

Chapter 1 Assessing the Investment in ITS: An Introduction

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Introduction

This volume evolves from a conference on *Measuring the Contribution of ITS to Transportation Services* held in Sacramento in February 2002. The conference, sponsored by the California Department of Transportation (Caltrans), summarized the state of developing methods and information on evaluating Intelligent Transportation Systems (ITS) investments and applications. The term *Intelligent Transportation Systems* refers to the multimodal package of transportation innovations that use advanced technologies in electronics and information to improve the performance of vehicles, highways and transit systems. Our research, supported through the PATH program at University of California-Berkeley, has initiated the move away from the engineering of ITS to an economic assessment. Policymakers have long looked at ITS as a potential technological fix for problems of congestion and dwindling productivity of the state's transportation system. However, the bulk of the literature was highly technical and focused on the engineering issues rather than providing information on the benefits (and costs) of ITS implementation and examining whether the features that were being supplied were actually wanted and valued by the market.

The introduction of ITS projects into the surface transportation system raised some concern and confusion among transportation planners, policy-makers, and professionals about evaluation. Unlike other types of transportation investments, there were relatively few examples of the application of ITS technology upon which to draw some experience. ITS represents a technological change, and cannot be assessed solely as a capacity addition. While ITS allows us to do old things better (squeeze a few more vehicles onto a roadway, tend to highway incidents), it also allows us to do new things (know when a bus is coming so that transit becomes a reliable mode with minimal uncertainty, or use variable pricing to manage peak demand). Without new tools to allow the evaluation of these new things, transportation agencies were rightly concerned that good projects would not be implemented and bad ones not rejected. Because of a lack of information to provide direction for evaluation, there is a risk that significant investments will be made with little economic payoff. How then should one proceed? What are the important considerations and what should be ignored? Finally, how should these projects be evaluated?

ITS: A Brief History

The Intelligent-Vehicle Act of 1991, part of the Intermodal Surface Transportation Efficiency Act (ISTEA), established a national ITS program. ISTEA represented the first major transportation bill in the post-interstate era. The interstate of course reshaped the American landscape; yet it failed to match the growth in travel it, along with rising incomes, spurred. Congestion, safety, the environment, and energy emerged as concerns that could not be fully addressed with road construction. Sussman (1996) notes that

consideration of the growing problems revealed two major points: 1) that national productivity and international competitiveness were closely tied to the efficiency of our transportation system and 2) the social and political costs could not be addressed by simply building additional conventional highways.

The forerunners of ITS date from the early days of the mass-produced automobile. Mechanical guides, that could be said to be the progenitors of modern electronic route guidance systems, provided detailed route instructions to drivers. One example, the *Live-Map*, consisted of a turntable connected by gears to one of the vehicle's wheels. After placing one of about 600 paper disks describing specific routes on the turntable, and setting the stylus to the beginning of the route, landmarks and course corrections would be announced.¹

The first actuated traffic signal controller was installed in Baltimore in 1928. Unlike today's actuators which use magnetic loops embedded in the roadway or video cameras, this actuator was acoustical. A vehicle approaching on a side street could activate the green signal by sounding its horn (Kraft, 1999). One can imagine the neighbors were not overly pleased.

The 1960s saw the installation of computer-controlled traffic lights in Wichita Falls, Texas. Also, Chicago received automated freeway surveillance and ramp metering. The first ramp meters, like early intersection control, employed a police officer letting one vehicle at a time onto the freeway. Later traffic lights were installed (Piotrowicz and Robinson, 1995).

The Bureau of Public Roads (BPR) (the predecessor of today's Federal Highway Administration) then housed in the Department of Commerce, began research into application of communication and control technologies for surface transportation. One program, the Electronic Route Guidance System, was an early conception of today's in-vehicle navigation systems, but was based on real-time traffic information, something we still have difficulties implementing today. (Saxton, 1993).

In the 1970s, the Urban Traffic Control System (UTCS) aimed to interconnect individual signalized intersections to a central control center. At the control center, a computer would control the entire network by selecting the most appropriate timing pattern from a family of pre-computed timing plans which had been optimized for different sets of traffic conditions.

Other initiatives included the Passing Aid System (PAS) intended to let drivers on rural two lane roads know whether or not it was safe to pull out and pass another vehicle; FLASH, a system for motorists to signal when they observed a disabled motorist; a roadside radio motorist information system; and a project to develop a fully automated highway system (Saxton, 1993). These projects all underwent field operational tests (FOT).

¹ See DOT website at <http://www.its.dot.gov/tcomm/history.app.htm>

As an alternative to the proliferation of conventional highways, a 1971 USDOT report to Congress recommended additional funding for research and development of automated highway concepts as well as legislation for a Post-Interstate Highway Plan that would enable highways to accommodate automated operation. But necessary major policy and funding support for a full national program did not develop and most projects did not proceed beyond the early concept evaluation phase.

During rest of the decade, the FHWA continued research in traffic operations, motorist information and communications, and automated highway systems. The research program was also instrumental in working with the Department of Interior and the FCC to establish the Traveler's Information Service (Highway Advisory Radio).

During this same time period, the Department of Defense developed its satellite-based Global Positioning System ("GPS") allowing such applications as vehicle navigation and location monitoring. The Bureau of Census developed maps and Geographic Information System (GIS) databases now employed automobile navigation and guidance systems, traffic management centers, and fleet dispatch offices.

Despite lack of federal research funding in the early 1980s in the United States, in Europe, advanced transportation projects were continuing. Globally, technological advances were occurring rapidly in semiconductors, electronics, computers, and cellular telephones. Congestion problems continued to grow.

In 1986, several events took place launching the modern efforts into ITS. The FHWA proposed an *R&D Program In Traffic Operations To Combat Urban Traffic Congestion* emphasizing seven major initiatives including navigation and vehicle control. In March, the Transportation Research Board of the National Academies hosted a workshop in Baltimore leading to a large research effort funded by the National Cooperative Highway Research Program (Saxton, 1993). It was suggested that ITS and a research effort into roadway powered electric vehicle (RPEV) technologies (the Santa Barbara Electric Bus Project), could be combined under a larger program to be run by the University of California. The Institute of Transportation Studies at U.C. Berkeley proposed that they assume the lead role in the broader program. In August, the PATH (Program on Advanced Technology for the Highway) Program began with the first contract from Caltrans to the University of California at Berkeley's Institute of Transportation Studies (Shladover, et al., 1993). In October, Caltrans organized a conference to examine ITS as an alternative to road-building to relieve congestion. The program continues with a growing emphasis on evaluation methods, implementation issues and economic analysis.

Background

California's Transportation Plan (CTP) was designed to set the course for the future of transportation in California.² At the heart of the plan are three comprehensive policies:

² See, California Department of Transportation, New Technology and Research Program, *Advanced Transportation Systems Program Plan: 1996 Update*, December 1996

- (1) Promoting the economic vitality of California by assuring mobility and access for people, goods, services and information,
- (2) Providing safe, convenient and reliable transportation and,
- (3) Providing environmental protection and energy efficiency.

The Caltrans Strategic Plan, in keeping with the CTP envisions a balanced, integrated multimodal transportation network to move people, goods, services and information freely, safely and economically. In order to realize this vision, Caltrans has invested in the Advanced Transportation Systems Program. This multimodal research and development program provides a foundation for the application of advanced technologies to transportation in California. The objective of the program is to accelerate implementation of advanced transportation technology applications.

ITS projects are designed primarily to enhance the productivity of the existing highway system. Only on rare occasions does the ITS project result in physical expansion of the system. For example, the information system may suggest an alternate less congested route for a trip, wherein the traveler completes her trip at a lower cost than otherwise. The information system is ancillary to the roadway system yet certainly contributes to an increase in productivity of the roadway system. An electronic toll collection investment replacing a set of tollbooths reduces the travel time of most if not all travelers using a facility so they complete their trips using less time as well. This is another example of how additions to or modifications of, the existing network allow it to be more efficient.

Among the various categories of ITS applications will be projects dealing with traveler information systems, traffic management systems, vehicle safety systems, public transportation systems and commercial vehicle operations to name a few. In some cases these projects will require significant capital [hardware] investments and continuing operations and management expenses while other projects will represent relatively small capital investments. Some projects will cover a metropolitan urban area while others may be specific to a particular road segment or corridor. Simply put the projects will vary across a number of dimensions from size, capital intensity, geographic coverage, to the people and agencies affected. This variety and coverage creates a challenge for project analysis.

Investments in infrastructure and their related management strategies under the new technology program will generate different types, magnitudes and longevity of costs and benefits. Both costs and benefits will have different degrees of risks associated with them. Certainly in the case of infrastructure development the loss of resources from making a bad decision are not easily recovered or reversed. Hence, the risks are perceived to be higher. The variability of both benefits and costs will also create a degree of uncertainty both regarding the evaluation of projects as well as concerning the development of accurate values for benefits and costs. These features create an important challenge since California's transportation needs are met through private initiatives, public investment, and public/private partnerships. In each case the investment dollars will be available from the private sector only if it can be shown that these projects will

meet California's transportation needs now and into the future in an efficient or cost effective way.

Funds are available from earmarked government sources such as gasoline taxes and federal transfers. Nonetheless not all projects can be undertaken and they need to be ranked in terms of economic returns. If these projects do not meet financial and economic tests in a transparent manner, including compensation for greater risk and uncertainty, the private sector is unlikely to undertake the development of new ITS products. This does not mean all projects must generate at least a market rate of return, indeed there may be some argument for subsidy. What it does mean is that significant policy issues can only be addressed if the benefits, costs, and risks can be identified for each project. Indeed, the lack of, or failure to use, aids that help guide the public use of scarce resources will threaten the quality of decisions.

Therefore, there appear to be two major reasons for undertaking a careful analysis of proposed ITS projects. First, the projects represent an expenditure of scarce public funds and planners and policy makers should ensure they are obtaining the greatest benefits from their investments. Those who have to make decisions about whether to undertake a project or to decide among competing projects need to understand the differences in the benefits that the projects generate. Second, projects will have positive impacts as well as negative consequences. The decision-maker would like to select the appropriate design to maximize the positive impacts and minimize the negative.

Our Take

We emphasize that this book differs from many previous efforts in that it focuses on deployed systems and the use of observed data. While simulation is an important technique, especially for speculative technologies, simulations calibrated with data, and the data itself, provide a much stronger basis to draw conclusions about the worthiness of ITS projects. For those reasons, this book does not comment on technologies such as Adaptive Cruise Control, Automated Highway Systems, and other high profile, yet nascent ITS technologies.

We have discovered from our analyses that ITS Technologies are most effective at *the edge of congestion* and for dealing with the unexpected. When traffic is uncongested, or very congested, there is little ITS can do but tell you, but at the margins, when traffic is about to become congested, ITS can provide relief through effective traffic management. While this may be little relief for those sitting on saturated streets, we note that there is at least one time at the margins each peak period, as traffic is transitioning from uncongested to congested. If this transition can be extended through management, there are measurable gains to be had, and congestion to be reduced.

By informing and managing users (with technologies such as ramp meters, or electronic toll collection such as described by Burriss in Chapter 10 and Liu, Recker, and Chen in Chapter 13), the transportation system becomes less variable and more reliable. This reliability has value, a point made by Lewis in Chapter 2, Hickman in Chapter 5, and Liu, Recker, and Chen in Chapter 13.

We further note that the question of "Synergies" is raised in several chapters in this text. Bertini and El-Geneidy in Chapter 15 note that many technologies require the same data,

and there are cost savings to be had. (The use of this common data is employed in a number of chapters, especially Chapter 14 by Levinson and Chen). In economic jargon, there are economies of scope resulting from the simultaneous production of multiple transportation services. But the more controversial notion, suggested by Brand in Chapter 3, is that there are benefits that are superadditive, having two technologies provides more benefits than the sum of having either. This is the claim that there are intertechnology economies (or economies of scope in consumption) which expand benefits when multiple ITS services are consumed together. While of course it would be nice if such demand-side synergies exist, we believe that the existence of synergies is not necessary to find benefits that exceed costs in ITS.

We need to think of ITS like other technologies, that goes through a cycle from birth through growth to maturity, the class S-curve. While many transportation technologies (such as highways) have reached the maturity phase, and some ITS technologies have in certain places (such as ramp meters in the Twin Cities), most that we consider here are still in the growth stage. As noted above, those still in the birthing stage are not considered here. Thus it may be premature to conclude the final state, and the more conservative tact, as suggested by Lee in Chapter 4, is to use more conventional cost-benefit analysis and find if the technology is warranted in that way. If it is, we will at least avoid the mistake of overinvesting. Deakin makes a similar point in Chapter 17 where she notes many decision-makers believe that ITS has been hyped. But Brand notes we still may make the mistake of underinvesting. However it is our location in the maturity phase in the S-curve of conventional technologies that has prompted the search for new alternatives over the past few decades, as agencies shift from being builder to managers. Due to uncertainty, many technologies will be empty rabbit holes before the one technology that is meritorious is discovered. Inevitably, there will be overinvestment in research into a number of false leads before a true lead can be followed. Such is the nature of research.

Institutional issues also matter in the implementation of ITS. Deakin makes this point in Chapter 17; Giuliano and O'Brien discuss institutions in the context of transit in Chapter 7. Institutional issues have been raised regarding ramp metering in the Twin Cities, where the legislature had to force the engineers at the Traffic Management Center to objectively evaluate their system (see Chapter 9 by Levinson and Zhang). Similarly, freeway service patrol operations (such as described by Parthasarathi, Levinson and Gillen in Chapter 11) are perceived to compete with private tow truck operators and auto clubs, and raise the question about the proper roles of the public and private sectors. The proper roles of value added services also confront advanced traveler information systems (see Khattak, Targa and Yim, Chapter 12).

Most of the analyses here (and elsewhere) evaluate transportation within the confines of the transportation system. The time is approaching when it would be more appropriate to place the evaluation of ITS in the context of an economy. Transportation uses networks, and an analysis of the effects of an important project on a single link without considering its upstream and downstream effects would be flawed. Yet we know that transportation is used because it adds value to people and firms, and transportation decision affect the individual's activity patterns and the firms decisions within the supply chain. Investments in transportation thus change non-transportation markets. In Chapter 2,

Lewis makes this point. ITS if it changes travel patterns, will have effects beyond the transportation sector, not only the negative externalities such as pollution and noise, but restructuring effects in other markets. An economy is an integration of markets with all participants interacting. Understanding economic business decisions require business and economic data. Economic methods such as Computable General Equilibrium (CGE) used in trade theory, begin to get at these impacts. But despite obvious applications, especially in freight, in transportation, these methods are still in their birthing stage, and have yet to be widely accepted.

Overview of Papers

The papers in this volume are divided into four sections. The next section provides information on the integration of ITS into the transportation system and into the economy. The following two sections provide case studies of ITS applications in transit and highways, respectively. The final section has a group of papers that examine the integration of ITS into transportation practice.

Section 1 contains three papers that have a broad theme of how and what does ITS contribute to the economy and how does one make the business case for ITS.

In Chapter 2, David Lewis argues that ITS serves as a basis for *Public-Private Partnering* in highway investment. He suggests that ITS offers benefits to private industry that public agencies need to recognize in order to leverage significant private financial participation in highway investment. The economics of a just-in-time economy turn on the effectiveness of the transportation system, central to which is the highway network. Reliability and predictability are the keys, without which there would be no business case for investing in the technology needed to facilitate just-in-time operations. The principal focus of analysts and planners in the ITS domain has thus far been in personal transportation, not the manufacturing and freight sectors. The conclusions warn that to ignore the manufacturing and freight nexus is potentially to miss the lion's share of what ITS has to offer.

In Chapter 3, Dan Brand considers *Benefit Measures, Values and Future Impacts of ITS*. He argues that recognizing how ITS differs from conventional transportation improvements allows us to avoid seriously underestimating of the benefits of ITS, collecting expensive data, and making mistakes in our planning and investment policies. Even when it is without tangible benefit, Advanced Traveler Information Systems (ATIS) are valued by travel consumers for giving them a sense of control over their lives as shown in surveys and focus groups which revealed that knowing what was going on was more important to consumers than saving time. Additionally, ATIS can act like added capacity in the transportation network in the sense that it can show where there is "available" capacity in real time. If we measure just aggregate changes in VMT and VHT on the network, we will grossly underestimate the benefits of ATIS.

In Chapter 4, *Making the Case for ITS Investment*, Doug Lee asserts the case for investing in ITS needs to be made on objective grounds that are credible to the decision maker who is seeking balanced information. Benefit-cost analyses (BCA) evaluate actions by comparing the results of taking the action against a base case in which the

action is not taken. Although BCA evaluation of ITS projects is feasible at a modest level of effort, few studies have been done, and, for most contexts, key data are not available. While BCA will never “prove” beyond a shadow of a doubt that ITS spending is either worthwhile or wasteful, it is readily possible to generate information that would be useful for guiding investment into productive projects and ensuring that their performance is as intended and expected.

Section 2 considers ITS applications in Transit.

The section opens with Chapter 5 wherein Mark Hickman evaluates *Bus Automatic Vehicle Location (AVL) Systems*. A combination of on-board electronics, communications with a control center, and software are currently being used to achieve five broad categories of AVL applications: passenger information, transit operations monitoring and control, service planning, air quality improvements, and safety and security enhancements. He finds that at present there appear to be quantitative economic benefits of bus AVL systems. If the AVL data are used to create estimates of bus arrival times at bus stops, there is strong evidence that passengers perceive real increases in travel utility, reflected in reduced “costs” of waiting time and, possibly, some slight increases in ridership and revenue for the transit agency although there has been relatively little direct empirical evidence of these benefits to date. In the area of operations management, the improvements in schedule adherence and headway regularity are well documented. However, the evidence does not yet exist to connect these directly to waiting time or utility gains on the part of passengers. The evidence on AVL-based operations control measures is largely based on simulation results, but improvements in passenger waiting times are clearly possible. The waiting time improvements must be balanced by the effects on total passenger travel times, on bus running times, and on the resulting bus operating costs. At this time, a reasonably well-developed methodology does exist to evaluate the impacts of control actions using bus AVL data, but additional empirical evidence of these benefits is needed. Finally, in the area of service planning, AVL data can be used to analyze schedule performance, improve schedule efficiency, and even reduce bus and operator requirements. The challenge remains to have sufficient resources to exploit these data effectively among the many data-rich applications in service planning

Ed Sullivan and Jeffrey Gerfin undertook a *Case Study: Impacts of Advanced Technology on a Small City Bus System*, presented in Chapter 6. As part of a demonstration of low cost Advanced Public Transportation System (APTS) technologies designed specifically for small transit systems, mobile data terminals with GPS locators were installed on all San Luis Obispo (SLO) Transit vehicles, with real-time bus location and emergency alarm data transmitted via radio modems using previously existing voice radios. Besides providing useful data for system planning, the real-time bus location data are used to advise drivers regarding schedule adherence and to generate messages regarding impending bus arrivals employing Smart Transit Signs at principal bus stops throughout town. The project has demonstrated the feasibility and positive impacts of applying APTS technologies to enhance small transit operations with indications to date that both the operators and bus customers perceive significant benefits from the deployment of this new technology.

In Chapter 7, Genevieve Giuliano and Thomas O'Brien seek go *Beyond Benefits and Costs to Understand Outcomes In Public Transit*. The purpose of Field Operational Tests (FOTs) is to determine whether the given technology application is appropriate for adoption on a larger scale. Six case studies of public transit technology tests were studied to identify determinants of successful deployment of ITS technology. The studies involve electronic payment and fare integration (San Francisco Bay Area TransLink, Washington DC SmarTrip, Chicago SmartCard), automated trip scheduling (Santa Clara SMART) and more ambitious service integration that may or may not include fare integration (San Gabriel Valley Smart Shuttle, Ventura Smart Card). Single agency FOTs were characterized by clear goals and objectives, an incremental approach to the technology, and effective management. These helped the agencies to make modifications to the technology as needed and appear to be requirements for all successful FOTs. Multi-agency tests, however, have had more mixed outcomes. While technical performance is essential, it does not guarantee FOT success. It is possible to deploy all the technological elements of a test and still not meet a given set of objectives. This is particularly the case with service integration. The tests also suggest that it is possible to only partially meet a test's technological objectives and still show some progress toward overarching service objectives. Operational tests in general can be valuable without being entirely successful because of the lessons they offer.

Part 3 explores ITS applications in the Automobile/Highway System.

Chapter 8, by Alex Skabardonis, details *Traffic Signal Control Systems*. Signal timing optimization, signal coordination, and advanced traffic control have all been proposed as components of ITS measures. This chapter presents the findings from the analysis of the impacts of these three signal control improvements based on a large number of real-world implemented projects. The results from over 163 implemented projects showed that signal timing optimization of coordinated signal systems produced an average of 8 percent drop in travel time and fuel use, 14 percent reduction in delays, and 13 percent reduction in stops for a typical weekday. Signal timing optimization is a highly cost/effective strategy because of its low cost. The estimated average Benefit/Cost ratio in the Fuel Efficient Traffic Signal Management (FETSIM) project areas is 17:1. Annual fuel savings alone outweigh the total program costs by more than 5:1. Signal coordination produces significant reductions in delay, stops and fuel consumption. The average improvements include 11 percent reduction in travel time, 25 percent reduction in delay, and 27 percent reduction in the number of stops. Signal coordination worsens the performance on entry (uncoordinated) movements in the system, typically side streets, and the trade-offs should be carefully assessed.

In Chapter 9, David Levinson and Lei Zhang evaluate the effectiveness of *Ramp Meters*. For eight weeks in October, November, and December 2000, ramp meters in the Twin Cities of Minneapolis and St. Paul Minnesota were turned off allowing the collection of data, with and without ramp meters, from several representative freeways. The data were then analysed using a variety of measures of effectiveness (MOE) to determine the effect of ramp meters on freeway traffic in the Twin Cities area. The study shows that Route 169 performs better in the presence of operating ramp meters than in their absence, judged by a majority of the MOEs. In contrast, however, I-94 shows that improvements to the operations of freeway mainline do not always offset the additional ramp delay.

Looking at the consistency of various performance measures developed in this chapter, it is found that mobility, consumers' surplus, productivity and accessibility tend to provide the same conclusions on the effectiveness of ramp meters. However, when ramp metering is present, long trips benefit while short trips are hurt, suggesting a less equitable situation than without metering. If a ramp metering objective only pays attention to mobility (efficiency), its poor equity indications will inevitably lead to an important public policy debate

Mark Burris considers *Electronic Toll Collection And Variable Pricing* in Chapter 10. This research analyzed the incremental costs and benefits of ETC at a retrofitted toll plaza, open road toll collecting (ORT), and variable pricing at an ETC configured plaza. Benefits were found to include reduced delay, reduced fuel consumption, and reduced emissions while costs included the purchase price, installation, and operation and maintenance costs. Under both low and medium traffic congestion scenarios a positive net present value was found for retrofitted ETC. For ORT, benefits were found to be significantly larger than those associated with a standard ETC system. However, due to the large operation and maintenance costs of ORT, the benefit cost ratios were actually smaller, with the costs outweighing the benefits in the low volume scenario. Finally, the incremental costs and benefits of incorporating a variable toll rate with ETC showed a positive, incremental net present value. However, under uncongested conditions, benefits were minimal and a negative net present value was found. The cost and benefit values used in this analysis were obtained from empirical evidence collected at toll roads and variable pricing projects around the country. Using these values yielded average transaction costs that appeared reasonable when compared to results from around the country that might be used as a framework for cost-benefit analysis. A toll agency interested in evaluating the potential costs and benefits of implementing ETC (with or without variable tolls) would need to apply the specifications of its toll facilities to this framework to obtain an estimate of their potential costs and benefits.

Chapter 11, by Pavithra Parthasarathi, David Levinson, and David Gillen, estimates the insurance value of *Freeway Service Patrols*. The main goals of freeway service patrols (FSP), often called highway helpers, are to identify incident locations, reduce incident duration time, restore full freeway capacity, and reduce the risks of secondary accidents. Studies conducted so far have focused on the effectiveness or economic efficiency of such patrols. This chapter seeks to determine the value that people place on the benefits offered by freeway service patrols in comparison to private assistance services (PAS) by estimating how much they would be willing to pay to avoid being stranded when their vehicle breaks down on the freeway. A stated preference survey of over 1000 individuals regarding choice of FSP or PAS showed that the variables Waiting Time, Cost, Gender, Age, Income, Auto Age, Maintenance Expense, Commute Length, Cell Phone Ownership, Towing Coverage, And Time-Of-Day were all significant. While freeway service patrols have value in improving traffic flow and safety by clearing incidents quickly, they also have value for the individuals who are helped by the patrols, who otherwise would have to wait for a private assistance service through their auto club or by calling a tow truck. The results indicate that freeway service patrols provide insurance benefits for their customers when they save time and money over private assistance services.

Asad J. Khattak, Felipe Targa, and Youngbin Yim observe *Advanced Traveler Information Systems* and relate it to traveler behavior in Chapter 12. The challenge for advanced traveler information systems (ATIS) is to provide dynamic information that meets traveler needs for making more informed decisions, is accessed and used, and contributes to improved travel experience for individuals and society. In congested networks, such systems can support several traveler choices including the selection of destinations, modes, routes, departure times, intermediate stops, and parking. Real-time information can also help with readjustments, e.g., diversions from the selected route to avoid unexpected traffic congestion. A growing body of empirical evidence from federally sponsored field operational testing suggests that such information is used by individuals to choose routes and set departure times. TravInfo, a regional traveler information system in the San Francisco Bay Area began its field operational testing in September 1993 and has now moved to full deployment. A behavioral evaluation of the field test found that saved travel time and help with travel planning were the key perceived benefits of dynamic information. Many respondents also cited a reduction in anxiety as a benefit. Almost all people in the surveys had access to or ownership of at least one device (on average about 4 devices) that could be used to obtain dynamic travel information with radio being the most widely used. Two-thirds of all respondents received travel information either regularly or occasionally, and one-third changed their travel decisions in response to that information. The most desirable types of information in order of desirability are: Frequent updated traffic conditions on radio or television, detailed information about alternate routes around congestion, in-car navigational computer showing highways and roads, estimation of the time of delay and directions to get from the point of departure to the point of arrival, information about traffic conditions at specific locations, information about mass transit alternatives, and automatic notification of unexpected traffic congestion. Additionally, there seems to be significant (latent) demand for personalized information services that would allow users to retrieve information when needed, to the point where a significant number of Bay Area travelers stated they would be willing to pay either on a per-call basis or a monthly subscription fee for a customizable service provided that the new information must be superior to that obtained for free through radio or television or other Internet outlets and services.

In Chapter 13, Henry Liu, Will Recker, and Anthony Chen use real-time loop data to estimate the contribution of *Travel Time Reliability* in a mixed logit route choice model. A wide range of factors influences the route choice of individual travelers including perceived travel time, monetary cost, comfort and safety. This model was applied to newly collected data concerning route choice in the California State Route 91 value-pricing project that gives travelers a choice of whether or not to pay a congestion-based toll in order to use the express lanes. It was found that the estimated median value of travel-time reliability is substantially greater than that of travel-time, and the median value of degree of risk aversion is greater than 1, indicating that travelers value more highly a reduction in variability than in the mean travel time saving for that journey.

Part 4 considers integrative issues.

Chapter 14 by David Levinson and Wei Chen assesses the performance of *Traffic Management Systems*. Three important traffic management systems in the Twin Cities metro area - Ramp Metering, Variable Message Signs (VMS), and Freeway Service

Patrol (FSP) were evaluated using multiple regression models to predict link speed and incident rate based on two case studies. In the first, a database of about 40,000 observations covering three years' data was used to estimate the long-run and systemwide performance of the traffic management systems for both the incident-free case and incident case. In general, ramp meters were found to increase freeway link speed and reduce the incident rate while Freeway Service Patrols increased link speed when incidents are present. The results for variable message signs are ambiguous.

In Chapter 15, Robert Bertini and Ahmed El-Geneidy use *Advanced Traffic Management System Data* to evaluate ITS investments. The quantification of ITS benefits and costs has been difficult using traditional transportation planning and analysis methods because such models lack the necessary sensitivity to many benefits derived from ITS technologies, and because information on the impacts and costs of many ITS technologies is not yet well-understood. Ten ITS program areas are introduced with examples of how advanced traffic management system (ATMS) data are being used to evaluate their benefits. It is clear from these programs that each system cannot be deployed to stand alone in the overall transportation system.

Reinaldo Garcia reports on *ITS In Europe* in Chapter 16. With major infrastructure investment reaching its limits, Intelligent Transport Systems (ITS) are a viable solution to make the movement of people and goods more efficient, economical, safer, and environmentally sound for all transport modes and are vital for the development of a European transport policy requiring better use of its existing transport infrastructure. To date, ITS has been successfully employed in Europe in the areas of urban road traffic management, rail transport, air transport, and the shipping industry, including both maritime and inland navigation systems. Among future projects, a European Global Navigation Satellite project, Galileo, will play a central role as an ITS technology for all transport sectors.

In Chapter 17, Betty Deakin explores *Mainstreaming ITS*. The paper employs results from interviews with over 50 leaders in California, noting that though leaders are aware of ITS, they think it is hyped. In particular they desire better information on the benefits and costs of ITS, particular benefits for users rather than system operators. However, it is unclear what direction future ITS investments should take, as ITS becomes a standard part of transportation projects.

Tom Horan summarizes the findings in the book and places them in context in Chapter 18: *Information Systems to Improve Surface Transportation*. Horan suggests ITS should be assessed for its contribution to the productivity of transportation systems, ITS should be tested against the demands of stakeholders, and ITS should be considered as an element of the broad information and communications technologies which have revolutionized daily activities.