear to be underutilized (see SA3). Thus the project report should be viewed as a "what if" evaluation. The San Antonio deployment of IVN devices to public emergency vehicles was a mid-course correction after it was found that Texas law required any publicly-purchased devices installed in private vehicles to be subsequently removed. A user survey was conducted of operators of various public vehicles with IVN devices—police, fire, public works, paratransit, etc.—but the results were of limited use for evaluation due to the unplanned nature of the deployment.

Two projects in Seattle—Bartizan and XYPoint mayday services—were intended as commercial follow-ons to a previous FOT, but apparently the market was not considered ready because neither came close to being implemented. These projects involve the installation of devices in vehicles that permit a central station to be contacted in an emergency situation (accident) or for a routine need (lost), and aid obtained. A project for emergency operations centers in Seattle has not been heard from.

Incident Management

A report on the use electronic surveying equipment to conduct incident investigations in Phoenix was prepared and is included here, but no data on the deployment were ever obtained from Phoenix police logs or actual users (see PH4 on Accident Investigations). Although the equipment seems very productive once located on-scene with a

[1] Extended descriptions of the results of these surveys are contained in the site evaluation reports, Zimmerman, et al. and Jensen, et al.

suitably trained crew, the actual level of utilization of the equipment is uncertain. The other two incident management projects in Seattle appear to have been dropped.

An incident model was developed for the benefit-cost task, but its power was not fully taken advantage of for the project analyses presented here, due to the lack of time and resources to sufficiently test it.

Railroad Grade Crossing

The only safety-oriented grade crossing project on the list is a non-MMDI project treating one crossing on the Long Island Railroad. The project is interesting because it involves both vehicle control and train control, with the possibility for giving priority to an emergency vehicle on the highway (see NY10). A field operational test has been planned for some time, but continues to be delayed.

A traveler information project for slow-moving freights that block grade crossings was implemented in San Antonio, but the results have not been especially useful (see SA5, AWARD).

Transit Management

Several transit management projects involve AVL for buses, for purposes of improved schedule adherence or traffic signal priority; other projects use IVN to help the operator of paratransit and service vehicles. One project involves placing video cameras in buses so that the operations center can view activities inside the bus and take action if necessary. These projects have proceeded slowly, sometimes (as in the case of AVL) building upon previous versions of similar technology.

Both AVL and electronic fare payment appear to have potential for producing net benefits, if they are deployed and used effectively (see PH5 on Phoenix AVL).

Traffic Signal Coordination

About a dozen projects seek to improve traffic flow by coordinating traffic signals across political jurisdictions. For many reasons, most of these projects were not completed. A large group in Seattle may be operational, but have not coordinated across jurisdictions due to inability to reach agreements. The one implemented and for which data were collected appears to be able to generate relatively large net benefits from small improvements in smoothing traffic flow (see the report on PH3).

Freeway Management

Freeway management consists of surveillance with CCTV and detectors, plus traffic controls using lane control signals, variable message signs, and highway advisory radio. Emergency vehicles may be dispatched to deal with incidents. Little is known about the effectiveness of these mechanisms, and no data were obtained from the sites. A typical deployment was evaluated using plausible parameters (SA2), and another project involving coordination between freeway incidents and arterial signal timing was also analyzed with a spreadsheet (SA1 Medical Corridor). Net benefits can be positive under the right circumstances, if the control mechanisms have reliably net favorable impacts.

Deployment Across Model Cities

Not much can be said about the cities from the few projects evaluated in each of them. Some differences can be remarked upon, however, without knowing whether the differences are of any significance. The second column of Table 2 shows a range of effort among the sites, in the number of individual projects defined for benefit-cost. The next column counts only those initiated under MMDI; others may have been completed already or were not ready for full deployment. The percent deployed column is an estimate of the *approximate* share of the MMDI projects that were deployed within the evaluation time frame. Some deployments were in not much more than name only, in that they did not achieved significant levels of usage.

Table 2: Number of projects deployed by City

MMDI Site	BC Projects	MMDI Projects	Percent Deployed
New York	10	5	0%
Phoenix	18	15	80%
San Antonio	10	10	80%
Seattle	28	26	50%

The difficulty of getting anything done probably goes up with the size of the city. New York got a late start, aimed low in terms of the number of projects, and is presumably still working on the projects. Seattle expressed large ambitions, but not all were realized.

Conclusions

The primary conclusion is that no data were collected or are being collected to determine whether ITS projects are worthwhile or not, in the contexts in which they are being deployed. Benefit-cost evaluation should take place as the project is being designed, to identify the critical performance factors—in both the engineering and the market sense—that will make the difference between success and failure. Subsequently, as the project is implemented, these performance measures should be monitored to see how well the actuals are meeting the forecasts. As a result of this ongoing evaluation, existing projects can be modified and new ones designed better or not deployed. This is a fundamental process that is followed in private sector ventures, and should be for ITS as well.

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