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Identification And Prioritization Of Environmentally Beneficial Intelligent Transportation Technologies

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Identification and Prioritization of Environmentally Beneficial Intelligent Transportation Technologies

Year Two Final Report

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ABSTRACT

This report documents activities of the project "Identification and Prioritization of Environmentally Beneficial Intelligent Transportation Technologies", being conducted by the Institute of Transportation Studies at Davis and Claremont Graduate School. It provides an extensive review of literature on the energy and environmental impacts of Intelligent Transportation System technologies, a presentation of the development of deployment/modeling scenarios, and a description of the modeling effort.

The report contains a revised and updated section that reflects the current policy context and regulatory arena in which ITS technologies will be deployed. In addition, the section of the report describing scenarios has been substantially expanded since the Year 1 interim report. The scenario analysis was the focus of significant project team effort in 1997. This section includes the scenario methodology, summaries from expert interviews, and the results of two expert scenario workshops (held in Washington, DC and Davis, CA). Furthermore, this section provides the final scenarios and market penetration estimates developed to form the basis of modeling efforts with the INTEGRATION model.

A large section of this report is devoted to a description of the INTEGRATION database for the SMART Corridor, obtained from researchers at UC Berkeley and being updated for use with INTEGRATION V2.0 in this study. The effort required updating this database due to changes between this version of the model and the version for which the database was originally developed (V1.5) has been extensive.

The report concludes with a summary and a description of future work. The modeling effort will focus on the following ITS technologies: advanced traffic signal coordination; electronic toll collection; en-route driver information; and vehicle navigation/route guidance. Model runs will be established for a subset of all possible runs in the matrix defined by: the four scenario 'worlds' (status quo, government, private, and public-private partnership); the four technologies; and the three model run years (1995, 2000, and 2005).

Keywords: Intelligent Transportation Systems, technologies, environmental impact, emissions, modeling, INTEGRATION, scenarios, policy, market penetration

EXECUTIVE SUMMARY

This report documents activities of year one and two of this project. It provides an extensive review of literature on the energy and environmental impacts of ITS technologies, elaboration of deployment scenarios and description of the modeling efforts. Since the Year one interim report, the policy context section of this document has been revised and updated to reflect the current regulatory arena in which ITS technologies will be deployed. In addition, the scenarios section of the report has been substantially expanded. In 1997, the scenario analysis was the focus of significant project effort. This section includes a description of the scenario methodology, a synopsis of the expert interviews, and summaries from expert interviews, the results of two expert scenario workshops (held in Washington, DC and Davis, CA, in the Fall of 1997). Furthermore, this section provides the final scenarios and market penetration estimates developed to form the basis of modeling efforts with the INTEGRATION model. A complete set of expert interview and workshop is contained in Appendix D.

A large section of this report is devoted to a description of the INTEGRATION database for the SMART Corridor, obtained from researchers at UC Berkeley and updated for use with INTEGRATION V2.0 in this study. The effort required to update this database due to changes between this version of the model and the version for which the database was originally developed (V1.5) has been extensive. Modeling with a detailed microsimulation model such as the INTEGRATION model is data intensive and requires substantial time and personnel resources. This research has confirmed that the use of a detailed simulation model is essential to reasonably estimate the impacts of ITS technologies.

The *initial* modeling effort will focus on the following ITS technologies: advanced traffic signal coordination; electronic toll collection; en-route driver information; and vehicle navigation/route guidance. Model runs will be established for a subset of all possible runs in the matrix defined by: the four scenario ‘worlds’ (status quo, government, private, and public-private partnership); the four technologies (listed above); and the three model run years (1995, 2000, and 2005).

The project team intends to begin the modeling efforts with runs based on the following scenarios:

(1) Status Quo World in 1995 and 2005 for each technology, and

(2) Public-Private Partnership World in 2005 for each technology

The project team will discuss additional possible model runs with the project sponsors to help determine which scenarios will be given priority for further work. Substantial effort is expected to be directed toward the identification of specific model runs in the near future, as model formulation is nearing completion.

The last two sections of this report provide a summary and conclusions for this study to date, and a description of future modeling work to be completed by June 1998.

Four appendices are contained within the report. The first contains summaries of two expert interviews conducted in 1996 on environmental and energy trends. The second presents regional ten-year forecasts for the South Coast region, the San Francisco Bay Area, and the Sacramento region. The third appendix provides background information related to the modeling effort, reproduced with minor modifications from the first year report. The final appendix, as mentioned earlier, contains a complete set of expert interview and workshop summaries from Washington, DC, and California.

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We would like to thank the Partnership for Advanced Transit and Highways (PATH) and Caltrans for their sponsorship of this important and timely research project.

DISCLAIMER

INTRODUCTION

Environmental factors, real and perceived, shape the development and deployment of transportation technologies. Intelligent Transportation System (ITS) technologies, because they are new and could be so pervasive, are coming under scrutiny by man. Environmental impacts are highly uncertain, however, because of the lack of reliable analytical tools for measuring air quality and energy effects of ITS technologies, advocates fear the worst. In this study, the Institute of Transportation Studies-Davis (ITS-Davis) and Claremont Graduate School (CGS) are evaluating the environmental effects of ITS technologies, using data from other studies and field tests and State-of-the-art modeling techniques. This ITS technology evaluation is being performed within the larger context of legal and regulatory requirements, State forecasts of vehicle miles of travel (VMT) and air quality, and broad transportation scenarios. The two-fold objective of this project is to: 1) identify those ITS technologies and systems that have positive environmental effects, and 2) rank order those technologies according to their energy and emission benefits and net reduction in VMT.

In attempting to examine the "environmental impacts" of ITS, we have limited the scope of this study--at least in terms of the modeling effort--to the analysis of emission and energy impacts (i.e., apart from a comprehensive review of environmental impacts, such as noise and land use). Besides helping to focus the study, this narrower approach to analyzing the environmental impacts of ITS has been necessitated by the current capabilities of ITS modeling (see the sections on modeling for further discussion of this issue). A broader examination of environmental issues related to ITS, however, is discussed qualitatively in various parts of the report. This includes, but is not limited to, a discussion of the implications of the "sustainability" concept for ITS deployment.

This year-two report is a summary of the study's status and our current understanding of the issues. To a large extent, this report contains literature reviews of models and ITS technologies; summaries of air, energy, and transportation regulations; and population forecasts (i.e., 10 years) from metropolitan areas relative to the environment. This report also includes a discussion of the modeling approach that we have selected and the scenarios that we have constructed to provide a context from which to assess the ITS impacts on energy, emissions, and VMT. This report is intended as a working draft, which forms the basis from which the project team will work to direct future modeling research and the final project summary and conclusions.

Following this introduction, the second section of this report provides a general literature review of a wide range of previous studies on the energy and environmental impacts of ITS technologies. This is followed by a more detailed review of qualitative and quantitative assessments from field operational test (FOT) data and previous modeling studies. Next, a number of ITS evaluation frameworks established by several authors are discussed. Furthermore, a range of modeling tools available for evaluating ITS technologies and user services are discussed, with an emphasis on tools capable of energy and emissions assessment.

The policy contexts that surround ITS-related issues are also presented. This discussion is followed by a presentation of the four scenarios that have been developed for the analysis (i.e., government, industry world, and public-private partnership world). The scenarios offer an overall framework for the specific modeling runs that will be used to provide the quantitative measures and to assess the environmental impacts of the ITS modeled technologies.

A detailed description is provided of the model development, which is based on the SMART Corridor database obtained from UC Berkeley researchers (Bacon *et al.*, 1995). Extensive time and resources have been directed toward updating that database for use with INTEGRATION V2.0 (the database was initially developed for INTEGRATION V1.5). Finally, a summary of the work completed in Year Two of this project is provided with a brief description of future work.

Four appendices are contained within this report. The first contains expert interviews conducted in 1996, on environmental and energy trends that could impact ITS deployment. The second appendix concludes the regional ten-year forecasts for the South Coast region, the San Francisco Bay Area, and the Sacramento area. The third appendix presents background information related to the modeling effort; it has been reproduced with minor modifications from the first year report. The final appendix contains a complete set of expert interview and workshop summaries from Washington, DC, and California.

REVIEW OF ITS AND AIR QUALITY RELATIONSHIPS

Air quality is a controversial issue within the ITS and the environment debate. The National ITS Program asserts that ITS deployments will reduce a wide array of harmful pollutants. In fact, a recent official report cited studies in which ITS technologies measurably reduced emissions of carbon monoxide (CO), hydrocarbon (HC), and nitrogen oxides (NOx) (United States Department of Transportation, US DOT, 1996). Some analysts disagree, arguing certain ITS applications could increase emissions by encouraging more travel (Cervero, 1995; Gordon, 1992). This section presents evidence and arguments on both sides of this issue, including studies that indicate that ITS technologies could reduce vehicle emissions and those that argue ITS-facilitated increases in highway capacity could increase vehicle miles traveled (e.g., spur "latent demand" for highway use) and ultimately worsen air quality. Further, we examine the analytic limitations in emission modeling that casts uncertainty over the entire ITS-air quality debate.

ITS and emissions reductions

Some studies indicate that ITS technologies can reduce emissions by providing information relevant to both supply-side and demand-side emission reduction strategies. "Supply-side" strategies seek to improve traffic flow by increasing the capacity of the transportation system. The goal is to reduce congestion-related emissions. Studies of supply-side improvements such as coordinating traffic signals and installing on-ramp meters and management systems on freeways show reductions in emissions (e.g., 10-15 percent reductions in CO) (Washington *et al*., 1994). Electronic toll collection (ETC)-- which allows drivers to pay road fees without stopping at toll booths --is another supply-side strategy, and studies show that ETC at toll booths reduces hydrocarbon emissions by up to 83 percent "per affected mile" (US DOT, 1996). A problem with supply-side enhancements, however, is that they may increase vehicle speeds and result in higher NOx emissions (Washington *et al*., 1994). This latter hypothesis is subject, however, to poor understanding of speed-emission relationships, especially at higher speeds.

"Demand-side" strategies take a different approach to emissions reduction. Instead of increasing highway capacity, demand-management strategies attempt to reduce vehicle travel, either by reducing VMT, the number of vehicle trips, or the number of single occupant vehicles (SOVs). Such strategies include both Transportation Control Measures (TCMs[1]) and road pricing. TCMs are traditional demand-side tools, and ITS technologies

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[1] Transportation Control Measures are defined in the 1988 California State Clean Air Act as "...any strategy to reduce vehicle trips, vehicle use, vehicle miles traveled, vehicle idling, or traffic congestion for

such as Advanced Traveler Information Systems (ATIS) and Advanced Public Transit Systems (APTS) can facilitate their use. The available evidence suggests, however, that TCMs provide only marginal emission reductions. The Government Accounting Office (1993), for example, estimated that TCMs in the Los Angeles Basin reduced hydrocarbon and carbon monoxide emissions by less than two percent, and by no more than five percent for any region studied in Los Angeles.

The limited effectiveness of TCMs has led many transportation experts to conclude that road pricing offers a more promising approach to demand management (UCLA, 1992). Pricing strategies may, in fact, provide four to eight times more emission reductions than traditional TCMs (Burbank, 1995). One controversial pricing strategy--congestion pricing--could generate significant revenue. One study showed that congestion pricing fees between $0.10 to $0.15/mi could reduce travel during peak periods by 10 to 15 percent (NRC, 1994). Despite the potential benefits, congestion pricing faces considerable political resistance, because these programs are often perceived as imposing a disproportionate cost on less affluent drivers or as a "tax increase" (Giuliano, 1994).

The conclusion drawn from this discussion is that some ITS technologies can reduce certain vehicular emissions under a range of scenarios. The most undesirable ITS scenarios, which would lead to an emissions increase is one that results in latent demand for travel.

Latent demand and emissions modeling

"Latent demand" refers to "the additional, unanticipated vehicles that appear on roads because people switched routes, modes, or travel times, or because they decided to take trips they had previously not taken. Latent demand is present when congestion is severe enough to deter people from taking trips using their most preferred routes, modes, or times of day..." (Kanninen, 1994: p. 2). The concern is that some ITS applications, particularly automated highway systems (AHS), would effectively increase highway capacity and, in turn, lead to more driving by unleashing latent demand for highway use. More driving would increase vehicular emissions, and an increase in highway capacity might encourage continued expansions in suburban development (e.g., "sprawl").

Concerns over latent demand, however, rest upon a great deal of analytic uncertainty. An extensive Transportation Research Board (TRB) report on the effects of highway capacity increases on travel and emissions concluded that context plays a critical role:

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the purpose of motor vehicle emissions." The 1990 federal Clean Air Act lists sixteen TCMs that States and localities can include in their transportation plans. These include traffic signalization improvements, ridesharing and carpooling programs, and high-occupancy vehicle lanes. Market-based measures such as congestion pricing, though consistent with this definition of TCMs, are not considered traditional TCMs. Consequently this paper makes the distinction between TCMs and pricing.

> On the basis of current knowledge, it cannot be said that highway capacity projects are always effective measures for reducing emissions and energy use. Neither can it be said that they necessarily increase emissions and energy use in all cases and under all conditions. Effects are highly dependent on specific circumstances, such as the type of capacity addition, location of the project in the region, extent and duration of preexisting congestion, prevailing atmospheric and topographic conditions, and development potential in the area (TRB, 1995, p. 7).

The debate over latent demand and ITS is further complicated by the lack of knowledge about how congestion reductions affect emissions. Empirical studies indicate that such reductions vary widely. Advanced Traffic Signal Coordination and incident detection, for example, can produce impressive emission reductions due to smoothed traffic flow. One such system, the Automated Traffic Surveillance and Control (ATSAC) system in Los Angeles, reduced traffic delay by 20 percent and emissions by 10 percent (Yates, 1994). ATIS systems provide similar though less pronounced emission reductions, yet it remains unclear whether such emission reductions are sustained over time (Shank, 1995).

The many uncertainties in this area underscore the need for improved traffic and emission models. ITS technologies, by making dramatic changes in "average" driving conditions, make average speed-based emission factor models such as the US Environmental Protection Agency's (US EPA) MOBILE5 and California's EMFAC7F inadequate tools for estimating the related environmental impacts (Konheim and Ketcham Inc., 1995). Imprecise emissions models could cause considerable problems, especially if (or when) ITS deployments face legal challenges on environmental grounds (Horan *et al*., 1996). This study seeks to address the need for more precise emission models for ITS technologies.

Speed-Emission Relationships

Modal activity and emissions

For many years, vehicle emission test procedures and models have characterized vehicle exhaust emissions in terms of the average speed of a trip or portion of a trip. However, average speed is not an adequate predictor of emissions. Emissions are a function of vehicle speed profiles and the modal activity (i.e., accelerations, decelerations, cruises, and idling) that makes up those profiles. Two vehicle trips with the same average speed will not necessarily have similar speed profiles, and hence different quantities of emissions will be generated. For example, one trip may consist of a smooth speed profile, while a second trip may consist of a mix of driving in congested conditions and on a freeway under free-flow conditions and yet have the same average speed.

The influence of modal activity distributions on emissions is of particular importance for the evaluation of transportation projects that smooth traffic flow, thereby changing the distribution of modal activity (i.e., reducing the proportion of accelerations and decelerations, increasing the proportion of cruises, etc.). Such transportation projects include many ITS technologies, such as traffic signal coordination and electronic toll collection.

Emissions have been shown to be not only dependent on speed, but also on the rate of change speed (acceleration/deceleration rate). In particular, high acceleration rates can generate emission rates much higher than those produced under less aggressive driving (e.g., LeBlanc *et al*., 1994; Carlock, 1992). As a result, emission models that have been developed as a function of average speed, ignoring the effect of modal activity (e.g. MOBILE5a and EMFAC7G), have a high level of uncertainty (Guensler, 1993). This is particularly true for predictions of emissions at very low and high speeds. For example, Guensler *et al*. (1994) show that although EMFAC7F would predict an eight percent reduction in carbon monoxide emissions associated with an increase in average vehicle speeds from 5 miles per hour (mph) to 65 mph (level of service (LOS) F_{III} to LOS A) for 1986 and later fuel injected vehicles. However, the upper and lower bounds for a 95 percent confidence interval (i.e., calculated using a bootstrap approach) suggest that the actual change in carbon monoxide emissions is probably between a reduction of 64 percent and an increase of 83 percent.

A good summary of the average speed modeling regime is presented in Guensler *et al*. (1994). This report also provides a discussion of emission-producing vehicle activities other than modal activity (e.g., cold, warm and hot engine starts, engine idling, vehicle refueling, and VMT). ITS technologies have the potential to affect many of these factors. For example, ATSC systems will reduce engine idling and ATIS (e.g., route guidance) can impact VMT. Whether the impact of ATIS results in an increase or decrease in VMT depends on the actual situation. A route guidance system is capable of providing information regarding the most direct route between an origin and a destination, thus minimizing the VMT for a given trip. On the other hand, an in-vehicle information system or a changeable message sign advising of downstream congestion may influence drivers to take an alternative route on which they travel a greater distance to save travel time.

Attempts to develop modal emission models suitable for use in transportation planning began a long time ago (e.g., Kunselman, 1974). More recent work includes that by Washington (1994) conducted as part of his dissertation research at the University of California at Davis. This research led to the development of the Davis Institute of Transportation Studies Emission Model (DITSEM). This model is comprised of two linear regression models that employ modal explanatory variables such as acceleration, positive kinetic energy, and proportion of cycle at idle to predict CO emissions from both ‘high’ and ‘normal’ emitting vehicles. The model is based on the speed correction factor (SCF) data used within the MOBILE and EMFAC models. However, unlike MOBILE and EMFAC, DITSEM was developed by disaggregating the 13 cycles represented in the SCF data into modal components. Consequently, DITSEM is capable of substantially better estimation of the emission impacts of microscopic changes in traffic behavior, such as those induced by the deployment of certain ITS technologies. The most significant limitation of the DITSEM model is that it is currently capable of CO emission estimation only. This is perhaps the main reason why this model has not been adopted as a tool in practice. Nevertheless, Washington and others have applied many theoretical aspects of the model in more recent work at the Georgia Institute of Technology (Georgia Tech).

Current modal emission model development

Currently, the two largest US efforts to develop emission models that account for vehicle modal activity are being conducted by Georgia Tech and a team of researchers from the University of California at Riverside (UC Riverside) and the University of Michigan (U of Michigan). The two research teams are employing different approaches to model development. UC Riverside/U of Michigan have used second-by-second emissions data to develop a detailed *parameterized physical model* of engine-out and tailpipe emissions, using many vehicle specific parameters (An *et al*., 1997; Barth *et al*., 1997; An and Ross, 1996). These data were collected for the Federal Test Procedure (FTP), US06, and MEC01 driving cycles. The MEC01 cycle is comprised of many discrete modal components and was developed by the team at UC Riverside to isolate the emission response of various modal events. On the other hand, Georgia Tech is using a large database of test data from the US EPA and other sources to develop empirical models using advanced statistics such as regression tree analysis. The test data are comprised of a range of both bag emission data and second-by-second data for many different driving cycles. The approach is based in part on the disaggregation of the driving cycle speed profiles into relevant modal components (e.g., high acceleration rates).

Recent research by Georgia Tech has clearly shown the relationship between emissions and acceleration rate, in addition to speed (Bachman, 1998). Imagine the CO, HC, and NOx emission curves embodied in the MOBILE5a and EMFAC7G models plotted as surfaces on a plane defined by speed and acceleration rate, with the vertical axis being emission rate in grams per second (g/sec). Figure 1 is an example of such a surface for HC emissions predicted by MOBILE5a. The work at Georgia Tech has shown that the resulting surfaces have very different shapes to the new curves being developed from second-by-second vehicle tests where emissions are measured as a function of speed *and* acceleration. This work has not been completed and is not published, so it cannot be presented in detail here.

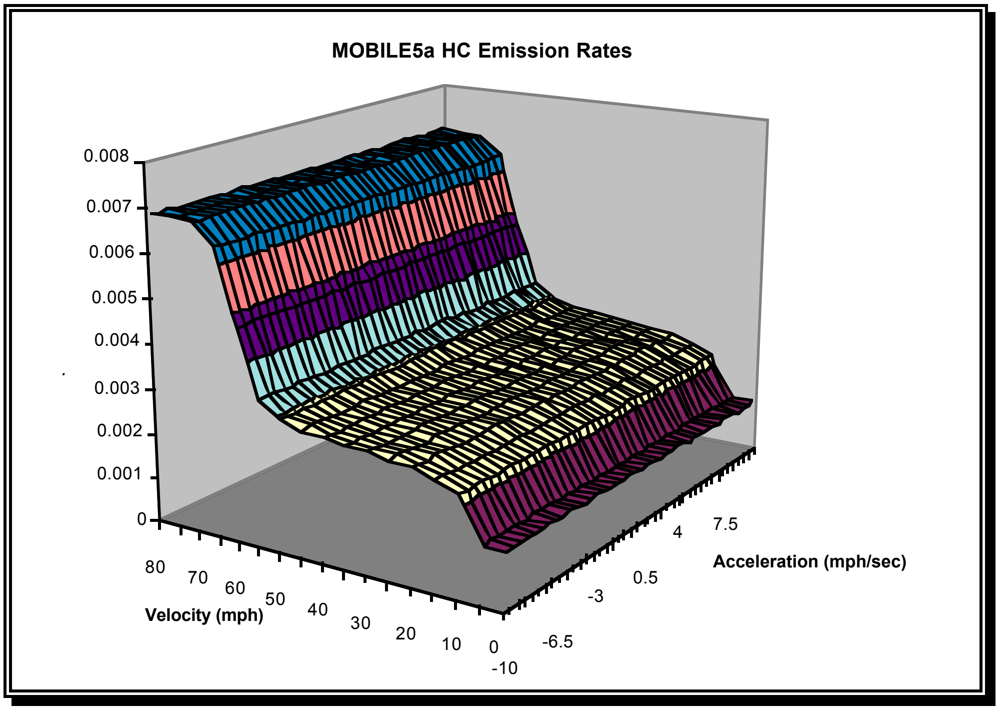

Figure 1: MOBILE5a CO Emission Rates (g/sec) as a Function of Speed and Acceleration

(Source: Bachman, W. (1998). *pers. comm. - Powerpoint file*, January 29, 1998)

The impact of these results is expected to be significant for the determination of the emission benefits of ITS technologies. Early results show that the surface for HC emission rates (in g/sec) may actually be quite *flat* for all values of speed and acceleration, except for a slight hill in the region where both speed and acceleration rate are high. If this proves to be true, the implications for the assessment of emissions from transportation plans will be substantial. It suggests that there is little to no benefit to be gained through flow smoothing, with respect to HC emissions. On the positive side, however, this also shows that there is not likely to be a significant increase in HC emissions as a result of higher travel speeds. Even for high acceleration rates (>5 mph/sec), the potential increase in HC emissions at high speeds appears to be less than 30 percent. This would lead to quite different conclusions than the previous evidence that moving from moderate travel speeds to very high free flow speeds is likely to significantly increase HC emission rates (Guensler *et al*., 1994).

The modal emission model being developed by researchers at the UC Riverside and the U of Michigan is a comprehensive modal emission model for light-duty cars and trucks. It is based on a parameterized physical approach and consists of six modules that predict: 1) engine power; 2) engine speed; 3) air/fuel ratio; 4) fuel use; 5) engine-out emissions; and 6) catalyst pass fraction. The model also accounts for four vehicle operating conditions: 1) cold and warm starts; 2) normal, stoichiometric operation; 3) high-power enrichment; and 4) lean-burn operation.

UC Riverside researchers have recruited and tested 327 vehicles (i.e., representative of the light-duty vehicle fleet), collecting second-by-second tailpipe and engine out emissions. These data have been combined with on-road emission data to formulate and calibrate the emission model. The model has been formulated for different vehicle/technology groups and addresses malfunctioning/high-emitting vehicles.

REVIEW OF THE FOUR ITS TECHNOLOGIES TO BE MODELED

General Description

The review above presented a broad introduction to the literature on ITS and air quality. This section focuses more narrowly on the air quality and emission impacts of four specific ITS technologies evaluated in the analytical sections of this report:

- electronic toll collection (ETC);
- advanced traffic signal coordination (ATSC);
- in-vehicle information systems supplying dynamic, real-time information; and
- in-vehicle navigation, or route guidance, systems.

With respect to these four ITS technologies, previous research indicates that they generally reduce emissions, although caveats apply to each technology and/or its application or both. Table 1 presents a "snapshot" of select findings from previous studies on the environmental impacts of these technologies and applications.

The technologies in Table 1 are arranged into three groups. The first group are "supply-side" enhancements such as advanced traffic signal coordination (i.e., with or without incident detection) and in-vehicle route guidance. The technologies in this group reduce emissions and fuel consumption by increasing highway capacity and, in turn, lead to smoother traffic flow and reductions in congestion-related emissions. The second group of technologies are "demand/emissions management" such as pre-trip ATIS and congestion pricing (i.e., possibly enabled by automatic vehicle identification). These technologies can reduce emissions and fuel consumption by either reducing the amount of travel or encouraging other changes in travel behavior (i.e., encouraging mode shifts or carpooling. The third group consists of bundles of these four ITS technologies, and the environmental benefits from this group result from a combination of strategies that manage supply, demand, and emissions.

The data in this table indicate a general, though not universal, conclusion that the four ITS technologies evaluated in this project are expected to produce emission reductions, and related to this, reductions in fuel consumption and travel during congested peak traffic periods. One study estimates peak period travel reductions of 10 to 15 percent for congestion pricing (i.e., facilitated by ETC). Estimates of fuel consumption reductions due to ATSC and in-vehicle information and navigation systems range from 3.0 to 13.1 percent; estimated reductions in CO emissions range from 5.0 to 13.6 percent; and estimated reductions in HC emissions range from 4.0 to 13.0 percent. Of the emission results summarized in Table 1, only NOx estimates possible increases. Three studies show different results: an increase of 4.2 percent, essentially no change, or a decrease of 13.0 percent in NOx emissions.

This last result highlights the appropriate interpretation of the ranges of impacts shown in Table 1. That is, these results reflect differences in ITS technologies, implementations, and study methodologies—they are not estimates of the range of real world benefits.

Table 1: "Snapshot" Overview of the Environmental Impacts of ITS Technologies

Study	*Environmental Impact Findings*	*Evaluation Method*	*Caveat*
Supply-side Enhancements: ITS Technologies Focusing on Enhancing Highway Capacity			
TRAFFIC SIGNAL COORDINATION			
Abilene, Texas Signal System (International ITS Information Clearinghouse, 1995)	-Fuel consumption: -5.5% -CO emissions: -12.6% -HC emissions: -9.8% -NOx emissions: +4.2%	N/A	-May increase vehicle speeds and result in higher NOx emissions. -Supply-side enhancements that increase highway capacity may induce travel demand.
Automated Traffic Surveillance and Control (ATSAC), Los Angeles Area (Los Angeles Department of Transportation, 1987)	-Fuel consumption: -12.5% -CO emissions: -10.3% -HC emissions: -10.2%	-Emission impacts calculated using factors obtained from the US EPA's MOBILE1. -Fuel consumption impacts obtained from TRANSYT-7F.	Same as above
Automated Traffic Surveillance and Control (ATSAC), Los Angeles Area (Los Angeles Department of Transportation, 1994)	-Fuel consumption: -13.1% -Emissions: -13.6% -Also predicted city-wide ATSAC implementation to result in the following over 15 year period: CO emissions: 8,650 tons (-13.6%) ROG emissions: 1,432 tons (-20%) NOx emissions: 2,022 tons (-13%) CO_2 emissions: 1005,461 tons (-13%)	-Emission impacts calculated using model developed at Texas A&M in 1992. -Fuel consumption impacts obtained from TRANSYT-7F.	Same as above

Table 1: "Snapshot" Overview of the Environmental Impacts of ITS Technologies (cont.)

Study	*Environmental Impact Findings*	*Evaluation Method*	*Caveat*
SCOOT, Toronto (Siemens Automotive, 1995)	-Fuel consumption: -6% -CO emissions: -5% -HC emissions: -4%	N/A	Same as above
IN-VEHICLE ROUTE GUIDANCE			
Comprehensive Automobile Traffic Control System, Tokyo, Japan (Kobaysahi, 1979)	-Fuel consumption: -3% to -7% -CO emissions: -6.5% -HC emissions: -6.2% -NOx emissions: -0.4%	-Conducted in 30 square mile area with 103 intersections. -Route guidance provided to 300 vehicles with two-way communication capability. -Emission impacts calculated using simulation models. -Fuel consumption impacts calculated using "the relationship between gasoline consumption and vehicle speed."	-May increase vehicles speeds and result in NOx increases. -Supply-side enhancements that increase highway capacity may induce travel demand.
FREEWAY INCIDENT DETECTION			
Institute of Transportation Engineers (1989)	-Estimate decreases of 10 to 42 percent in travel delays resulting from traffic congestion attributable to accidents, thus leading to reduced congestion-related emissions.	N/A	-Increased vehicle speeds may increase NOx emissions. -Supply-side enhancements that increase highway capacity may induce travel demand.

Table 1: "Snapshot" Overview of the Environmental Impacts of ITS Technologies (cont.)

Study	*Environmental Impact Findings*	*Evaluation Method*	*Caveat*
ITS Technologies Focusing on Demand/Emission Management			
PRE-TRIP ATIS			
SMARTRAVELER (SmartRoute Systems, 1993): provides travelers with real-time, location-specific traffic and transit information by telephone.	Estimated 1999 emission reductions range as follows: -CO emissions: -2,726 to -7,338 kg per day; -VOCs emissions: -270 to -726 kg per day; -NOx emissions: -14 to -26 kg per day.	-Emission impacts calculated using the US EPA's MOBILE5a emission model. -Study calculated emission impacts by predicting impacts on VMT and speed resulting from expected changes in travel behavior and avoided delay.	-Must gain market share to have significant impact on travel behavior.
PRICING (ETC/AVI)			
National Research Council, TRB (1994)	-Congestion pricing fees of about $0.10 to $0.15/mi could reduce travel during that period by 10 - 15 percent.	N/A	-Formidable political obstacles. -Various concerns about "equity:" -Those most likely to be negatively impacted may be from a broad spectrum of lower and middle income working households least able to make changes in their driving schedules (Giuliano, 1994). -Congestion pricing might negatively affect economic activity in areas where it is implemented (Hodge, 1995).

Table 1: "Snapshot" Overview of the Environmental Impacts of ITS Technologies

Study	*Environmental Impact Findings*	*Evaluation Method*	*Caveat*
Marshall (1994)	-Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area estimates that raising the Bay Bridge toll from $1 to $3 (excluding low-income drivers) during the morning rush hour would reduce traffic by seven percent and, consequently, reduce emissions.	N/A	Same as above
ITS Technology Bundles (mix of "supply," "demand" and emission management)			
PREDICT, Athens Greece (a 1990 field demonstration of environmental optimization that involved emission monitoring technologies, en-route driver information, and signal coordination; project incorporated into ongoing APOLLON field trial) (Castle Rock Consultants, n.d.)	-Evaluators concluded that the demonstrated technologies could reduce vehicular emissions between 4 percent (i.e., for driver information alone) and 50 percent (for all technologies combined).	Used four models to evaluate emission/air quality impacts: -traffic assignment model (PDIAL) -traffic model (TRANSYT) -emissions model (PREMIT) -air dispersion model (unnamed).	

Quantitative Studies of Relevance

This section builds upon the previous "snapshot" overview by providing a more detailed review of some of the literature that has attempted to provide quantitative assessments of the impacts of ITS technologies and user services. It is not intended to be an exhaustive review, but rather it is intended to provide sufficient level of detail for the more extensive efforts to follow. To the extent possible, results in this section are separated into assessments based on the results of field operational tests and those based on modeling studies. However, it should be noted that there is some overlap, due to the fact that some modeling studies have attempted to simulate real-world ITS deployments. Furthermore, many of the conclusions from FOTs have been drawn from the results of modeling studies that have applied data collected during the FOT to simulate the impacts at another level. For example, Van Aerde and Rakha (1996) applied some measures of traffic impacts to simulate environmental impacts.

Field operational tests (FOTs)

A large number of FOTs have been conducted, are currently underway, or are being planned across the U.S. Unfortunately, the focus of most of these tests has been primarily to determine the operational performance and reliability of the ITS technologies themselves, not to evaluate either their traffic or environmental impacts. Some information has been obtained regarding the effects of various technologies on traffic operations and driver behavior, but little effort has been made to directly assess the environmental impact of ITS deployment. This is due in part to the difficulty of actually *measuring* energy and environmental benefits. The only reasonable assessment of the environmental benefits directly from FOT is a highly localized emission measurement at a specific system site, such as an intersection or a ramp meter.

In this section, we summarize here the results of two comprehensive reviews of ITS FOTs. The first of these is the most comprehensive collection of results from FOTs that review the impacts of ITS deployment. This review was performed at Mitretek, and the results are contained in a series of reports from US DOT (Shank and Roberts, 1996; US DOT, 1997; US DOT, 1995d; US DOT, 1996). The most recent of these US DOT reviews (1997) provides qualitative and quantitative evaluations from FOTs and modeling studies. We also summarize a review prepared by Little and Wooster's (1994).

US DOT (1997) discusses the benefits of the application of ITS in the context of the goals of the National ITS Program plan. The goal that is directly relevant to this project is: "Reduce energy and environmental costs associated with traffic congestion." This goal has three primary objectives: "reduce harmful emissions per unit of travel, reduce energy consumption per unit of travel, and reduce new transportation right-of-way requirements."

US DOT (1997) categorizes the benefits data into the following classes:

- *outcome* ("results from field measurement of desired quantities through engineering studies, which are the most compelling");
- *anecdotal* ("output measures or estimates made by people directly involved in field projects, which are compelling, but less reliable in terms of estimated quantitative benefits than they are in measured outcomes"); and
- *predicted* ("results from analysis and simulation, which can be useful tools to estimate the impact of an ITS deployment when field experience is not available or when projects are not of a sufficient scope to determine system impacts").

The table below (from US DOT, 1997) summarizes the availability of benefits data for ATMS, ATIS, APTS, advanced rural transportation systems (ARTS), Commercial Vehicle Operations (CVO), advanced vehicle control and safety systems (AVCSS), and integrated systems (incorporating aspects of ATMS, ATIS, APTS, and possibly ARTS into a single facility or coordinated facilities). The data availability is shown for each of the three classes described above (i.e., outcome, anecdotal, and predicted) and grouped by a few key outcomes, or performance measures (i.e., time, crashes, fatalities, throughput, cost, and customer satisfaction). Notably, environmental benefits are not summarized by US DOT in this report.

Table 2: Summary of ITS Benefits Availability Data

Measure	ATIS	ATMS	APTS	ARTS	CVO	AVCSS	Integrated
Time	Outcome Anecdotal Predicted	Outcome Anecdotal Predicted	Outcome Anecdotal		Outcome	Predicted	
Crashes	Anecdotal Predicted	Outcome Anecdotal		Outcome Anecdotal Predicted	Outcome Anecdotal	Outcome Anecdotal Predicted	
Fatalities	Anecdotal			Predicted	Predicted		Anecdotal Predicted
Throughput	Predicted	Outcome				Predicted	
Cost		Outcome	Outcome Predicted		Outcome Anecdotal Predicted		Predicted
Customer Satisfaction	Outcome Anecdotal	Outcome	Outcome Anecdotal				

Source: US DOT (1997), Table 1

The absence of a summary of environmental benefits for any of these ITS technologies reflects the lack of data. US DOT (1997) addresses energy and environmental benefits at the end of the paper, providing a two page summary of the limited information available. In that summary, Shank concludes that the environmental benefits of ITS services will be modest, with two possible exceptions: "congestion/road pricing and the use of remote sensing technology to detect gross polluters."

In addition, Shank claims that traveler information can have a small positive effect on emissions, citing results from the Boston SmarTraveler ATIS program (Tech Environmental, 1993). The interesting thing to note here is that although the emission reductions were estimated to be significant for participating travelers, only a small proportion of the total number of trips in the metropolitan area were expected to be affected. Hence, the system wide benefits are small.

Little and Wooster (1994) discuss the fundamental elements and relationships that must be considered by FOTs in order to evaluate the emission and fuel consumption impacts of ITS technologies and user services. FOTs with environmental evaluation objectives in the United States, Europe, Japan, and Australia are identified and findings on the environmental impacts of ITS for completed FOTs are discussed. The paper also discusses the State-of-the-practice for environmental evaluation of ITS technologies in field settings, including experimental design, data collection, and analytical methods.

The ATMS-related tests identified in the U.S. include ATSAC (City of LA Department of Transportation, 1994), FAST-TRAC, and SMART Corridor (JHK & Associates, 1992), which all demonstrate the impacts of dynamic signal coordination on arterial traffic flow. The SMART Corridor project also includes testing of dynamic ramp metering. Little and Wooster (1994) briefly describe a range of other tests involving the deployment of ATIS, Emergency Management Systems (EMS), APTS, and CVO technologies and user services.

They conclude that the FOTs with published results indicate favorable environmental impacts for ITS technologies and user services. However, they note that most of these tests address more conventional traffic management user services, such as dynamic signal coordination, and tests of ATIS and APTS user services are not well represented. Little and Wooster reported that the focus of most of the FOTs had been on "technical feasibility and, to a lesser extent, user response." They found that in the U.S. a number of the FOTs were struggling to identify appropriate data collection and analytical techniques to determine environmental impacts. The need and importance of a standard evaluation framework was highlighted to allow proper comparison of ITS technologies.

Similarly, large emission reductions can be achieved at individual ETC facilities; however, the overall benefit (on a corridor- or system-wide basis) is dependent on the frequency of toll plazas. A report by the Clean Air Action Corporation. (1993) estimated the average emission reductions to be 72 percent for CO, 83 percent for HC, and 45 percent for NOx, per mile of impacted operation. However, these results are based on the assumption that the distance involved in the average barrier toll transaction is only 0.55 miles. Hence, the reductions, although large, are highly localized and may be insignificant at the network level. The Clean Air Action Corporation estimates are based on a study of the Muskogee

Turnpike in Oklahoma, Asbury Plaza on the Garden State Parkway in New Jersey, and the Western Plaza on the Massachusetts Turnpike.

Adaptive traffic signal coordination has significant potential for providing energy and environmental benefits. The ATSAC program in Los Angeles California (City of LA Department of Transportation, 1994) reported a 13 percent reduction in fuel consumption and a 14 percent reduction in vehicle emissions. Similarly, the City of Abilene ATSC system (Orcutt Associates, 1994) estimated a 6 percent reduction in fuel consumption, 10 percent reduction in HC emissions, and a 13 percent reduction in CO emissions. In contrast, NOx emissions were estimated to increase by 4 percent.

Modeling studies

Results from FOTs can be useful for studying the potential benefits of ITS deployment. However, it is difficult to make robust comparisons of ITS systems from the performance of FOTs since each environment is different and most test conditions cannot be varied systematically. Hence, the majority of environmental evaluations of FOTs are the result of qualitative assessments, or are made by computer modeling using measures of travel behavior and traffic performance obtained from the FOT.

Simulation models can be very useful tools to study the benefits of various ITS technologies and the benefits of differing configurations of individual technologies. The modeling process enables sensitivity analyses to be performed for key deployment factors. With a modeling tool designed to simulate aspects of ITS technologies, controlled studies can be conducted with different traffic demand patterns, different levels of market penetration, and different optimization strategies. Such simulations can provide information to facilitate the identification of ITS deployment levels and specific strategies that are most likely to have positive measurable impacts on the transportation system.

This section provides a review of several modeling studies that have provided some quantitative assessments of various real-world and modeled deployments of ITS technologies and user services under differing scenarios. It should be noted that all the modeling studies discussed here that applied INTEGRATION used earlier versions of the model than are available now, and some of the limitations of these versions of the model do not exist in the latest version.

US DOT (1995b). "Intelligent Transportation Systems Impact Assessment Framework: Final Report." US DOT, Volpe National Transportation Systems Center, September 30, 1995.

US DOT (1995b) reports the application of the impact assessment framework (described briefly in the section of the report titled "Evaluation Frameworks") to assess the performance of a corridor across a set of five alternative ATMS scenarios. These scenarios were made up of various combinations of fixed time and demand-based signal coordination, with fixed time and synchronized freeway ramp metering. The performance of the corridor under each scenario is compared with that for a baseline configuration (the existing network). The simulations were based on the I-880 freeway and a parallel arterial.

The scenarios considered are as follows (US DOT, 1995b):

- *Scenario 1:* *baseline configuration* in which fixed time signal coordination is based on morning peak volume.
- *Scenario 2:* demand-based arterial signal coordination over a three hour morning.
  Period from 7:00 am to 10:00 am.
- *Scenario 3:* fixed time metered freeway ramps, based on morning peak volume, combined with fixed time signal coordination on the parallel arterial.
- *Scenario 4:* synchronized freeway ramp metering, optimizing free flow, combined with fixed time signal coordination on the parallel arterial.
- *Scenario 5:* synchronized freeway ramp metering combined with demand based signal coordination on the parallel arterial.
- *Scenario 6:* fixed time metered freeway ramps, based on morning peak volume, combined with arterial demand-based signal coordination.

The general conclusion drawn from the results of these simulations was that the application of the ATMS user services provided a general increase in speed and a reduction in total delay. Maximum benefits were achieved with the simultaneous implementation of signal coordination on arterial streets and ramp metering on freeway facilities. However, despite the increased speeds and reduction in total delay, the impact on various measures of effectiveness (MOEs, including fuel consumption, CO, HC, and NOx emissions, numbers of accidents and injuries) on the parallel arterial varied widely for each scenario tested. The nature of the signal coordination (fixed or dynamic) had a marked effect on the parallel arterial performance. However, the freeway data indicated that most of the scenarios tested influence freeway operation in a consistent manner. The only exception was Scenario 2 (arterial dynamic signals), which produced very different results (in terms of MOEs) due to the absence of any form of ramp metering. The benefits of ramp metering were found to be significant reductions in delay without encountering increases in congestion. Average speeds increased and emissions of CO and HC both decreased. However, fuel use and NOx emissions increased, as did the number of accidents and injuries.

Bacon Jr., Vinton W., Windover, John R., and May, Adolf D. (1995). "Investigating Intelligent Transportation Systems Strategies on the Santa Monica Freeway Corridor." PATH RR, UCB-ITS-PRR-95-38, November 1995.

Bacon *et al*. (1995) focused on the impact of in-vehicle information systems (IVIS) with two different levels of information quality (i.e., perfect information and distorted information) under non-incident and various incident conditions (i.e., minor and major incidents).

The modeling effort centered around the INTEGRATION model (i.e., versions 1.5d and 1.5e). Much effort was expended in attempts to calibrate the INTEGRATION model for the Santa Monica Freeway corridor network. Calibration of only fourteen of the twenty-eight time slices that were planned to be simulated was attempted, and only six of these were successfully calibrated. This was the first attempt to calibrate a network of this size and complexity with the INTEGRATION model or an equivalent model.

Based on this experience, they highlighted the importance of complete and accurate data sets for simulation modeling efforts. Unavailable and incomplete data were cited as the main reason for difficulties experienced during the calibration process. Critical data needs include:

- freeway on-ramp and off-ramp volumes and freeway-to-freeway connector volumes;
- freeway performance measures, such as temporal and spatial velocity patterns; and freeway end-to-end travel times (i.e., collected during the freeway data collection efforts); and
- signalized intersection turning movement volumes for arterial roads.

A warning was issued that "future simulation projects should be very conservative in their estimation of the effort required for data collection and coding, model testing and calibration, and investigations. The effort required to simulate a network is directly proportional to the size (i.e., both temporal and spatial) and complexity of the network."

One of the limitations encountered with the INTEGRATION model was the inability to establish a run with the network loaded entirely with unguided vehicles. Hence, the base run for the ATIS investigations was carried out with a network loaded entirely with guided vehicles.

The research by Bacon *et al*. (1995) also highlighted the difficulty that detailed simulation models (such as INTEGRATION) have in determining origin-destination demand patterns. Hence, it was recommended that a travel demand model be applied to generate origin-destination matrices for future simulation exercises.

These investigations revealed that for a minor incident, a 100 percent IVIS system could offset the adverse traffic effects. However the effect of the major incident was only partially offset by all vehicles in the system being guided vehicles. Bacon *et al*. (1995) did not comment on how the results might change if not all vehicles were guided.

There is a generally accepted theory that a threshold exists for increasing benefits from the penetration of IVIS technologies. Glassco *et al*. (1996) State that "the value of information to the ITS user decreases as the proportion of the population receiving that information increases. The value of information to the overall system, however, generally increases as the proportion of the population receiving that information increases." The exception to this is when a very large proportion of the population reacts to the information, in which case the system performance may decrease. Gardes and May(1993) found that more than half of the system benefits resulting from the presence of guided vehicles on a portion of the Santa Monica Freeway corridor was possible with the first five percent of guided vehicles. An average travel time savings of 3.8 percent resulted from the presence of five percent guided vehicles, compared to 5.6 percent for 25 percent guided vehicles, and 6.2 percent for 100 percent guided vehicles. Additionally, Gardes and May (1993) found that the travel time benefits of route guidance were similar under incident and non-incident scenarios.

Another interesting finding of the study by Bacon *et al*. study (1995) was the conclusion that the effect of "distorted" information on total trip time was almost as adverse as a major incident upon which motorists receive perfect information.

Despite the difficulties encountered with applying the INTEGRATION model, Bacon *et al*. (1995) still considered it to be the most suitable model for such studies. Unfortunately, this same study made no attempt to assess the environmental impacts. Nevertheless, this project team intends to consider extending their work to evaluate energy and environmental impacts.

Glassco, R.A., Proper, Allen T., Salwin, Arthur E., and Wunderlich, Karl E. (1996). *Studies of Potential Intelligent Transportation Systems Benefits Using Traffic Simulation Modeling*, prepared for FHWA, Mitretek, McLean, Virginia, June, 1996.

Glassco *et al.* (1996) report on five studies performed by Mitretek Systems, Inc. to analyze the potential benefits of ITS deployment. The studies focused on the following four ITS user services:

- en-route driver information (ATIS);
- route guidance (ATIS);
- pre-trip travel information (ATIS); and
- traffic control (ATMS).

These studies applied the INTEGRATION and THOREAU simulation models and Mitretek's Smart-Shift Framework in a typical urban (i.e., using the Urbansville network from the ITS Architecture project) and inter-urban scenarios (i.e., using the Thruville network) scenarios and to study sensitivities related to travel demand, levels of market penetration, incident severity, incident type, and different strategies for adaptive signal control.

Mitretek's evaluations consistently measure ITS benefits from the baseline of an efficient and optimized but non-adaptive system. Hence, Glassco *et al*. (1996) note that the potential benefits for non-adaptive systems that are not optimized may be greater than those estimated in their modeling studies.

Glassco *et al*. (1996) found that adaptive signal control strategies and traveler information services have positive impacts on user and system efficiency for both recurrent congestion and non-recurrent congestion scenarios. However, the modeling studies revealed greater benefits resulting from these ITS user services, under non-recurrent congestion conditions (e.g., during incidents or periods of unexpected heavy demand). One specific finding was that vehicles that bypass incidents in an inter-city corridor network due to a route guidance system can reduce travel delays by 50 percent or more.

The potential benefits (i.e., a reduction in travel time and delay) of the ITS user services modeled were found to be greater when the network experiences a greater deviation from expected conditions. Hence, these ITS technologies may be most beneficial for a highly variable transportation system. In a highly predictable system, traffic control systems and travelers tend to adapt their plans according to the anticipated congestion. This process can take place without the influence of ITS technologies such as traveler information services.

One of the interesting key findings of the study by Glassco *et al*. (1996) is that "the value of traveler information is proportional to the value of the alternative opportunities available. When the time required to follow an alternate route or to shift mode is high, then the timeliness and accuracy of travel time prediction is more critical." This would implies that pre-trip information (e.g., information available on a WWW page or on television) has greater potential for providing benefits than en-route information, as once a traveler has started a trip he is not likely to have the opportunity to change mode, and by definition the number of route choices decreases for any trip as the traveler gets closer to the destination. In addition, once the trip has begun, the choice has already been made to make the trip at that time. If information was provided prior to the trip, warning of high levels of congestion, travelers have the option of postponing or even canceling the trip.

Glassco *et al*. (1996) concluded that perhaps one of the most positive results of their studies of ATIS user services was that a relatively small number of probe vehicles are needed to support adequate network surveillance. They found that an unguided probe population as low as one percent can provide over 50 percent of the benefit of full surveillance, and that the value of route guidance with low probe percentages can be increased by updating travel times more frequently than every ten minutes. It is more effective to use unguided vehicles as probes than guided vehicles, since if all guided vehicles are being routed around an incident, the route guidance system does not learn that congestion has dissipated when the incident is cleared.

Van Aerde, M. and H. Rakha (1996). *TravTek Evaluation Modeling Study*, prepared for FHWA, Publication No. FHWA-RD-95-090, March, 1996.

Van Aerde and Rakha (1996) present the methodology and results of a modeling study of the Orlando TravTek operational field test. This test involved the deployment of 100 vehicles equipped with in-vehicle information systems (IVIS) for a one-year period. The modeling study attempted to extrapolate from the available field data the expected performance of a TravTek type system for levels of market penetration ranging from one percent to 100 percent, in terms of measures of effectiveness such as vehicle stops, fuel consumption, vehicle emissions, and accident risk.

The Orlando TravTek network consisted of 2,700 links and 90 origin-destination (O-D) zones, with a traffic loading of approximately 65,000 vehicles. The INTEGRATION model (version 1.6) was used to simulate recurring congestion scenarios and freeway incidents for the afternoon peak period, with a small number of simulations of increased and reduced traffic demand to represent future and off-peak conditions, respectively. Consistent with findings by Glassco *et al*. (1996), travel time benefits were found to be greater for the higher levels of congestion. An interesting finding relating to the much debated issue of latent demand, was that the LMP can be increased to provide travel time savings that have the potential to offset much of the induced demand that may be generated.

Travel time reductions were found for all levels of market penetration (LMPs) analyzed; however, the most significant marginal benefits were achieved at lower market penetration levels. The maximum reduction in travel time was found to occur for a LMP of 100 percent, where the network travel time saving was 15 percent.

In addition to travel time savings, the study considered travel distance savings and found that a 7 percent reduction was possible at an LMP of 100 percent. En-route traveler information can have two conflicting effects on travel distance: distance traveled can be reduced by route guidance information which minimizes navigational errors, and distance traveled may be increased when users receive real-time traffic information and subsequently divert around an incident.

The fuel consumption benefits of the TravTek system were predicted to be proportional to the travel time savings, with respect to the various LMPs. The magnitude of potential fuel consumption benefits is related to the topology of the network. That is, if when an incident occurs there are alternative routes available with little or no increase in travel distance, the potential for energy savings is greater. This is similar for emission benefits; however, the relationship between vehicle emissions, and traffic conditions and distance traveled is much more complex than for fuel consumption.

HC emissions were found to decrease for all LMPs, with a maximum of 16 percent being achieved at a LMP of 100 percent. CO emission increased up to three percent for LMP’s less than 10 percent, and then decreased up to seven percent for LMP’s up to 100 percent. Van Aerde and Rakha (1996) claimed that ATIS may tend to always cause an increase in NOx emissions—they predicted increases in NOx of up to five percent, with the only reduction being one percent at an LMP of 100 percent.

Johnston and Rodier (1996). "Travel, Emissions, and Consumer Benefits of Advanced Transit Technologies in the Sacramento Region." Report prepared for PATH, ITS-Davis, July, 1996.

Johnston and Rodier (1996) used the Sacramento Regional Travel Demand model (SACMET 95) to simulate the travel effects of advanced transit technologies in the Sacramento region. Output from the SACMET model was then used as input for the California Department of Transportation's Direct Travel Impact Model (DTIM2) and the CARB's EMFAC7F emission factor model to estimate emission impacts of each scenario. The scenarios considered included:

- advanced transit information (ATI);
- ATI combined with demand responsive transit (DRT);
- ATI combined with personal rapid transit (PRT); and
- ATI, DRT, and PRT.

Analyses showed reductions in daily emission projections for all of the modeled scenarios. However, the estimated reductions were *small* (i.e., between 0.18 to 0.46 percent) and probably insignificant given modeling uncertainty. As an hypothesis for further research, the authors offer the following: "The results of this study suggest that advanced technologies acting as feeder service to rail or line-haul transit service may not result in a significant reduction in congestion or emissions in the Sacramento region. We hypothesized that this result was due primarily to limited market penetration of light rail service in the Sacramento region."

Apogee Research, Inc. (1997a). "Reader, Expert Panel Session: Emissions and Fuel Consumption Impacts of ITS," Apogee Research, Inc., January 16, 1997.

Perhaps the most extensive contribution to the evaluation of the environmental impacts of ITS deployment will come from the work briefly introduced below.

The US EPA has commissioned Apogee Research to construct an evaluation framework to quantify the fuel consumption and emission impacts of ITS deployment. In particular, the evaluation framework is aimed at assessment of the ITS in the four cities selected for the metropolitan Model Deployment Initiative (MDI); namely, Seattle, San Antonio, New York City, and Phoenix. A relatively extensive ITS infrastructure already exists at each of these sites, and MDI plans focus on expansion of the existing infrastructure and integration across systems. The evaluation is to be performed by Michel Van Aerde of Queen's University, a subcontractor to the SAIC evaluation team under contract with the ITS Joint Program Office of the US DOT. Dr. Van Aerde is also the developer of the

INTEGRATION simulation model, perhaps the most advanced model available for simulating the effects of ITS deployment.

Apogee Research convened an Expert Panel (Apogee Research, 1997a; 1997b), which met at the US DOT in Washington, DC, on January 16, 1997, to provide input on the types of analytic tools that are available for quantifying the fuel consumption and emission impacts of ITS deployment. One of the objectives of the Expert Panel was to identify the most effective models for evaluating ITS impacts and to identify the types of data that must be collected to support those models.

The findings and conclusions of the expert panel were presented in a later document produced by Apogee (1997b). The work related to this effort on the MDI plans is being carefully monitored by the project team.

Qualitative Studies of Relevance

A study by Ostria (US DOT, 1995a; Ostria and Lawrence, 1994) provides qualitative assessments of the potential short- and long-term, corridor- and regional-level impacts of ITS technology bundles. The technology bundles include:

- traffic and incident management systems,
- route guidance systems,
- accident reduction systems,
- vehicle control systems,
- commercial vehicle inspection systems,
- trip guidance and public transportation systems,
- enabling technologies for travel fees, and
- emission control enabling technologies.

The impacts are defined as:

- *positive* (reflecting improvements in traffic flow, reductions in number of vehicle trips or trip distance, or mode shifts from Single Occupancy Vehicles (SOVs) to high Occupancy Vehicles (HOVs);
- *negative* (reflecting increases in congestion, vehicle trips or trip distance, or mode shifts from SOVs to HOVs);
- *insignificant* (reflecting no (or very small) changes in traffic flow, vehicle trips or trip distance, or mode shifts); or
- *uncertain* (those for which changes in traffic flow, trip making, trip distance, or mode cannot even be qualitatively assessed given the current State of knowledge).

The assessments are based on: 1) relevant studies conducted by academia and government; 2) a video conference on ITS and air quality held on March 8, 1993; and 3) results from the National IVHS/Air Quality Workshop hosted by the South Coast Air Quality Management District on March 29-30, 1993 (Horan, 1993).

Ostria gives the highest environmental awards (i.e., positive impact for all three emission types: HC, CO, and NOx) to *commercial vehicle inspection systems* for short-term corridor-level impacts, and *emission control enabling technologies* for both corridor-level and regional-level impacts in the short term. The same is true for long-term impacts, with the addition of *enabling technologies for travel fees* at both the corridor and regional levels.

According to US DOT (1995a), the most uncertainty (i.e., uncertain impact for all three emission types) lies around *traffic and incident management systems* and *enabling technologies for travel fees* for short-term, corridor-level and short-term, regional-level impacts, respectively.

Summary of Emissions Impacts Assessments

FOTs have provided little direct evidence of emission impacts of ITS in general, but they do provide some insights to ETC and ATSC. The US DOT's comprehensive review of data available from FOTs does not even classify emissions or other environmental impacts in their summary table. Other FOT reviews do extract some limited results specific to ETC and ATSC and other traffic flow control systems, but echo the DOT's general conclusion that FOTs have provided limited insight into environmental impacts. Little and Wooster (1994) reported that the focus of most of the FOTs had been on "technical feasibility and, to a lesser extent, user response." Further, they note that most of these tests address more conventional traffic management user services, such as dynamic signal coordination.

ETC facilities are one of the types of ITS technologies for which FOTs have produced emission assessments. Large emission reductions can be achieved at individual electronic toll facilities; however, the overall benefit (i.e., on a corridor- or system-wide basis) is dependent on the frequency of toll plazas. The reductions, although large, are highly localized and may be insignificant at the network level. ATSC has shown significant potential for providing energy and environmental benefits in more than one FOT.

Modeling results support the FOT conclusions regarding ETC and ATSC and provide additional insight for traveler information and vehicle guidance. Results reported in US DOT (1995b) show that the application of the ATMS user services provided a general increase in speed and a reduction in total delay, although they do not analyze emissions specifically. Maximum benefits were achieved with the simultaneous implementation of signal coordination on arterial streets and ramp metering on freeway facilities. Glassco *et al*. (1996) found that ATSC strategies and traveler information services have positive impacts on user and system efficiency for both recurrent congestion and non-recurrent congestion scenarios. However, the modeling studies showed greater benefits resulting from these ITS user services under non-recurrent congestion conditions (e.g., such as during incidents or periods of unexpected heavy demand).

Modeling results reveal mixed results for navigation and traveler information systems. Analysis of Orlando's TravTek network indicated varying levels of travel time, travel distance, and emissions effects depending on levels of market penetration. HC emissions were found to decrease for all LMPs, with a maximum of 16 percent being achieved at a LMP of 100 percent. CO emission increased up to three percent for LMPs less than 10 percent, and then decreased up to seven percent for LMPs up to 100 percent. Van Aerde and Rakha (1996) claimed that ATIS may always tend to cause an increase in NOx emissions. They predicted increases in NOx of up to five percent, with the only reduction being one percent at an LMP of 100 percent.

Market Penetration Estimate Studies

Many researchers are trying to estimate the market for various ITS technologies. Three methods that are popular for estimating the market for ITS technologies include: focus groups with potential market segment members, interviews, focus groups and surveys of ITS experts, and evaluations of the traveler response to ITS demonstration programs (e.g., SmarTraveler in Boston). Without actual data and experience, it becomes virtual impossible to accurately predict the market for single and multiple ITS products and services.

In market and traveler behavior research, the more innovative the solution or the farther into the future an innovation will be introduced, the more researchers must rely upon survey research methods and participant responses to experimental situations to understand the types of impacts that are probable or even possible. Turrentine and Kurani (1998) conclude that an experimental situation will often elicit and engage the decision processes of its participants and reveal participant lifestyle goals. Decision processes are often initiated by the presence of a new technology in the marketplace. Based on their new technology experience, Turrentine and Kurani (1998) conclude that current Stated preference survey methods often produce inaccurate estimates of the demand for unknown and new technologies. Other methods such as interactive Stated response when presented in the context of a household's actual activity space and modal split data can produce more accurate demand estimates.

In market evaluations of electric vehicles (EVs), many Stated preference studies often estimate huge price penalties for limited-range vehicles (e.g., Beggs and Cardell, 1981, and Morton *et al*., 1978). In general, these studies rely on data from hypothetical-choice experiments in which participants are presented with choice sets of the vehicle. Then, participants are asked to identify the one vehicle, from each of the choice sets, they would be willing to purchase. All vehicles are described by attributes that are common to all of the study vehicles, e.g., range. The attribute levels are varied over several trials to elicit different choices. With these data, econometric models are run to estimate the partial utility values for consumer preferences of each attribute

Turrentine and Kurani (1998) argue that the underlying assumptions of consumer behavior in many EV Stated preference studies are flawed. These studies assume that the survey respondents have well-formed preferences for driving range, for example. Second, they assume that these preferences remain stable to forecast changes in preferences (or there must be enough longitudinal data). Finally, these studies evaluate several vehicle attributes, which study participants have not yet experienced. Consequently, it is very difficult to explore the market for unknown technologies.

Demonstration projects can provide a useful platform for examining early reactions and traveler responses to new transportation technologies. In the absence of such field studies, many researchers rely upon Delphi techniques--repeated queries of a panel of respondents--to explore the potential market for ITS technologies. In this evaluation, researchers conducted a modified Delphi evaluation of the market for various ITS technologies to construct the ITS scenarios, which include market penetration estimates, that will be used in the modeling exercise in this study. The modeling results will be used to identify and prioritize a range of ITS technologies on the basis of a set of energy and environmental criteria.

The degree to which individuals and organizations use or purchase ITS goods and services or both has direct effects on environmental implications of ITS. Zimmerman (1994: p. 1), for example, correctly notes that debates over likely environmental impacts of ITS include:

> "assumptions, expectations, and projections about the users of [ITS] technologies. These [ITS] users will, by virtue of the travel behavior they exhibit, have an impact on environmental quality. Despite this fundamental linkage between users and the environment..., basic questions remain unanswered, such as how many people will use [ITS] technologies, how will they change their travel behavior, what motivates those changes, and what are the impacts of those changes on environmental conditions?"

Results from ITS operational tests underscore the importance of user acceptance in estimating the environmental impacts of ITS. For example, the SmarTraveler project in Boston (i.e., an ATIS FOT) found that nearly half of those who used the services changed their travel behavior in ways that could reduce traffic congestion. Nevertheless, system usage remained "too low by any measure to provide noticeable impacts on congestion" (Multisystems, 1995). As cited above, Van Aerde and Rakha (1996) showed for Orlando's TravTek that emission impacts were a function of market penetration, and could even switch from negative to positive depending on market penetration.

This section presents an overview of various market penetration estimates that have been made for the ITS technologies examined in this study. This is followed by an overview of select market research studies of these technologies. The market penetration results presented here serve as context and comparative points for the estimates we produced in our modified Delphi study. As with the emission studies reviewed earlier, each of these market studies was conducted using differing methods and a variety of ITS descriptions. As mentioned above, One common methodological approach has been the use of Delphi techniques. This technique is designed to facilitate the convergence of the estimates provided by experts.

It is important to note that various studies define market penetration differently. Some estimate the number of vehicles on the road that are equipped with a specific technology, others estimate the percent of VMT affected by a particular ITS system. Such differences are appropriate to different ITS technologies. In our research, we use the following measures of market penetration:

ETC: Percent of lanes in toll facilities that are ETC equipped;

ATSC: Percent of all signals along different corridors that are coordinated; and

In-vehicle information and navigation: Percent of vehicles that are equipped with such technology and the percent of users who respond to the information.

*1) National ITS System Architecture, "Urbansville"** Scenario*

Table 3: Market Penetration Estimates from ITS Architecture

Technology	Equipment Package	Market Penetration Estimate Ranges 10 year low		10 year high
ATIS				
Pre-trip	*Personal Basic Information Reception*	0.50%	(Users)a	2.00%
	Personal Interactive Information Reception	3.00%	(Users)	5.00%
en-route	*Personal Route Guidance*	5.00%	(Users)	10.00%
	Vehicle Route Guidance	2.00%	(TVs)b	7.00%
Freeway Incident Detection	*TMC Incident Detection*	100.00%	(TMCs)c	100.00%
ETC/AVI	*Toll Plaza Toll Collection*	100.00%	(Booths)d	100.00%
	Vehicle Toll/Parking/I/F	2.00%	(TVs)	10.00%

**The specific equipment packages used in our study may vary somewhat as we progress in our modeling efforts.
a. % of persons using personal travel information
b. % of total vehicles
c. # of transportation management centers, 3 such centers in an urban area equals 100% penetration
d. % toll booths equipped with ETC/AVI capability

2) Cheslow, Melvyn (undated). Estimates for 2000 and 2010. Mitre Corporation, Washington DC.

Cheslow (*undated*) used Delphi methods from the University of Michigan (Underwood *et al.*, 1991) as well as estimates from other sources to derive market penetration rates for large and small urban areas. Market penetration was defined as total VMT, while affected by the ITS technology bundle. The results are presented in Table 4 below.

Table 4: Estimated Market Penetrations for ATMS and ATIS by 2000 and 2010

	Large Urban Areas		Small Urban Areas	
Technology	**Year 2000**	**Year 2010**	**Year 2000**	**Year 2010**
ATMS	20%	60%	0%	20% (40% for arterials & freeways)
ATIS	10%	40%	2%	20%

3) Cole, David (1994). Cited in Richardson (1994)

Cole (1994) also used DELPHI methods and defined market penetration as the percentage of new vehicle sales sold in the U.S. that include the ITS technology (i.e., presumably an AVI tag or transponder for ETC). Table 5 shows Cole's estimates.

Table 5: Market Penetration Rates for ATIS and ETC by 2003

Technology	**Market Penetration by the Year 2003**
ATIS	10%
ETC	5%

4) Owen, Stephen (1996). "Forecast of the U.S. Advanced Traveler Information (ATIS) Market." Frost & Sullivan

Owen (1996) used various methods and conducted a comprehensive review. Owen defined market penetration as the percentage of new cars sold in the U.S. with ATIS.

Table 6: Market Penetration Rates for ATIS by 2002 and 2010

Technology	**Market Penetration by 2002**	**Market Penetration by 2010**
ATIS	2.5%	15%

5) Drumheller , Bill (1996).

Drumheller conducted a comprehensive review of ITS market penetration literature; the results are presented in Table 7 below.

Table 7: Summary of Market Penetration Estimates Collated by Drumheller (1996)

Technology	Market Penetration Estimate	Justification
ATIS	Conservative estimate that no more than 25% of commuters that regularly use a given route are subscribing to system (despite higher percentages indicated in WTP studies)	• Two best studies to date, Harris & Konheim (1995) and Gourdin and McIntyre (1991) support both this price range and monthly service. • Selection bias appears to inflate WTP studies. 25% penetration a compromise figure between DELPHI results, WTP results and market studies, but this a highly uncertain figure.
ATSC	Assume ~2,200 lights in CA to be affected by 'advanced' traffic signal coordination that is more advanced than simply signal retiming. This is approximately 1/8 of the signals in CA. No assumption regarding ramp metering due to lack of data.	• Estimate based on Deakin (1985): 31% of jurisdictions interested in FETSIM program, 6,500 'high' priority lights, so roughly (1/3)(6,500) are estimated lights to be affected. • These estimates seem roughly in line with MITRE estimates. Lack of data prevents extrapolating result to highway metering lights. • This is judged to be a conservative estimate. What is highly uncertain is how 'advanced' any modifications will be to the traffic signals.
ETC w/AVI	Assume a $15-20 tag deposit, then for Bay Area assume ~90% of commuters use system and for the rest of CA assume ~50% where commuters use tollways. Given the varied data it does not make sense to estimate a single level of market penetration for the whole country since interest in ETC seems to vary substantially form one toll area to the next (presumably due to varying levels of congestion).	• Bay Area estimate based on Yim (1991). Some selection bias but statistically significant results at the 95% confidence level seem to justify the very high usage assumption for regular commuters. • *No* assumption for non-regular traveler due to lack of data. • 50% figure is highly uncertain and is based on median results from ETC studies mentioned above. This is a loose assumption but seems justified by the WTP trends that fall in this price range.

Overview of Market Research Studies on the Technologies to be Modeled

Partial list of Market Research Findings on Electronic Toll Collection

Author(s)	Subjects/ Methodology	Potential Market Size	Willingness to Pay Info.	Key Findings/Notable Quotes
Parish, Thomas R. "Case Studies of Market Research for Three Transportation Communication Products." Prepared for John A. Volpe National Transportation Center and Federal Highways Administration. March 1994. Washington DC: U.S Department of Transportation.	Surveyed market research done on electronic toll collection by various entities, including: EZ Pass research done by Port Authority of New York and New Jersey for EZ Pass electronic toll system in the NY/NJ/PA area (1990 survey: 12,00 distributed & 900 returned); Virginia DOT survey for the Dulles Toll Road; AT/Comm's survey of Route 93 users in New Hampshire (mail survey of 10,00 users on Route 93)	• "The market research on ETC does not result in any clear general conclusions about the expected penetration rates...The forecast penetration rate is dependent on the details of how specific ETC system was described, the present commuting environment, and numerous other factors." • At the Toll Authority level: Potential market is the entire universe of toll facilities. In U.S., this amounts to 55 authorities, "with a likely minimum of at least 1,000 individual toll booths."	• AT/Comm's Route 93 survey found that nearly 50% of users would use ETC with a $15 charge for the tag and no discount on the toll. Slightly greater than 80% would buy tag if it were $15 and had a 25% discount on tolls. • Dulles Toll Road Survey: 37% of users would "definitely join" with no incentives on the tolls or tag. 59% would "definitely join with a $10 incentive.	• General finding from Parish: 1992 survey revealed ETC to be one the fastest growing ITS applications; at that time, at least 7 operational ETC systems in the he United States, with 17 agencies planning ETC systems and four agencies "planning" such systems. • Unique market structure: ETC has two distinct and a third "hybrid" levels of customer groups: *Commercial aspect*: toll authorities the primary customer, especially for toll plaza hardware, communications system, and accounting intelligence, and may be primary customer for vehicle tags. *Consumer aspect*: end users, i.e. the driving public; consumer is the customer for the service provided and often for the tag. "Ultimately, it is consumers who will determine the success of ETC through their acceptance or rejection of the characteristics of the service and equipment that is provided."

Partial list of Market Research Findings on Electronic Toll Collection (cont.)

Author(s)	Subjects/ Methodology	Potential Market Size	Willingness to Pay Info.	Key Findings/Notable Quotes
Parish (1994) (cont'd.)				*Private Toll Road Operators*: "Companies funding and operating the roads must account for both the commercial and the consumer aspects in order to assure themselves that the use of ETC equipment does not inhibit their ability to meet their required traffic volume needs."
Mitre Corporation. 1996. "Intelligent Transportation Infrastructure Benefits: Expected and Experienced." Sponsored by Federal Highway Administration. Washington DC: US DOT		• Twelve authorities currently using ETC, with two more scheduled to be operational by the end of 1995.		
Shank (1995)		• By the end of fifteen months of operation NY Thruway distributed over 90,000 tags.		

Partial list of Market Research Findings on Electronic Toll Collection (cont.)

Author(s)	Subjects/ Methodology	Potential Market Size	Willingness to Pay Info.	Key Findings/Notable Quotes
Yim, Youngbin. 1991. "Consumer Responses to Advanced Automotive Electronics: Electronic Toll System - User Survey." *Transportation Research Board 71st Annual Meeting, January 12-16, 1992.* (Paper #920363) Washington DC.	Survey population was Bay Area bridge users who were mailed survey w/follow up phone call (n=5,095).	• Cited many studies: • In Oklahoma Turnpike Authority study, 56% of survey respondents interested in using ETC. • In IL State Toll Authority study, 69% of survey respondents interested in using ETC. • In FL Dept. of Transportation study, 67.4% of survey respondents interested in using ETC. • In VA Dept. of Trans Study, 65% of survey respondents interested in using ETC. • In Yim's own study, 82.4% of survey respondents interested in using ETC	• Cited many studies, including: • Port Authority of NY and NJ, 1990: 47% would use system if tag price is between $35-50 (or $30-50 w/discount toll) and 48% would sue system if agency pays for tag. • Il State Highway Authority, 1989: 4% would use system if tag price between $50-60, 28% if tag price between $35-50, and 50% if tag price between $20-35. • Yim's own study, 1991: 88.5% of respondents would use system with $30 tag deposit, 93.8% would use system with $15 deposit, 95.5% would use system with $5 deposit.	

Partial list of Market Research Findings on Advanced Traffic Management Systems (ATSC/ATMS)

Author(s)	Subject	Potential Market	Willingness to Pay Info.	Key Findings/ Notable Quotes
Mitre Corporation. 1996. "Intelligent Transportation Infrastructure Benefits: Expected and Experienced." Sponsored by Federal Highway Administration. Washington DC: US DOT	TMC study	• Listed 6 State and/or regional integrated transportation management centers (TransGuide Control center in San Antonio, State of Maryland CHART Operations Center, Montgomery County Traffic management Center; Michigan Intelligent Transportation Systems Center in Detroit; Houston TranStar Center; and Atlanta Advanced Traffic Management Center to be operational by 1996 Summer Olympics).	None.	
Deakin, Elizabeth A., Alexander Skabardonis, and Christine E. Monsen 1985. "Market Potential for the Fuel-Efficient Traffic Signal Management Program: Findings from Surveys of California Cities." *Working Paper UCB-ITS-WP-85-6*. Institute for Transportation Studies, University of California, Berkeley, June 1985.	ATSC study	• 31% of public officials surveyed in CA Stated that they would be interested in future participation in the Fuel Efficient Traffic Signal Management Program • roughly 6,500 'high priority' and 8,300 'low priority' signals could be retimed in California (with 'low' and 'high' based on FETSIM eligibility criteria)	None.	
US Government Accounting Office. 1994. *Transportation Infrastructure: Benefits of Traffic Control Signal Systems are Not Being Fully Realized*. GAO/RCED094-105, March 1994.	ATSC study	• See potential market as 240,00 signalized intersections in the U.S.	None.	• 30,000 need improved signal timing; 148,000 also need equipment

Partial List of Market Research Findings on Advanced Traveler Information and Vehicle Navigation Systems

Author(s)	Methodology & Traffic Info Examined	Potential Market Size	Willingness to Pay Information	Key Findings
Ben-Akiva *et al.* (1993)	Reviews methodology and scope of consumer acceptance research		• Research has not been conducted in realistic market environment so it's difficult to use.	• Develops model of traffic information awareness and access, usage and response and learning. • Most previous research focuses on usage and response. • Evaluates the pros and cons of using surveys, travel simulators and operational tests in consumer acceptance.
Gaurdin & McIntyre (1992)	Telephone survey of interest in advanced traveler info; focused on commuters; primarily en-route, although pre-trip also examined		• Average willing to pay $14/month. • Middle/Upper income were very interested	• Interested in info on accident sites, congestion and alternate routes.
Green & Brand (1992)	Focus group on interest in advanced traveler info; en-route		N/A	• Preferred directions based navigational system over map based system • Interested in warning lights that could head off serious mechanical problems • Interested in hands free cellular phones
Lappin *et al.* (1994)	Develops a model of the traffic information business		• Increasing proximity of payment of traffic info towards the consumer. • Traffic information may be bundled.	• Radio broadcasts of traffic information appeal to all ethnicities and SES levels and are thus attractive to advertisers. • Model of traffic info consists of data gathering, data processing, info broadcasting and the consumer.

Partial List of Market Research Findings on Advanced Traveler Information and Vehicle Navigation Systems (cont.)

Author(s)	Methodology & Traffic Info Examined	Potential Market Size	Willingness to Pay Information	Key Findings
Parrish (1994)	Evaluates previous market research for other transportation technologies		• Easier to be accurate with commercial customers than private consumers. • Consumers willing to pay for time savings. • Willingness to pay influenced by economic and non-economic forces. • Consumers prefer monthly to up-front payments.	• Very difficult to accurately assess consumer's needs. • Recognize multiple customers and stakeholders. • Needs change over time. • Do not over promise to the consumer. • Single product firms will experience more risk in developing a new product than multi-product firms.
Perez *et al.* (1993)	Travtek: Operational evaluation of services and navigational technology; en-route focus		• 50% of the users were willing to pay $1000 or more • 30% were willing to pay over $1195 as option on new car.	• Higher satisfaction for navigational systems over service systems only. • Navigational system helped drivers find way and pay attention to driving. • Increased feelings of safety and decreased time to destination. • Voice guidance was used in over 90% of time navigational system was used.
Polak & Jones (1993)	Revealed preference using model of simulated travel estimates; pre-trip		N/A	• Drivers inquired about preferred modes and times of departure first, then examined alternates. • Examined only a few alternatives; few examined a range of potential travel options. • Commuters changed either mode but not time of departure or changed time of departure but not mode. • Non-work travelers were much more flexible.

Partial List of Market Research Findings on Advanced Traveler Information and Vehicle Navigation Systems (cont.)

Author(s)	Methodology & Traffic Info Examined	Potential Market Size	Willingness to Pay Information	Key Findings
Turrentine *et al.* (1991)	Focus group on interest in advanced traveler info and collision avoidance systems; en-route	• 68% of participants said they would not buy such a system.	• Willing to pay between $500 and $3000 for system. Average was $1500.	• More interested in use of advanced traveler technologies as a tool and not as a convenience. • Concerned with safety and had doubts about the reliability of such a system.
Wenger *et al.* (1990)	Telephone survey of commuters' access and use of current traffic information; pre-trip and en-route		N/A	• Four types of commuting patterns. • Commuters access pre-trip information. • They have a relatively stress-free time before they leave for work and could use a graphical interface traffic information system. • Drivers know their commutes well, and base decisions to change on observations first and traffic reports second. • Changing routes is very stress inducing. • Commuters who do not change routes do not have a good knowledge of their routes as compared to others.
Whitworth et al (1994)	A survey of operational tests and university and government research		• In JHK & Associates study (93), 66% of participants in Pathfinder study would buy system for the price of a car radio (15% neutral, 16% would not); test area was the Santa Monica Freeway • In Marans (91) study, 50 % of participants would pay .50 for incident information, 15% would pay $1.00, and 5% would pay $2.00 per day for information .	• Reviews the State of consumer acceptance work that has been done in operational tests and other research. • Most projects have not explicitly considered consumer acceptance.

Partial List of Market Research Findings on Advanced Traveler Information and Vehicle Navigation Systems (cont.)

Author(s)	Methodology & Traffic Info Examined	Potential Market Size	Willingness to Pay Information	Key Findings
SmartRoute Systems (1993)	SmarTraveler Operational test in Boston; focused on commuters; looked at pre-trip and en-route info.		• Preliminary report does not contain willingness to pay analysis	• Average use was 5 times per week • 82% of the users considered the system very useful. • 97% considered the service more useful than radio, and 71% consider it much more useful than radio. • 96% of the users changed time, route or mode of travel at least occasionally based on the information their received. 30% changed one of these aspects frequently. • 63% ranked information received about alternate routes as very important.
Streff & Wallace (1993)	Mail survey of drivers travel information access, use and satisfaction; pre-trip and en-route examined		N/A	• Maps were primary pre-trip information source, although people wanted more than just this. • Interested in local traffic information on trips but did not know where to access it. • Less than 1% of participants did not use any information sources on trips. • Generally showed favorable opinion of current information sources. • 65% obtain traffic info before and during trip; 90% find it to be helpful. • However, 40% find this info timely, 30% find it arrives too late.
Marans (1990)	Develops model of cons. acceptance research			• Three stages of consumer acceptance research: Exploratory, Evaluative and Monitoring.

Partial List of Market Research Findings on Advanced Traveler Information and Vehicle Navigation Systems

Author(s)	Methodology & Traffic Info Examined	Potential Market Size	Willingness to Pay Information	Key Findings
Harris and Konheim, 1995		• 78% of people on NYC tri-State area willing to pay something for improved traveler information.	• 30% of NYC metro area drivers willing to pay $15/month, 40% at $10.00/month, and 53% at $5.00/month (Median equal to $11.00/month). 64% would pay $.50/call for information and 50% would pay $1.00/call.	
Guthrie & Phillips 1994		• Upwards of 14 million elderly, agility-challenged, and cognitively-challenged individuals could use ATIS systems.		

REVIEW OF EVALUATION FRAMEWORKS

This section reviews a selection of literature containing a discussion of frameworks for evaluating ITS technologies. Some of the information presented below is outside the specific scope of the evaluation frameworks, but it is included to provide a more complete summary of each of the documents reviewed.

US DOT (1995a). Qualitative Assessment of IVHS Emission and Air Quality Impacts, Final Report, DOT-VNTSC-FHWA-93-4, September 1995.

A report by Sergio Ostria (US DOT, 1995a), under contract to the US DOT Volpe National Transportation Systems Center, provides a *qualitative* assessment of the potential effects of various ITS technologies and outlines a framework for further research to develop tools that will be capable of quantifying impacts. The relationships between ITS, travel, and emissions are discussed and individual technologies are grouped into bundles defined by similar travel and emission effects. The bundles are defined as follows:

- Traffic and incident management systems (including ATMS, ATIS, and CVO technologies);
- Route guidance systems (ATIS technologies);
- Accident reduction systems (including CVO and AVCS technologies);
- Enabling technologies for travel fees (including AVI, AVL, AV Classification, and ATMS and APTS technologies);
- Vehicle control systems (AVCS technologies);
- Commercial vehicle inspection systems (CVO technologies);
- Trip guidance and public transportation systems (including ATIS and APTS technologies); and
- Emission control enabling technologies (including RSD and ATIS technologies).

The potential travel and emission impacts of each bundle are assessed by Ostria on the basis of: (1) relevant studies conducted by academia and government; (2) a video conference on ITS and air quality held on March 8, 1993; and (3) results from the National IVHS/Air Quality Workshop hosted by the South Coast Air Quality Management District on March 29-30, 1993 (Horan, 1993). The travel impacts considered include impacts on traffic flow, vehicle trips, trip distance, and mode shift. The impacts on emissions are limited to HC, CO, and NO_x. These assessments are purely qualitative, defining impacts as positive, negative, insignificant, or uncertain. Short- and long-term impacts are assessed at both the corridor and regional levels. Finally, Ostria discusses the analytical tools (i.e., including emission models, traffic simulation models, and travel behavior models) that will be necessary to develop *quantitative* evaluations of the environmental implications of ITS technologies and the types of data that will be needed to support ITS-related modeling advances.

Ostria expects ITS technologies to lead to improvements in the level of service at both the corridor and regional levels. However, these improvements are expected to be small and not large enough to induce significant additional travel, particularly in the short term.

US DOT (1995b). "Intelligent Transportation Systems Impact Assessment Framework: Final Report." US DOT, Volpe National Transportation Systems Center, September 30, 1995.

In 1992 the Volpe National Transportation Systems Center was commissioned by the Federal Highway Administration (FHWA) ITS Joint Program Office (JPO) to develop an analytical framework to predict ITS impacts and assess the potential benefits of ATMS user services. The study (US DOT, 1995b) focused on ATMS under the premise that it provides the foundation for other types of ITS services. Within the bundle of ATMS services, the study concentrated on ramp metering, signal coordination, integrated traffic management systems, and HOV lanes and ramp meter HOV bypass lanes.

The framework integrates a regional planning model (SYSTEM II) with freeway (FREQ) and arterial (TRANSYT-7F) simulation models, which provide input to emission models, a fuel consumption model, and a safety model. The emission modeling component of the framework uses MOBILE5a and EMFAC7F to provide emission rates for input to EMISSION (i.e., for calculation of trip based emissions) and EMIS (i.e., for calculation of running exhaust emissions). The EMIS model also provides the structure for applying fuel consumption rates to link-based data. The fuel consumption rate model used for this study was developed by the Caltrans Office of the Transportation Laboratory in cooperation with the US DOT and the FHWA (Talaga *et al*., 1983). A new safety model was developed specifically for the framework, incorporating safety factors that were determined from historical accident data for the study corridor.

The US DOT (1995b) framework generates a set of MOEs that can be used to evaluate the impact of implementing ATMS user services. The MOEs are categorized under four major impact areas: (1) congestion or operational measures; (2) emissions; (3) fuel consumption; and (4) safety. No attempt was made to distinguish between supply- and demand-related impacts as in Brand (1994).

The framework was applied to model five alternative ATMS scenarios and the results were compared to those for a baseline configuration. The scenarios were made up of various combinations of fixed time and demand-based signal coordination with fixed time and synchronized freeway ramp metering. A summary of the findings of these analyses are presented in the section of this report titled "Quantitative Assessment: Modeling Studies."

US DOT (1995c). "An Environmental Evaluation Guidebook for ITS Deployments and Field Tests." US DOT, Volpe National Transportation Systems Center, October, 1995.

The US DOT's Environmental Evaluation Guidebook (US DOT, 1995c) prepared by the Volpe National Transportation Systems Center develops an environmental evaluation framework for

ITS projects, provides an example application of the framework, and presents specific evaluation guidelines for the following user service groups: travel and transportation management; travel demand management; public transportation operations; electronic payment; and commercial vehicle operations. The document also provides an extensive review of available travel demand, traffic operations, emission, and fuel models, and the status of ongoing development in such models (i.e., particularly in the area of modal emission models).

The environmental evaluation framework presented in US DOT (1995c) is a seven step process as follows:

1. hypotheses of ITS user service impacts,
2. evaluation of goals and objectives,
3. measures of effectiveness (MOEs),
4. evaluation study design,
5. data collection and monitoring,
6. data reduction and analysis, and
7. result interpretation and presentation.

The first four steps make up the evaluation planning phase, and the last three steps are the evaluation implementation phase.

Step 1 involves development of hypotheses for possible travel behavior, transportation system performance, and environmental impacts. These hypotheses and the evaluation needs then become the basis for establishing evaluation goals and objectives (*step 2*). *Step 3* uses the evaluation goals and objectives to define MOEs for achieving the goals and addressing the problems Stated in the objectives. The goals and objectives are then transformed into specific problems or requirements, including data requirements, available study methods and tools, specific needs for data collection and analysis, and interpretation of results. In addition, study methods are developed to obtain the MOEs, considering relevant technical and resource issues. These two tasks make up the evaluation study design (*step 4*). *Step 5* applies the data collection techniques and procedures selected in the planning phase to obtain data that will be used in the implementation phase. Data can be collected directly from field observations or taken from secondary sources (e.g., MPO modeling results). Empirical or modeling analysis methods are then applied to analyze the data, derive MOEs, and assess the environmental impacts (*step 6*). Finally, *step 7* involves interpretation of the results of the analyses in terms of trend, scope, and magnitude, and presentation in an appropriate format.

The US DOT (1995c) report does not provide detailed guidance with respect to specific models to use for *step 6* of the evaluation framework. There is a brief discussion in Appendix H of ongoing enhancement of modal emissions and fuel consumption prediction capabilities of the *ITS Benefits Assessment Framework*. The base framework is very similar to that presented in US DOT (1995b), as summarized above. The traffic modeling component of the framework (i.e., integrating SYSTEM II, FREQ, and TRANSYT-7F) will be modified in the future by the addition of microscopic traffic models (i.e., INTEGRATION and CORFLO). While still using

MOBILE 5a and EMFAC7F, another emissions and fuel consumption model has been added - an updated version of Sierra Research's VEHSIM/VEHSIME modal emission and fuel consumption model. The original model was updated by Sierra Research under contract to the Volpe Center, using the instrumented chase car data collected by Sierra in 1992 and 1993 (e.g., Sierra Research, 1993).

Brand, Daniel (1994). Criteria and Methods for Evaluating Intelligent Transportation System Plans and Operational Tests. *Transportation Research Record No. 1453*, pp. 1-15.

Brand (1994) describes an evaluation framework that is designed to be sensitive to the differences between ITS and traditional transportation improvements. An extensive set of evaluation criteria is presented, distinguishing between the supply and demand impacts of ITS deployment. The criteria are categorized into five main impact types. The first two criteria types, increased operational efficiency (i.e., supply) and increased output (i.e., demand adjustments), are separated to avoid the possibility of dramatically underestimating the benefits of a given technology. These criteria are also structured in a second dimension explicitly to address the time frame of the impacts (i.e., short, medium, and long term impacts). The additional criteria types are safety, energy and environmental, and implementation impacts. Brand shows how the full set of criteria can be grouped to avoid double-counting of benefits because of the correlations that exist between certain criteria. An example also demonstrates how evaluation criteria can be weighted to allow the evaluator to produce an overall weighted measure of merit for each project. Finally, Brand provides default values to evaluate ITS improvements for inclusion in transportation system plans.

Underwood, Steven E. and Stephen G. Gehring (1994). Framework for Evaluating Intelligent Vehicle-Highway Systems. *Transportation Research Record No. 1453*, pp. 16-22.

Underwood and Gehring (1994) highlight a number of challenges that are unique to the evaluation of ITS technologies. These unique characteristics of ITS generate a special need for approaches, methods, and tools not required for evaluation of traditional transportation improvements. The challenges described by Underwood and Gehring involve public and private benefits, new products and functions, market penetration effects, human interaction, institutional factors, and multi-site deployment.

REVIEW OF MODELING TOOLS

This section provides a discussion of modeling tools for evaluation of the energy and environmental impacts of ITS technologies. First, a review of some earlier evaluations of various tools is presented (Evaluation of Tools). Then the focus of this section turns to three specific traffic simulation tools (i.e., INTEGRATION, WATSim, and DYNASMART) and their capabilities as they relate to this project (Specific Tools).

The information presented in this section forms the basis for the project team's decision to establish a modeling framework centered around the INTEGRATION simulation model. In summary, the INTEGRATION model was selected for the following primary reasons:

- it is the most *advanced* model capable of simulating the broadest range of different ITS technologies;
- it is the most *widely applied* model; therefore, it has many of the 'bugs' identified and corrected;
- there are *existing databases* and networks available for the INTEGRATION model; and
- several *supporting models* have been developed for use with INTEGRATION.

Previous Evaluations of Tools

Little, Cheryl, Tai-Kuo Liu, Norman Rosenberg, David Skinner, and Lawrence Vance (1993). "IVHS: Evaluation of Models for Predicting the Emission and Energy Benefits of IVHS Alternatives." ***Draft prepared for FHWA, Advanced Systems Division.*** **Volpe National Transportation Systems Center, January 22, 1993.**

This report was prepared at the completion of the first task of the FHWA sponsored project to develop an ITS Benefits Assessment Framework (US DOT, 1995b). Little *et al*. (1993) collated substantial information gathered from a survey of all the significant existing planning, traffic, emission, and fuel consumption models that were candidates for inclusion in the analytical benefits framework. The models are described in detail and evaluated with respect to key model variables, sensitivities within the models, and interfaces and boundaries with other models. The models identified by Little *et al*. (1993) include:

- Four-step transportation planning models (e.g., MINUTP, Tranplan, TRIPS, SYSTEM II, EMME-2, TMODEL2, and QRSII);
- Land use and transportation forecasting models (e.g., CATLAS, ITLUP, TOPAZ, and HLFM II);
- Travel behavior models (e.g., San Francisco Bay Area MTC model);
- Traffic simulation models (e.g., CORFLO (NETFLO1, NETFLO2, and FREFLO), FREQ, FRESIM, INTEGRATION, ROADSIM, and NETSIM);

- FTP-based emissions models (e.g., MOBILE, CALIMFAC/EMFAC, UROAD, SAPOLLUT, DTIM, the SYSTEM II Emissions Model, and the SANDAG TCM Emission Analysis Model);
- Modal emission models (e.g., Modal Analysis Exhaust Emission Model, University of Leeds Integrated Model, POSTRAN7, and VEMISS);
- Air quality models (e.g., CALINE4, IMM, MICRO2, and TEXIN2); and
- Fuel consumption models (e.g., MOBILE Fuel Consumption Model, and other traffic models capable of predicting fuel consumed; such as SATURN and NETSIM).

Little *et al*. (1993) provide an appendix containing a detailed listing of the input and output data types associated with each of the six traffic simulation models listed above.

JHK & Associates, SAIC, and COMSIS (1992). "Supplemental Information for Volume 1: Inventory of Models for Predicting the Emission and Energy Benefits of IVHS Alternatives." Prepared for the US DOT, December 4, 1992.

JHK & Associates *et al.* (1992) provides a review of the operational status, hardware and requirements, assumptions, validation, output information, level of effort data for a number of planning, traffic simulation, fuel consumption, and safety models. Each model is evaluated with respect to its treatment of ITS strategies and associated strengths and weaknesses/limitations. The models include:

- Planning models (e.g., San Francisco Bay Area Metropolitan Transportation Commission model and Portland Metropolitan Service District Model);
- Traffic simulation models (e.g., CORFLO, FREQ, INTEGRATION, FRESIM, TRANSYT-7F, NETSIM, SATURN, CONTRAM, ROADSIM);
- Fuel consumption models (e.g., DRIVE, fuel consumption components of NETSIM, TRANSYT-7F, and FREQ10); and
- Safety models (e.g., Central Artery Accident Model and the Garber and Gadiraju Model).

Rathi, Ajay (1995). "Models for Assessing the Impacts and Potential Benefits of Intelligent Transportation Systems." Draft working paper prepared for IVHS Research Division, Joint Program Office, FHWA. Oak Ridge National Laboratory, August 15, 1995.

Rathi (1995) prepared a report for the ITS Joint Program Office that discusses modeling requirements for evaluating alternative ITS technologies. Rathi uses these requirements as a basis for a discussion on the conceptual and analytical frameworks for assessing the benefits of ITS technologies. The report then summarizes the current capabilities of a range of models and modeling systems including: INTEGRATION and THOREAU; the *enhanced* Volpe ITS Benefits Assessment Framework (mentioned briefly in the summary of US DOT (1995c) above); DYMOD; DYNASMART; MITTNS; enhanced TRAF model family; Purdue ITS Benefits Assessment Framework; and the TRANSIMS model. These models and modeling systems were identified by Rathi (1995) as viable options for assessing the impacts and potential benefits of

ITS technologies. Rathi concludes that "none of the existing models or analytical frameworks are fully capable of providing a systematic and faithful assessment of the impacts and benefits of ITS technologies for a region for an analysis period of up to 5-years." However, Rathi claims that each of these options are capable of providing the required framework and modeling capabilities, given enough time and money. He then recommends that the FHWA direct their efforts toward Mitretek's work using INTEGRATION, THOREAU, and planning models, or the Volpe ITS Benefits Assessment Framework (with major enhancements), for near-term operational capability. For mid-term capability, Rathi recommends that the FHWA choose from DYMOD, DYNASMART, MITTNS, and TRAF, and provide support on the order of $2 million, for further development over a two-year period. Rathi also advises the FHWA to utilize models/algorithms developed from other on-going efforts to minimize the duplication of effort for the long-term modeling projects such as TRANSIMS.

US DOT (1995c). "An Environmental Evaluation Guidebook for ITS Deployments and Field Tests." US DOT, Volpe National Transportation Systems Center, October, 1995.

This report provides an extensive review of available travel demand, traffic operations, emission, and fuel models. The status of ongoing development of such models is also discussed, particularly relating to *modal* emission models. A summary of the advantages and limitations of each of the modal emission modeling efforts presented is provided after some detail on the various modeling approaches.

Lo, Hong K., Wei-Hua Lin, Lawrence C. Liao, Elbert Chang, and Jacob Tsao (1996). "A Comparison of Traffic Models: Part 1, Framework", California PATH Research Report, UCB-ITS-PRR-96-22, August, 1996.

Lo *et al*. (1996) developed a framework for comparison of dynamic traffic models, emphasizing the dimensions of functionality, traffic and route choice dynamics, and overall network performance. The framework is set up to compare the models against a check-list of functions and also to compare the ability of each tool to model twelve scenarios developed for five different test networks. The report provides a list of performance measures to be determined for each modeling tool and a discussion of how the results are to be interpreted.

The comparison framework is designed to be generic and permit comparison of many traffic models. However, four specific models were selected for comparison in this study: INTEGRATION, DYNASMART, DINOSAUR, and METS. The comparison results and the impact of perturbations to O-D data will be presented in Part II and III of the report, which are almost complete.

Some of the traffic simulation tools mentioned above are capable of estimating (i.e., to varying levels of accuracy) the energy and environmental impacts of the simulated traffic conditions (e.g., INTEGRATION, DYNASMART, and NETSIM). Others can provide output suitable for input to some fuel consumption and emission models. However, modeling frameworks that provide output suitable for average speed based emission models such as the US EPA MOBILE and the

California Air Resources Board EMFAC models are not capable of providing accurate assessments of the environmental impacts of the ITS scenarios being considered.

The MOBILE and EMFAC emission factors predict vehicle emissions based in part on average trip speeds and a large number of FTP (and other cycles) *bag* emission measurements. These models are intended to predict *regional* emission inventories, and hence they are not adequate for evaluating microscopic-level operational improvements, such as those achieved by ITS strategies. To evaluate the emission benefits of such systems, it is necessary to employ an emission model that considers the modal operation of a vehicle (i.e., emissions that are directly related to vehicle operating modes such as idle, cruise, accelerations, and decelerations).

The INTEGRATION and DYNASMART models make use of *modal* emission models that account for microscopic changes in vehicle speed profiles (Baker (1994) and Ramachandran (1995), respectively). A brief summary of these models is presented in the sections below (Specific Tools: INTEGRATION and Specific Tools: DYNASMART).

Specific Tools

A review of the available literature on various traffic simulation models identified the most viable tools for this research to be INTEGRATION, WATSim, and DYNASMART. The following three sections provide more detail concerning the function and abilities of these models. Next, we provide a summary that lists the reasons for our selection of INTEGRATION as the primary tool for this study. Finally, a brief description of two modal emissions models is presented. It is intended that these models (i.e., the DITSEM model (Washington, 1994) and UC Riverside's interim model (e.g., An *et al*., 1996)) be used as a basis for comparison with the emission-related outputs from INTEGRATION, for a limited selection of scenarios.

INTEGRATION

Much has been written about the capabilities of the INTEGRATION traffic simulation model (e.g., Bacon *et al*., 1995; Van Aerde and Rakha, 1996; Glassco *et al*., 1995). This section presents some of the aspects of this model that are relevant to our research. For more detailed information about the model development, capabilities, limitations, and applications, the reader is referred to the reports just mentioned and the INTEGRATION User's Guide (Van Aerde, 1995).

The INTEGRATION traffic simulation model was developed by Michel Van Aerde of Queen's University in Ontario, Canada (Van Aerde, 1985; 1995). This microscopic simulation model was developed with the purpose of simulating integrated networks composed of freeways and arterial roads, with a particular emphasis on modeling ITS scenarios.

INTEGRATION 2.0 simulates the behavior of individual vehicles on signalized arterial and mainline freeway links, with the ability to model merges, diverges, and weaving sections. The model contains algorithms to simulate many aspects of traffic behavior including: lane changing; link-to-link lane transitions; car following; route selection and traffic assignment; signal cycles, including turning movements, shockwaves, oversaturation delay, and gap acceptance at traffic signals; signal coordination; stop and yield signs; and incidents and diversions. INTEGRATION also provides estimates of effectiveness measures for individual vehicles; links; O-D pairs; and complete networks, including link travel time, fuel consumption, and vehicle emissions.

One of the useful features of INTEGRATION is the capability to define vehicles as one of five types, based on their ability to access real-time or historical information or both. The vehicle types are as follows:

- *Background/unguided vehicles* (i.e., route choice is based on free flow speed unless specified path trees are provided);
- *Guided vehicles* (i.e., route choice is based on real-time information that is provided at every node in the network);
- *Vehicles that have knowledge of expected future link travel times* (i.e., route choice is based on a combination of real-time and historical information);
- *Vehicles with in-vehicle advanced route guidance systems*; and
- *Special facility users* (i.e., route choice based on specified path trees or real-time information; vehicles have exclusive access to specific links (e.g., HOV vehicles).

Bacon *et al*. (1995) discuss the capabilities of INTEGRATION to simulate various ATIS and ATMS strategies and scenarios. These include:

- Ramp metering;
- Real-time traffic signal control (i.e., limited optimization of individual traffic signals);
- Route guidance systems;
- Quality of information provided to motorist;
- Changeable message signs;
- High-occupancy vehicle lanes;
- Incidents (indirectly, by restricting capacity of specific link for specific period of time); and
- Combinations of ATMS and ATIS strategies (reported, but untested capability).

Rathi (1995) ascribes the following capabilities to the INTEGRATION model (version 1.5):

- Transportation network representation: highway network down to minor arterial;
- Representation (complete and faithful) of ITS technologies and user services: ATIS;
- Modeling effect of ITS technologies on: O-D matrix and route selection;
- Representation of dynamic aspects of traffic operations: spillback, incidents, merging and weaving, and traffic assignment;
- Representation of traffic network operational features: signals, ramp metering, changeable message signs, and high-occupancy vehicle lanes;
- Representation of traveler's response to information; and
- Modeling energy and environmental impacts: fuel consumption and air quality (emissions).

It should be noted that the INTEGRATION model has undergone substantial development since this report was prepared and is capable of modeling additional technologies (e.g., the lane changing and car following algorithms in INTEGRATION 2.0 enable it to better model ATMS technologies).

INTEGRATION does not simulate mode choice decisions, therefore, it cannot evaluate APTS technologies or the effect of pre-trip information on mode shift behavior. However, it could be used in conjunction with an independent modal choice model. Mitretek has developed a model called SmartShift for studies of the effect of pre-trip traveler information (e.g., Glassco *et al*., 1996). Another limitation of INTEGRATION related to modeling of APTS technologies is that it does not represent commercial vehicles in any way.

Bacon *et al*. (1995) found that INTEGRATION versions 1.5d and 1.5e are only capable of limited investigations of ATMS control strategies. They are not able to simulate optimized ramp meter timing plans or optimized signal coordination along an arterial route, but these models can perform limited optimization of *individual* traffic signals.

The INTEGRATION 2.0 User's Manual (Van Aerde, 1995) claims that this version can evaluate the impact of alternative signal coordination effects such as "the impact of a lack of coordination at the boundary of 2 coordinated subnetworks, and/or...the impact of removing a single traffic signal out of a coordinated network."

Bacon *et al*. (1995) concluded that "...while INTEGRATION had some limitations it appeared to be significantly better for simulating ITS strategies than any other known simulation models." According to Bacon *et al*. (1995), INTEGRATION has been proven to be robust in simulating HOV lanes, and that it is capable of simulating CMS and HAR strategies. A further advantage of the INTEGRATION model is that several programs/utilities have been developed to manipulate input data for use with INTEGRATION and analyze the output data files from INTEGRATION in a more timely manner.

Modeling energy and environmental impacts with INTEGRATION

INTEGRATION has a built-in capability to predict the energy and environmental impacts of various ITS strategies. This functionality is based on models developed by Mark Baker during his Master's degree at Queen's University. The model development is described in detail in Baker (1994), and a more brief presentation of this model's calibration and validation can be found in Van Aerde and Rakha (1996: pp. 48-60).

These models were established from on-road fuel consumption and speed profile data measured with the TravTek vehicle (i.e., a 1992 Oldsmobile Toronado) in Orlando, Florida. Data from this vehicle were used to develop a constant speed fuel consumption model, a stop/go model, and the idle fuel consumption rate. The stop/go model estimates the additional fuel used to drop from one speed, to another speed, and then to return to the original speed, as compared to traveling the same distance at a constant speed. This model accounts for complete vehicle stops and partial stops (i.e., slow downs).

The fuel consumption model for the TravTek vehicle was validated using data collected from four sample road networks (including a major arterial, a small urban network in downtown Orlando, a simple suburban residential network, and two freeway routes). The average absolute percentage error between the modeled and measured trip fuel consumption for all tests was between 3 and 14 percent. However, the correlation between observed and modeled fuel consumption rates across all facilities was high ($R^2 = 0.95$).

Baker used information from the available literature to develop correction factors for the fuel consumption model, to account for the effects of ambient temperature and cold starts. Both these corrections use very simple relationships between fuel consumption rates and ambient temperature.

The TravTek vehicle fuel consumption model was extended to other vehicles by developing relationships between the six parameters that define the cruise and stop/go models, and the US EPA highway and urban fuel economy ratings for a particular vehicle.

Finally, links (or simple ratios) were developed between the derived fuel consumption models for three MOBILE5a vehicle classes (i.e., light-duty gasoline vehicles and two classes of gasoline trucks) and the MOBILE5a emission rates (see Baker, 1994; Van Aerde and Rakha, 1996).

WATSim

The **W**ide **A**rea **T**raffic **Sim**ulation model (WATSim) is based on the highly regarded TRAF-NETSIM urban network microscopic stochastic simulation model. WATSim was developed by KLD and Associates to make TRAF-NETSIM capable of simulating traffic on a road network comprised of freeways, ramps, interchanges, urban streets, and arterials. Further work in 1995, supported by the PATH program, extended WATSim to include logic to replicate driver path selection in response to information from an ATIS system. The features added to TRAF-NETSIM to create WATSim include (Lieberman and Goldblatt, 1995):

- Intra-link lane-changing logic,
- Refined car-following logic,
- Expanded vehicle-generation logic,
- Capability of simulating grade-separated freeway interchanges of any design including single-point configurations,
- Refined treatment of vehicle-movements within at-grade intersections, and
- Vehicle path processing.

According to Lieberman and Goldblatt (1995), the vehicle path processing capability of WATSim allows simulation of ATMS and ATIS scenarios.

WATSim is capable of providing estimates of energy use and emissions for each simulated scenario. The current models (look-up tables) that provide this functionality are outdated, but work is being performed at Oak Ridge National Laboratory to improve and update this capability of the TRAF-NETSIM and the WATSim model (McGill and West, 1997).

DYNASMART

DYNASMART (**DY**namic **N**etwork **A**ssignment **S**imulation **M**odel for **A**dvanced **R**oad **T**elematics) is a traffic simulation model developed by Mahmassani, Jayakrishnan, Hu, and others at the University of Texas, Austin (e.g., Mahmassani *et al*., 1992; 1993; Jayakrishnan *et al*., 1994; Hu and Mahmassani, 1995) and further by Jayakrishnan at the University of California, Irvine. The model was designed as a research tool for the study of ATIS/ATMS scenarios at the network level, including the evaluation of strategies for providing traveler information, traffic control measures, and rules for route assignment.

DYNASMART is a mesoscopic model, using macroscopic flow models while capturing the movements of individual vehicles. Seven different driver (or behavior) classes can be specified as a function of vehicle type, information availability, and network restrictions. These classes allow modeling of user behavior in response to ATIS information.

The model has been designed to allow the simulation of *proposed* strategies with limited modification to the core of the model. For example, user behavior rules can be changed to reflect evolving knowledge in this field, and traffic control logic at signals or ramp meters can be changed to test new proposals. DYNASMART has been incorporated into a day-to-day evaluation framework, to account for the fact that the magnitude and orientation of ITS impacts vary over time, as users learn from their experience with the system. This framework allows the dynamic evolution of system performance to be investigated.

In addition to the model capabilities listed above, DYNASMART incorporates the following features:

- Models for time-dependent O-D demand patterns,
- Explicitly models vehicle paths as the outcome of individual decisions at each node in the network,
- Explicitly models junction control and delay,
- A front-end processor for data input and a post-processor for displaying results, and
- Links to a set of network assignment modules to simulate user-optimal or user-equilibrium patterns.

Rathi (1995) ascribes the following capabilities to the DYNASMART model:

- Transportation network representation: highway network down to minor arterial and mass transit system *;
- Representation (complete and faithful) of ITS technologies and user services: ATIS;

- Modeling effect of ITS technologies on: O-D matrix, trip departure time *, and route selection;
- Representation of dynamic aspects of traffic operations: spillback, incidents, merging and weaving, and traffic assignment;
- Representation of traffic network operational features: signals, ramp metering, changeable message signs, and high-occupancy vehicle lanes;
- Representation of traveler's response to information; and
- Modeling energy and environmental impacts: fuel consumption and air quality (emissions).

Those capabilities marked with a star (*) reflect capabilities not attributed to INTEGRATION 1.5, by Rathi (1995).

Development of DYNASMART has also continued since Rathi reported on its capabilities. Rathi (1995) contains an appendix that includes a "Discussion Paper from The University of Texas at Austin on DYNASMART." This paper describes proposed short-, medium-, and long-term modifications including:

- Development of appropriate performance measures in a multicriteria framework, improvement of ATMS strategy representation, and enhancement of emissions and energy consumption models (short term);
- Capture of substitution and complementary effects between tripmaking and telecommunications use (medium term); and
- Incorporation of impacts of land use and spatial activity patterns (long term).

DYNASMART makes use of the simple fuel consumption and emission models developed by Ramachandran (1995) at the University of Texas at Austin. These models are simple relationships between instantaneous speed and uniform acceleration rate. No adjustments are made for ambient temperature, cold starts, etc. However, different models were created for "good," "average," and "bad" cars, with respect to the emissions they generate.

Summary of Modeling Tools

In this section we have discussed a range of available modeling tools for ITS simulation and the capabilities of these packages, with a particular emphasis on three traffic simulation models (i.e., INTEGRATION, WATSim, and DYNASMART). The information presented here, led to selection of the INTEGRATION model for the traffic simulation and environmental evaluations to be conducted as part of this research project. The main reasons for this decision are as follows:

- It is the most *advanced* model, capable of simulating the broadest range of ITS technologies;
- It is the most *widely applied* model, therefore, it has many of the 'bugs' identified and corrected (Bacon *et al*. (1995, pp. 36-37) presents a summary of some previous applications of INTEGRATION);

- There are *existing databases* and networks (i.e., calibrated to various levels) available for the INTEGRATION model, because of its application elsewhere (e.g., Urbansville, Thruville, SMART Corridor, Orlando); and
- Several *supporting models* have been developed for use with INTEGRATION (by Van Aerde, Bacon *et al*. (1995) and Mitretek).

In addition to the application of the INTEGRATION model, the project teams hopes to carry out some comparison of emissions results with either the UC Riverside parameterized physical model or the Georgia Tech statistical model (see the Literature Review for a brief description of these models). Of course, this will depend on which of these models (if any) is made available within the timeframe of our project. Discussions are taking place with the UC Riverside team to determine how the working model may fit into the framework of this research. The extent to which either of these two models will be used to estimate emissions for comparison with INTEGRATION estimates will depend in part on the level of difficulty involved in linking traffic performance related output from INTEGRATION to the modal emission models. The default output files do not provide all the necessary information as input to either of these modal emission models. However, the developer of the INTEGRATION model has informed this project team that the data required *could* be accessed. It has not yet been determined how much work is involved to achieve this access.

POLICY CONTEXT

This section of the report contains a review of many of the pertinent national and California-based energy, emissions, and other relevant regulations to an analysis of ITS and the environment. This reviews helps to establish the context in which ITS technologies will be deployed in the future. The status of these regulations have been reviewed and revised throughout the second year of this project.

In the first year of this project, two experts were consulted on the regulatory context. A summary of these interviews is contained in Appendix A of this report. In the second year of this study, project researchers conducted a series of expert interviews and scenario workshops in Washington, DC, and California, to assess the policy context for the modeling scenarios developed for this project. (See the "Scenarios" section of this report).

In addition, this section contains a discussion of "sustainability," which is an important concept relevant to a discussion of ITS and the environment. This section also makes some possible linkages between the sustainability concept and the deployment of ITS technologies.

Review of National Energy and Environmental Laws Pertaining to Transportation

The consequences of a more mobile populace include auto accidents, congestion, air pollution, greenhouse gas emissions, poor visibility, health effects, and ozone layer depletion. In recognition of these problems, the U.S. has developed legislation to regulate transportation activity in consideration of the environment. Some legislation is focused directly on reducing the environmental impacts of the transportation system, such as the mobile source provisions for cleaner vehicles and the implementation of transportation control measures (TCMs) under the Clean Air Act (CAA) of 1970, and its subsequent amendments (Shaheen *et al.,* 1994). Other legislation focuses on transportation planning and energy efficiency.

Clean Air Act (CAA)

<u>The 1970 Clean Air Act and the National Ambient Air Quality Standards (NAAQS)</u>

In the 1970 Clean Air Act (CAA), Congress established the National Ambient Air Quality Standards (NAAQS) to protect the health and well being of citizens (42 U.S.C.A. §7409(a)). Not surprisingly, Congress intended the NAAQS to be the ultimate regulatory goal and measure of programmatic success of the CAA. The 1970 CAA required that the US EPA Administrator establish primary and secondary standards for "each air pollutant for which air quality criteria have been issued prior to such date" (42 U.S.C.A. §7409(a)). Primary standards were set to protect public health. Secondary standards, which are less stringent, protect the public from "any known or anticipated adverse effects associated with the presence of [air pollutants] in the ambient air" (42 U.S.C.A. §7409(b)(2)) (Shaheen *et al.,* 1994).

This Act required each State to prepare a State implementation plan (SIP), which outlined each State's process for achieving and maintaining primary and secondary standards for criteria pollutants throughout the State. Criteria pollutants are those pollutants for which ambient air quality standards have been established. These pollutants may be present in the atmosphere in the form in which they are emitted from a source, such as CO, or they may, like ozone, be formed in the atmosphere from precursor substances (e.g., in the case of ozone, from hydrocarbons and oxides of nitrogen). Ambient standards are standards set to maintain only specified concentrations or levels in the air of major pollutants; these levels are not considered to be harmful to human beings or other organisms.

The SIPs set schedules for the application of emission control devices to existing and new stationary sources; however, SIPs can apply land use and transportation controls, as well. The Act also required that each State or interstate region be divided into air quality control regions. For any air quality control region that failed to attain an air quality standard, an additional air quality management plan (AQMP) was required. If the regions exceeded standards for motor vehicle-related emissions (e.g., ozone or CO), the AQMP had to include a transportation control plan. Transportation control plans did not represent a major requirement of the CAA at this time.

The Clean Air Act Amendments of 1977

In 1977, Congress amended the CAA. These Amendments also require transportation control plans for areas that had not attained standards for ozone and CO. Failure of States to comply with this requirement resulted in federal funding cuts for highways and sewage treatment plant construction. However, in the history of these requirements, there has been a series of postponements and relaxation of the deadlines, standards, and inspection requirements for mobile sources.

Throughout the 1980s, the many ambiguities in the provisions led to disagreements between the US DOT and the US EPA (Hawthorn, 1991), which ultimately produced few substantive changes in the planning procedures (Shaheen *et al.,* 1994). This suggests that regulations are often iterative, requiring successive adjustments until society and technology are able to make the sacrifices and advances necessary to achieve the initial regulatory goals.

The Clean Air Act Amendments of 1990

In October 1990, President Bush signed the CAA Amendments of 1990 (42 U.S.C.A. §§ 7401 to 7671q). One significant direction of this clean air policy are the clean vehicles and fuels provisions. There were many problems associated with the earlier federal CAA legislation with respect to automobile pollution.

Over the past twenty years, Congress has gained a more comprehensive understanding of the impacts of vehicle emissions on air quality. The 1990 Amendments demonstrate this, requiring more stringent control of motor vehicles emissions and the integration of alternative fuels into fleets. As mentioned above, the CAA of 1990 encourages States to adopt California's stricter emission standards for motor vehicles and tighter transportation control measures. The Amendments also include several transportation requirements, such as: 1) sell reformulated gasoline in the nine smoggiest cities by 1995; 2) sell oxygenated fuels in CO "non-attainment" areas in 1992; 3) reduce emissions from cars and trucks in fleets of ten or more in polluted cities by 80 and 50 percent, respectively, starting in 1998; 4) install hose-and-nozzle controls at gas-station pumps to capture vapors during refueling and install fume catching canisters on new cars, starting in the mid-1990s; 5) adopt transportation control measures, such as carpooling programs, driving restrictions, and high occupancy vehicle lanes to counteract VMT growth; 6) produce 150,000 cleaner non-gasoline alternative-fuel vehicles by 1996 under a California pilot program (See California Clean Air Act of 1988, below); and 7) phase in tighter tailpipe standards (30 percent HC reduction and 60 percent NO_x) starting in 1994, and require manufacturers to certify these higher levels for ten years or 100,000 miles.

Due to the failure of many regions in achieving the NAAQS commitments established in the SIPs, the 1990 Amendments strengthened the demands of the CAA by tasking the US EPA and US DOT to develop a regulation to implement the general conformity language of Section 176. In November 1993, the US EPA published the Conformity Rule, which is titled "Criteria and Procedures for Determining Conformity to State or Federal Implementation Plans of Transportation Plans, Programs and Projects Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act" to enforce the CAA mandates and comply with the requirements of Section 176(c)(4) (Shaheen *et al.,* 1994).

<u>The Conformity Rule</u>

The Conformity Rule prescribes the processes to be followed by the FHWA, the Federal Transit Administration (FTA), and Metropolitan Planning Organizations (MPOs) in making conformity determinations for highway and transit projects. The requirements of the Conformity Rule work to ensure the integrity of a State's implementation plan by requiring transportation projects, plans, and programs to conform to the State or federal implementation plan (SIP or FIP) for the area. SIPs and FIPs establish an emissions budget that prescribes the allowable emissions for stationary and mobile sources within a State. To be in conformity, a transportation plan, program, or project must "conform" to this budget (Shaheen *et al.,* 1994).

Conformity requirements are applicable to all transportation plans, programs, and projects, funded or approved under title 23 U.S.C. or the Federal Transit Act. The Conformity Rule requires that transportation planning agencies employ transportation demand and emission models to ensure that transportation plans and all projects contained in a plan will not cause exceedances in the allowable emission budget established in the air quality management plan or violate local air quality standards. The Conformity Rule is designed to affect the planning and decision making process (Shaheen *et al.,* 1994).

New developments in the 1993 Conformity Rule and policy assessments

Since 1993, there have been several developments in the Conformity Rule. This section includes a description of each change (and proposed amendments) and an assessment of each development. ITS projects will no longer receive an exemption from conformity analyses (e.g.,, FOTs) in the future. Hence, the conformity requirements are relevant to a study of the emission impacts of ITS technologies.

General Preamble for Exemption from Nitrogen Oxides Provisions (June 17, 1994)

The US EPA clarified with this general preamble that "nonclassifiable (i.e., submarginal, transitional, and incomplete/no data) ozone nonattainment areas that are outside the Northeast ozone transport region and have ambient monitoring data demonstrating attainment of the national ambient air quality standard for ozone may be exempted from the Conformity Rules' nitrogen oxides (NOx) requirements" (US EPA, 1994). This general preamble simply clarifies the NOx requirements contained in the Conformity Rule and increases the ease of implementation.

The First Amendment: Transition to the Control Strategy Period (August 8, 1995)

This amendment fixed the timing of some consequences of SIP deficiencies under the Conformity Rule with the imposition of the CAA highway sanctions. For the SIP deficiencies described, conformity lapses were delayed until the CAA section 179(b) highway sanctions became effective: 1) ozone nonattainment areas with an incomplete 15 percent emissions-reduction SIP with a protective finding; 2) incomplete ozone attainment three percent rate-of-progress plan or finding of failure to submit an ozone attainment three percent rate-of-progress plan; and 3) areas whose control strategy implementation plan for ozone, CO, particulate matter, or nitrogen dioxide is disapproved with a protective finding (US EPA, 1995a). This delay in the lapse in conformity for the SIP deficiencies listed above was allowed because the US EPA realized that in practice the time allowed to correct the SIP deficiencies was "too short to be reasonable for purposes of determining when transportation plans and TIPs should lapse following SIP development failures" (US EPA, 1995a). Prior to the amendment, new highway and transit project approvals, for instance, would have been delayed due to a lapse in the conformity status.

This amendment to the Conformity Rule generally makes it easier and less costly for State and local governments to implement the Rule without undermining its effectiveness. In certain instances, the amendment allows for a delay in conformity lapses, and in some instances, avoids highway and transit project approval delays.

Second Amendment: Miscellaneous Revisions (November 14, 1995)

This amendment made a variety of changes to the Conformity Rule. First, it permitted the implementation of TCMs from approved SIPs during a conformity lapse. Second, it "aligned the date of conformity lapses with the date of application of CAA highway sanctions for any failure to submit or the submission of an incomplete control strategy SIP" (US EPA, 1995b). Third, the grace period was extended for submissions of control strategy implementation plans for purposes of a conformity determination. Fourth, a grace period was established for transportation plan and program conformity determinations in new nonattainment areas. Fifth, the NO_x provisions of the transportation Conformity Rule were corrected making them consistent with the CAA and prior US EPA commitments.

This amendment allows for a delay in conformity lapses and an extension of the grace periods, which make conformity less costly to implement from the perspective of State and local governments. However, the process toward air quality improvement can be slowed. According to this amendment, CAA highway sanctions would still be imposed, maintaining the integrity of the Conformity Rule. This amendment also allows for TCM implementation during conformity lapses. Since TCM implementation should generally work toward improving air quality, it would make good sense to implement them during a conformity laps.

Amendments and Final Rule (Summer 1997)

Below follows a general overview of the final transportation conformity amendments (final rule).

State and local governments have more authority in setting the performance measures used as tests of conformity.

- There is more flexibility for States to use their emissions budgets before the US EPA has approved their air quality plans.
- Areas that are not required to develop emissions budgets have more flexibility to choose among several conformity tests.
- Rural areas have flexibility to choose among several conformity tests for years beyond the timeframe of the air quality plan.

State and local governments have more discretion when the transportation plan does not conform to the State air quality plan.

- State and local governments have more flexibility to use their own money and approval authority.
- Previously planned federal transportation projects can be approved and funded following the US EPA disapproval of a State air quality plan.

Specific modeling requirements apply only to large, urbanized areas. Other areas can select regional models through the consultation process •FHWA, 1997)

Below follows highlights of changes in the final transportation Conformity Rule.

The regulatory text is streamlined and clarified.

- Separate sections for transportation plans, TIPS, and projects are now integrated into one section.

- Applicability of particular conformity criteria is described by pollutant and nonattainment classification (for easier reference).

The build/no-build test is eliminated when SIP budgets have been submitted.

- Submitted SIP budgets are the primary measure of conformity, even before the US EPA approves them through formal rulemaking.

- Newly submitted SIPs replace the build/no-build and other emission reduction tests after a 45-day adequacy review period by the US EPA.

- If an existing approved SIP is in place, the submitted SIP will override the existing one when it is approved.

There is more flexibility even where there are no submitted SIP budgets.

- Areas that are not required to submit SIP budgets can either satisfy the build/no-build test, or show that emissions are less than or equal to 1990 levels.

- The first analysis year for the build/no-build test can be any year that is no more than five years away.

- Maintenance plan budgets can be used after they are submitted (and before the US EPA approval).

State and local governments can approve previously planned non-federal projects when there is no currently conforming transportation plan and TIP (or supporting regional emissions analysis).

- A non-federal project can be approved and advanced during a lapse if it is from the first three years of the most recent conforming plan and TIP (or supporting regional emissions analysis).

Requirements for network modeling are limited to large, urban areas.

- Network modeling is required in serious and above ozone and CO nonattainment areas with an urbanized population greater than 200,000. Areas currently using network models continue to use them.

Rural areas have flexibility to choose among several conformity tests.

- When demonstrating conformity for years beyond the timeframe of the attainment SIP or maintenance plan, rural areas can choose among the following tests:
  - -- the budget test;
  - -- the build/no-build and/or other emission reduction tests (depending on what is required of the area's classification);
  - -- air quality modeling to demonstrate that violations will not be caused or worsened.

Consequences of the US EPA disapproval of a SIP are less severe.

- Following the US EPA disapproval of a SIP without a protective finding, projects from the first three years of the currently conforming transportation plan and TIP could proceed. Existing SIP policy for SIP/plan timeframe "mismatch" is retained.

- Conformity must be demonstrated for a 20-year timeframe.

- Exiting policy allows SIPs to establish motor vehicle emissions budgets for conformity purposes for years outside the timeframe that the SIP normally addresses.

- Such budgets are subject to less stringent requirements, (i.e., these budgets can contain enforceable commitments to approve control measures in the future).

Modeling requirements have been streamlined and clarified with these final amendments. Additional guidance will be issued in the future.

New NAAQS for particulate matter and ozone

In July 1997, the US EPA adopted new NAAQS for particulate matter (PM) and ozone (O_3). At present, there is no guidance on PM10. Currently, regions can do qualitative analysis for PM10. For the first time, fine particles (i.e., PM2.5) will be regulated. The new PM standard regulates particles 2.5 microns or smaller in diameter, which the US EPA deems the most potentially damaging because they can penetrate and remain deep in the lungs. The standard establishes an annual limit of 15 $\mu g/m^3$, with a 24-hour limit of 65 $\mu g/m^3$ (Federal Register, 1997).

The new standards will not require additional local controls until the year 2004 for ozone and the year 2005 for PM, with no compliance determinations until the year 2007 and 2008, respectively, with possible extensions (Environmental Management, 1997). Hence, the timeframe for the new standards is outside of the timeline for this project's modeling analysis (i.e., the year 2005). Nevertheless, the new NAAQS for PM and ozone will have an impact on environmental assessment of transportation projects in the future. Consequently, compliance details are listed below for both PM2.5 and ozone.

The ozone rule changes the existing standard from 0.12 parts per million (ppm) of ozone measured over a one-hour period to a standard of 0.08 ppm measured over an eight-hour period, with the average fourth highest concentration over a three-year period determining whether an area is out of attainment with the standard (Environmental Management, 1997). The US EPA determined that longer-term exposures to ozone at levels below the existing 0.12 parts per million caused health effects such as asthma attacks, breathing and respiratory problems, loss of lung function, possible long-term lung damage, and decreased immunity to disease (Environmental Management, 1997).

Implementation of PM Standards

The US EPA's implementation plan has initiated a new round of review for PM science. This review must be completed before areas are designated as non-attainment and before any pollution controls are required. By July 2002, the Clean Air Scientific Advisory Committee (CASAC) will have completed its review of particulate matter, and the US EPA will have determined whether to revise or maintain the PM standards. The PM2.5 determination will be made before any areas are designated as "nonattainment" and controls are required. As mentioned earlier, the new standard will not require local controls until the year 2005 for PM, with a no compliance determination until the year 2008 and with possible extensions (Federal Register, 1997).

As required under the Act, within the next five years the US EPA will complete the next periodic review of the PM criteria and standards, including review by the CASAC. As with all NAAQS reviews, the purpose is to update the pertinent scientific and technical information and to determine whether it is appropriate to revise the standards in order to protect the public health with an adequate margin of safety or the public welfare. Although the US EPA has concluded that the current scientific knowledge provides a strong basis for the revised PM10 and new PM2.5 standards, there remain scientific uncertainties associated with the health and environmental effects of PM and the means of reducing them (Federal Register, 1997).

Interagency Research Program for PM

As part of the implementation plan, the US EPA will administer an Interagency Research Program to address PM research concerns. This program includes several components. First, recognizing the importance of developing a better understanding of the effects of fine particles on human health, including their causes and mechanisms, the US EPA will continue to sponsor research in these areas.

Second, the US EPA Administrator will initiate a new review of the scientific criteria on the effects of airborne particles on human health and the environment. The US EPA will develop and provide to CASAC a plan and proposed schedule for this review to assure that the review is completed within five years. The plan and schedule will be published in the Federal Register. Hence, by July 2002, the US EPA will have determined, based on available data from its review, whether to revise or maintain the standards. Again, this determination will be made before any areas are designated as nonattainment under the PM2.5 standards and before imposition of any new controls related to the PM2.5 standards (Federal Register, 1997).

Implementation of Ozone Standards

The revised ozone standard is intended to replace the current one-hour standard with an eight-hour standard. However, the one-hour standard will continue to apply to areas not attaining it for an interim period to ensure an effective transition to the new eight-hour standard.

Title I of the CAA addresses the requirements for different classifications of nonattainment areas that do not meet the current one-hour standard (i.e., marginal, moderate, serious, and severe). These requirements include such items as: 1) mandatory control measures, 2) annual rate of progress requirements for emission reductions, and 3) offset ratios for the emissions from new or modified stationary sources. These requirements have contributed significantly to the improvements in air quality since 1990. Based on the US EPA's legal review, the Agency has concluded that Title I should continue to apply as a matter of law for the purpose of achieving attainment of the current one-hour standard. Once an area attains the one-hour standard, those provisions will no longer apply and the area's implementation of the new eight-hour standard would be governed only by the provisions of Title I.

To streamline the process and minimize the burden on existing nonattainment areas, the one-hour standard will cease to apply to an area upon a determination by the US EPA that an area has attained air quality that meets the one-hour standard. In light of the implementation of the new eight-hour standard, which is more stringent than the existing one-hour standard, States will not have to prepare maintenance plans for those areas that attain the one-hour standard.

For areas where the air quality does not currently attain the one-hour standard, the one-hour standard will continue in effect. The provisions of Title I would also apply to designated nonattainment areas until the time each area has met the one-hour air quality standard. At that time, the US EPA will take action so that the one-hour standard no longer applies to such areas. In any event, the ``bump-up'' provisions of Subpart 2, of Part D of Title I, which require that areas not attaining the standard by the applicable attainment date be reclassified to the next higher classification, will not be triggered by the failure of any area to meet the new eight-hour standard. The purpose of retaining the current standard is to ensure a smooth legal and practical transition to the new standard (Federal Register, 1997).

Implementation of New Eight-hour Ozone Standard

This section discusses the general timeline for implementing the eight-hour standard, the importance of regional approaches to address ozone, and options for classifying and designating areas relative to the eight-hour ozone NAAQS.

Following promulgation of a revised NAAQS, the CAA provides up to three years for State governors to recommend and for the US EPA to designate areas according to their most recent air quality. In addition, States will have up to three years from designation to develop and submit SIPs to provide for attainment of the new standard. Under this approach, areas would be designated as nonattainment for the eight-hour standard by the year 2000 and would submit their nonattainment SIPs by the year 2003. The Act allows up to 10 years plus two, one-year extensions from the date of designation for areas to attain the revised NAAQS.

Transitional Classification

For areas that attain the one-hour standard but not the new eight-hour standard, the US EPA will follow a flexible implementation approach that encourages cleaner air sooner, responds to the fact that ozone is a regional as well as local problem, and eliminates unnecessary planning and regulatory burdens for State and local governments. A primary element of the plan will be the establishment under Section 172(a)(1) of the CAA of a special ``transitional'' classification for areas that participate in a regional strategy and/or that opt to submit early plans addressing the new eight-hour standard.

Because many areas will need little or no additional new local emission reductions to reach attainment, beyond those reductions that will be achieved through the regional control strategy, and will come into attainment earlier than otherwise required, the US EPA will exercise its discretion under the law to eliminate unnecessary local planning requirements for such areas. The US EPA will revise its rules for new source review (NSR) and conformity so that States will be able to comply with only minor revisions to their existing programs in areas classified as transitional. During this rulemaking, the US EPA will also reexamine the NSR requirements applicable to existing nonattainment areas, in order to address issues of fairness among existing and new nonattainment areas. The transitional classification will be available for any area attaining the one-hour standard but not attaining the eight-hour standard at the time the US EPA promulgates the new rules.

Eight-hour standard: Areas Will Follow Approaches Based on Their Status

(1) Areas attaining the one-hour standard but not attaining the eight-hour standard for which a regional transport strategy is not sufficient for attainment of the eight-hour standard.

To encourage early planning and attainment for the eight-hour standard, the US EPA will make the transitional classification available to areas not attaining the eight-hour standard that will need additional local measures beyond the regional transport strategy, as well as to areas that are not affected by the regional transport strategy, provided they meet certain criteria. To receive the transitional classification, these areas must submit an attainment SIP prior to the designation and classification process in the year 2000. The SIP must demonstrate attainment of the eight-hour standard and provide for the implementation of the necessary emission reductions on the same time schedule as the regional transport reductions. The US EPA will work with affected areas to develop a streamlined attainment demonstration. By submitting these attainment plans earlier than would have otherwise been required, these areas would be eligible for the transitional classification and would achieve cleaner air much sooner than otherwise required.

(2) Areas not attaining the one-hour standard and not attaining the eight-hour standard.

The majority of areas not attaining the one-hour standard have made substantial progress in evaluating their air quality problems and developing plans to reduce emissions of ozone-causing pollutants. These areas will be eligible for the transitional classification provided that they attain the one-hour standard by the year 2000, and comply with the appropriate provisions of section (1) above depending upon which conditions they meet.

Areas not Eligible for the Transitional Classification

For areas not eligible for transitional classification, their work on planning and control programs to meet the one-hour standard by their current attainment date (e.g.,, the year 2005 for Philadelphia and the year 2007 for Chicago) should advance toward meeting the eight-hour standard. While the additional local reductions that they will need to achieve the eight-hour standard must occur prior to their eight-hour attainment date (e.g.,, the year 2010), for virtually all areas the additional reductions needed to achieve the eight-hour standard can occur after the one-hour attainment date. This approach allows them to make continued progress toward attaining the eight-hour standard throughout the entire period, without requiring new additional local controls for attaining the eight-hour standard until the one-hour standard is attained.

These areas, however, will need to submit an implementation plan within three years of designation as nonattainment for the new standard for achieving the eight-hour standard. Such a plan can rely in large part on measures needed to attain the one-hour standard. For virtually all of these areas, no additional local control measures beyond those needed to meet the requirements of Subpart 2, Part D of Title I, would be required to be implemented prior to their applicable attainment date for the one-hour standard. Nonattainment areas that do not attain the one-hour standard by their attainment date would continue to make progress in accordance with the requirements of Subpart 2, and the control measures needed to meet progress requirements under Subpart 2 should generally be sufficient for meeting the control measure and progress requirements of Subpart 1, as well (Federal Register, 1997).

Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA)

In October 1991, the U.S. Congress passed a new transportation bill, i.e., the Intermodal Surface Transportation Efficiency Act (ISTEA), which re-authorized the national highway and transit programs for six years. ISTEA was a significant divergence from the highway legislation of the past. ISTEA marked a major departure from traditional highway policy by: 1) increasing the funding potential for transit, 2) opening dedicated highway funding to a broad spectrum of uses ranging from historic preservation to bicycle trails, and 3) elevating metropolitan planning organizations from an advisory capacity to full partners in programming transportation funds. Together, the CAA and ISTEA may provide a means of achieving greater accessibility and clean air.

NEXTEA Update

ISTEA expired on September 30, 1997, and at this time (i.e., this section was updated on February 19, 1998), no long-term transportation bill has been adopted by Congress and signed by the President to take its place. While President Clinton has signed the fiscal year 1998 Transportation Appropriations Act, much of those monies cannot be made available until ISTEA is re-authorized or given a short-term extension. On October 1, 1997, the House of Representatives passed an $11.9 billion six-month extension of ISTEA, the funds from which would be distributed under the formula established in the original ISTEA (1991). However, no such extension has been passed in the Senate. Given the uncertainty surrounding the future of ISTEA, it is difficult to speculate on the future of national policy toward ITS.

Corporate Average Fuel Economy (CAFE) (1975)

After the 1973 OPEC oil embargo, Congress and the public became concerned about the increasing dependence of the U.S. on foreign oil. Since the price of petroleum products was controlled well below market levels, many individuals thought that conservation should be encouraged through the use of nonprice mechanisms. In 1975, Congress enacted the Energy Policy and Conservation Act, which placed a particular emphasis on auto fuel economy since the greatest share of petroleum consumption was used by the automobile sector . "This legislation required that the corporate average fuel economy (CAFE) for new cars be raised gradually from 14.2 miles per gallon in model year 1974 to 27.5 miles per gallon by model year 1985" .

From the early 1970s to the mid-80s, the average fuel economy of new domestic automobiles increased more than 100 percent (CED, 1993). Gains in CAFE were achieved by: 1) reducing the weight of automobiles, 2) improving engine and drivetrain efficiency, 3) reducing tire rolling resistance, and 4) improving the aerodynamics of design. Nevertheless, overall gasoline consumption by light-duty vehicles did not decline sharply and is now higher than ever before.

There are several reasons why CAFE has not been a more effective instrument for reducing gasoline consumption. The four major factors influencing fuel consumption include: 1) more vehicles in the fleet, 2) more miles driven per vehicle. From 1985 to 1994, there was a 7.6 percentage point increase in the number of trucks and a 0.2 percentage point decrease in the number of passenger cars. The fuel economy of trucks was notably lower (i.e., 16.3 mpg) than passenger cars (i.e., 21.9 mpg) (ORNL-6919(17), p4-S, Table 4.4). This growth appears to have been driven mainly by demographics, vehicle prices, and consumer incomes. The second factor, average vehicle miles driven, has also risen, particularly for trucks. In addition, the shift in consumer preferences toward light trucks has had an important impact on gasoline consumption. The total number of vehicles miles traveled has been influenced by low gasoline prices.

Not surprisingly, the price of gasoline also appears to affect the average miles per gallon through its influence on consumer preferences for more fuel-efficient vehicles and on the decisions of two-car families to drive more fuel-efficient automobiles. Nevertheless, it is important to note that CAFE only directly improves miles per gallon of new vehicles. The overall impacts on the fuel economy of the entire fleet occurs very slowly, as older vehicles are retired. At present, the average fuel economy for the entire fleet is approximately 24 miles per gallon, which is about the same as in 1980.

In an evaluation of the effects of CAFE on the nation's fuel consumption, it is important to recognize two counterproductive effects of these standards. First, CAFE encourages increased driving because it lowers the cost of travel. Second, CAFE can encourage the retention of older, low-mileage vehicles because it adds to the costs of manufacturing new vehicles. Hence, these factors have the potential to inadvertently increase pollution because emissions increase proportionately with miles driven and more than proportionately with the age of the vehicles (CED, 1993).

Energy Policy Act of 1992 (EPACT)

The Energy Policy Act (US EPACT) was passed in 1992. Overall, there are 30 Sections or Titles in the Act. Not surprisingly, there are several titles relevant to transportation. For instance, Title II focuses on natural gas. Title III discusses general alternative fuel requirements. Title IV addresses alternative fuel programs in non-federal areas. Title V discusses requirements of the availability and use of replacement and alternative fuels, and alternative-fueled private vehicles. Title VI focuses electric motor vehicles. Title XVI addresses global climate change. Title XVIII discusses oil pipeline regulatory reform. Title XX focuses on reduction of oil vulnerability. Title XXI addresses energy and the environment.

A notable feature of the US EPACT is the alternative-fuel vehicle (AFV) requirements. Specifically, The US EPACT contains requirements for the purchase of AFVs, including electric vehicles. There are different requirements for federal, State, and other fleets to purchase AFVs. A federal fleet refers to a group of 20 or more light duty motor vehicles that are used primarily in metropolitan areas with populations more than 250,000, centrally fueled, and owned by a federal Department (Lipman, *et al.,* 1994). At present, federal fleets are not purchasing the required amount, and the requirement for State and private fleets have never been finalized.

National Environmental Policy Act (NEPA) of 1969

The National Environmental Policy Act (NEPA) is one of the most significant pieces of environmental legislation in U.S. history. Passed by Congress in 1969 and signed into law in 1970, NEPA requires federal agencies to consider the environmental consequences of their actions before executing them. In preparing and passing NEPA, Congress recognized "the profound impact of man's activity on the interrelations of all components of the natural environment, particularly the profound influences of population growth, high-density urbanization, industrial expansion, resource exploitation, and new and expanding technological advances" (42 U.S.C. §4331(a)). The language of NEPA recognizes the importance of several things: 1) preserving the environment for future generations; 2) maintaining the safety, health, productivity, and well being of the American people; 3) using the products and materials of the natural environment of the country without diminishing them to the point of destruction; and 4) maintaining a balance between the growing population of the U.S. and the country's natural resources (Shaheen *et al.,* 1994).

NEPA requires all agencies of the federal government to assess the possible adverse environmental impacts of proposed actions and legislation. NEPA applies to actions where FHWA, FTA, or agencies delegated the authority for such decisions have control over project approval. Consequently, NEPA applies to many of the projects to which conformity applies (Shaheen *et al.,* 1994).

If a federally proposed project has the potential to yield a significant environmental impact, compliance with the NEPA mandates is accomplished through the preparation of an environmental impact Statement (EIS). Under NEPA, all EISs must include: 1) a detailed Statement on the environmental impact of the proposed action; 2) a description of any adverse environmental effects that cannot be avoided should the proposal be implemented; 3) a discussion of alternatives to the proposed action; 4) a treatment of the relationship between local short-term uses of the environment and long-term productivity of the area; and 5) a discussion of any irreversible commitments of resources to be involved in a proposed action (42 U.S.C. §4332(c)) (Shaheen *et al.,* 1994).

In Title II of NEPA, Congress established the Council on Environmental Quality (CEQ) as the administering agency of the Act. NEPA required that CEQ develop a set of regulations for implementing the NEPA mandates. These Regulations are contained at 40 CFR Parts 1500 to 1508. Under the CEQ regulations, federal agencies are required to adopt procedures to ensure that applicable project-related decisions are made in accordance with the policies and purposes of the Act. The US DOT's FHWA and FTA NEPA regulations are contained at 23 CFR Part 771 (Shaheen *et al.,* 1994).

Telecommunications Act of 1996: Brief Summary and Possible Implications for ITS

The Telecommunication Act of 1996, the first major reform of U.S. telecommunications laws since 1934, seeks to reduce the regulation of and increase competition in telecommunication services, particularly in the local and long distance telephone and cable television markets. An overview of the Act's seven titles is provided below:

Table 8 : Telecommunications Act

Summary of Act's Titles		
Title 1	Telecommunications Services	Promotes the development of competitive markets for telecommunications services with special emphasis on the obligations of incumbent local telephone companies to open up their monopoly control of the local telephone market. Permits the Baby Bells to offer long distance, electronic publishing, alarm monitoring services and equipment manufacturing.
Title II	Broadcast Services	Lifts restrictions governing multiple ownership of television and radio licenses; regulates the provision of Advanced Television Services.
Title III	Cable Services	Sunsets rate regulation; amends the existing statutory framework to provide alternative ways of opening up competition to alternative providers including local telephone companies.
Title IV	Regulatory Reform	Directs the FCC to forbear from regulating telecommunication services if they are provided on a just and reasonable basis and are otherwise competitive.
Title V	Obscenity and Violence	Governs obscene or harassing use of broadcast, cable TV and interactive computer services; requires establishment of television rating codes, "V-chip" technology.
Title VI	Effects on Other Laws	Removes the applicability of various consent decrees and preempts local taxation of direct-to-home services.
Title VII	Miscellaneous Provisions	Includes: requiring privacy of customer information; requiring the pole attachments be made available to cable systems on just and reasonable terms; prohibiting the FCC from pre-empting local and State land use decisions except in limited circumstances; and preempting local and State regulations that prohibit the placement, construction, or modification of personal wireless services.

Source: Kelly and Povich, 1996

Preliminary speculation highlights the likely consequences of this Act for ITS deployment. First, there will likely be greater participation by telecommunication companies in ITS deployment. State and local governments are likely to have increasing numbers of telecommunication companies submitting responses to requests for proposal (RFPs) for the deployment of ITS infrastructure. Second, the Act may ultimately speed the deployment of ITS infrastructure. It is possible, for example, that telecommunication companies will bundle traditional voice, data and video transmission services with real-time traffic information and route guidance and other personalized traveler information.

Review of California Energy and Environmental Laws Pertaining to Transportation

California Clean Air Act of 1988

In response to many air pollution problems, California adopted the California Clean Air Act (CCAA) in 1988 (California Health and Safety Code, Sections 39612 and 43018). California enacted the legislation in recognition of the fact that most urban areas of the State had not attained federal ambient air quality standards by the federal deadline of August 31, 1988 (Stats. 1988, ch. 1568, uncodified section 1(b) (4).). The CCAA directed the development and implementation of California's own program to attain the ambient air quality standards at the earliest practicable date. Although a significant portion of the CCAA focuses on attainment of ambient standards in air pollution control districts, the statute directs the CARB to reduce emissions of motor vehicles (Health and Safety Code Section 43000.5, 43013, and 43018).

The CCAA added a new section to the Health and Safety Code, Section 43000.5, which States: "the State board should take immediate action to implement both short- and long-range programs of across-the-board reductions in vehicular emissions which can be relied upon by the districts in the preparation of their attainment plans or plan revisions" (Section 43000.5(d)). The CCAA also amended Section 43013, which added a subsection authorizing standards for specific types of motor vehicles and related equipment. "The State Board may adopt and implement motor vehicle emissions standards, *in-use performance standards, and motor vehicle fuel specifications* for the control of air contaminants and sources of air pollution which the State board has found to be necessary, *cost-effective*, and technologically feasible to carry out the purposes of this division" (Section 43013(a)). Finally, the CCAA enacted Section 43018(a-d). Section 43018(a) States that the State Board shall try to achieve the maximum degree of emission reduction in mobile and vehicle emissions to meet the State standards. Section 43018(b) States that the Board shall take whatever actions are necessary, no later than January 1, 1992, to attain a reduction in the emissions of HC (55 percent) and NOx (15 percent) by December 31, 2000. The Board must also achieve maximum feasible reductions in particulates, CO, and toxic air contaminants. Section 43018(c) establishes that the Board must adopt standards that result in cost-effective control measures on all motor vehicles and motor vehicle fuels. Finally, Section 43018(d) "...establishes a specific timetable for the Board to conduct workshops and rulemaking hearings for specific regulations regarding motor vehicles and motor vehicle fuels."

In summary, the California legislators enacted the CCAA as a result of the State's recognition of its air pollution problems and its inability to meet the federal ambient air quality standards in many urban areas by August 1988. The Act is ambitious and far-reaching in its goals and objectives. For the first time, a vehicle and its fuel would be treated as a system that would have to meet exhaust emission standards. This integrated approach, based on performance of the vehicle/fuel system, provides flexibility and encourages the vehicle and fuel industries to work together to develop the least polluting and most cost-effective vehicle and fuel technologies. Hence, California was the first State to adopt the most stringent vehicle emissions legislation.

It is important to note that California legislators had established these goals and standards prior to enactment of the federal CAA 1990. Although the California regulations were already in place, the CAA of 1990 require the introduction of clean-fuel cars in California beginning in 1996. The CAA of 1990 also provides a voluntary "opt-in" provision that allows other States to adopt the California standards (the California pilot program). California is the only State that can set higher emission standards than the federal government; after California has established higher standards other States can then adopt them. The CAA of 1990 acts as an insurance policy that California continue meeting the goals established in the CCAA. However, the California program will meet the federal requirements by default.

California's Zero Emission Vehicle (ZEV) Mandate of 1990

In September 1990, CARB adopted the California Low-Emission and Clean Fuels (LEV/CF) program that established stringent emission standards for four new classes of light- and medium-duty vehicles: Transitional Low-Emission Vehicles (TLEVs), Low-Emission Vehicles (LEVs), Ultra-Low-Emission Vehicles (ULEVs), and Zero-Emission Vehicles (ZEVs). The LEV/CF regulations took effect in model year 1994, and become increasingly more stringent through the year 2003. For the first time, an increasingly stringent annual fleet average emission requirement was established to provide a flexible mechanism for phasing-in low emission vehicles (LEVs), which allows manufacturers to choose the mix of LEVs that they will produce in any given year. The establishment of a marketable credit system provides additional flexibility. Manufacturers who produce more LEVs than needed to meet the fleet average requirements will earn credits. These credits can be banked internally for future use or traded to other manufacturers who cannot or do not want to meet the requirement.

The ZEV mandate, part of the 1990 LEV/CF program, required that two percent of the new cars sold in California in 1998 be ZEVs. That percentage increased to five percent in 2001 and ten percent in 2003. Because of the long-term nature and technological challenges presented by the LEV regulations, as well as the market-based consideration, the implementation of the program has been updated several times. The most recent modification was in March 1996, which eliminated the ZEV percentage requirements from 1998 through 2002, while retaining the ten percent requirement for 2003 and beyond.

In October 1995, CARB introduced a new class of medium duty truck standards called "Super Ultra Low Emission Vehicle" (SULEV), which sets emission levels at twice as clean as those required in the ULEV standard, the State's tightest internal combustion engine standard.

In November 1997, new amendments were proposed to the LEV regulations. These amendments include a proposed modification to passenger car, light-duty truck and medium-duty vehicle exhaust emission standards beginning with the 2004 model year. The recent technology developments indicate that gasoline, alternative fuel, and hybrid electric vehicles (HEVs) could potentially reach a significantly lower emission level. Further, a partial ZEV credit was proposed that allows hybrid-electric and fuel cell vehicles, as well as certain gasoline-powered SULEVs, qualify for a portion of the 10 percent “ZEV” sales requirement.

ZEV Definition

The ZEV definition, as specified by CARB means any vehicle that produces zero emissions under any and all possible operational modes and conditions (Section 1900 of Title 13 of the California Code of Regulations). Basically, this means that there can be no tailpipe emissions or on-board combustion (i.e., except for heaters in cold climates). Electric vehicles (EVs) represent the only technology that meets the current ZEV definition. It is possible, however, that a hybrid vehicle (i.e., a vehicle that combines electric motors with small internal-combustion engines or fuel cells to allow extended driving range) could produce lower net emissions under some operating modes. A controversy has thus arisen over the appropriateness of excluding vehicles from the ZEV definition, and therefore the potential for receiving ZEV credits, that may in effect be as "cleaner" as battery EVs (BEVs) on a fuel cycle basis. At present, CARB is considering the possibility of awarding ZEV credits to hybrids and other vehicles in the ZEV mandate.

Applicability of the ZEV Mandate

Manufacturers producing an average of over 3,000 vehicles or units per year for sale in California (i.e., large volume manufacturers) are required to comply with the 2003 ZEV mandate.

California Environmental Quality Act (CEQA) of 1970

Although NEPA regulates many actions, it does little to address proposed projects on a Statewide or local level. Consequently, California and thirteen other States have enacted environmental legislation to govern activities affecting their respective territories (Mandelker, 1984). “For most State programs, the points that must be covered in environmental impact documents are similar to those in Section 102(2)(C) of NEPA” (Ortolano, 1984). Nevertheless, a few States include additional environmental assessment requirements (Ortolano, 1984). For example, California requires “an assessment of the ‘growth-inducing impact’ of proposed actions and a description of ‘mitigation measures’ that could be taken to minimize adverse impacts” (Ortolano, 1984) (Shaheen *et al.,* 1994).

In 1970, the California legislature passed the California Environmental Quality Act (CEQA), which requires that environmental analyses be performed by State and local governments before proposed actions are undertaken. CEQA recognizes several key goals for the State of California: 1) maintaining a quality, healthy environment for the future as well as the present; 2) maintaining the capacity of the environment well beyond minimal thresholds of health and safety; and 3) regulating the activities of citizens of the State to safeguard the environment, while preserving the lifestyles and living environment for the citizens of California (Public Resources Code (PRC) §21000) (Shaheen, *et al.,* 1994).

In general, CEQA's intent is to require "all agencies of the State government which regulate activities of private individuals, corporations, and public agencies which are found to affect the quality of the environment [to] regulate such activities so that major consideration is given to preventing environmental damage, while providing a decent home and satisfying living environment for every Californian" (PRC §21000(g)). In comparison to other State programs, California has the broadest environmental-planning coverage (Ortolano, 1984). For instance, CEQA "applies to State-initiated actions, such as highway projects, as well as a variety of decisions made by cities, counties, and regional agencies. Local agency actions, which include the granting of building permits and zoning variances, have made the California impact assessment requirements applicable to proposals made by private parties. Environmental impact reports (EIRs) have been written for virtually thousands of private land development projects in California" (Ortolano, 1984) (Shaheen *et al.,* 1994).

When both NEPA and CEQA are applicable to a proposed project, both regulations may be satisfied with the preparation of a joint EIS/EIR document. To help agencies fulfill the requirements of CEQA, the State Office of Planning and Research has prepared a set of CEQA guidelines. Arrangements for administering environmental impact requirements vary from State to State. In some cases, the EIS program is managed by the State Departmentof natural resources. Other States rely on their environmental protection agencies (Shaheen *et al.,* 1994).

New Paradigms in ITS Evaluation: ITS and Sustainable Communities

While this report has focused on the energy and emission impacts of ITS technologies, it is also possible to analyze ITS within a broader environmental framework. This broader evaluatory framework, which is often labeled "sustainability" or "sustainable communities," seeks to understand which short- and long-term environmental, social, and economic impacts ITS deployments are likely to result. The sustainability paradigm was at the heart of the transportation reforms made by ISTEA, and the concept is gaining increasing currency in the transportation policy-making community. This section summarizes the sustainable communities concept and makes some preliminary applications of the concept to ITS.

Introduction

The 1990s may well be remembered as the decade in which the idea of "sustainability" first took hold in government, business, academia, and popular culture. The most well-known expression of sustainability--sustainable development--occurred at the 1992 Earth Summit, where representatives from more than 150 nations, including 117 presidents and prime ministers, pledged to integrate environmental and economic development in their respective nations' planning and policy. Defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED,1987), sustainable development has become a leading standard for measuring human progress (Hempel 1995).

In the U.S., concerns about sustainability or sustainable development have entered policy discussions at various levels of government and sectors of society. Important sustainable development projects exist at the national level (e.g., President's Commission on Sustainable Development), the State level (e.g., Minnesota Sustainable Development Initiative), and the local level (e.g., Sustainable Seattle). Similar efforts to incorporate sustainability concepts are now underway in the transportation sector. For example, the Transportation Research Board completed a major study on the concept of "Transportation and a sustainable environment." Other efforts to link transportation and sustainability include a White House sponsored dialogue on greenhouse gas emissions from personal automobiles (called "Car Talk") and the Institute of Transportation Engineers' adoption of "Transportation and Sustainable Communities" as the theme of its 1997 conference. All of these initiatives will have important impacts on the design of future transportation systems.

Efforts to apply the sustainability paradigm to transportation have coincided with the advent of ITS, and a debate is now underway over whether ITS will facilitate or undermine efforts to promote sustainable communities. Replogle (1994), for example, argues that an ITS program stressing demand management strategies could "be the most important enabling technology driver in decades to reform and progress in American transportation, winning for our citizens sustainable high wage jobs, reduced traffic delay, more livable communities, and a healthy environment." Cervero (1995), however, expresses far less optimism about ITS's potential contribution to sustainable communities, arguing that a major ITS deployment program "stands to worsen by orders of magnitude" the problems of excessive auto travel, suburban sprawl, and air pollution.

We argue that ITS technologies can indeed promote efforts to build sustainable communities. By providing vast amounts of information on the performance of the transportation system, ITS could allow for greater operational control of that system and reduce the negative externalities associated with transportation. Easily disseminated information about the transportation system--such as price signals that convey the true costs of driving, "real-time" traffic and emissions data, or information on the costs and benefits of alternative transportation policies -- could enable transportation to serve the multiple economic, social, and environmental goals implied by the sustainable communities paradigm. ITS offers the prospect of a "knowledge-intensive" transportation system in which the information provided could increase mobility, reduce environmental damage, and improve the overall quality of life in communities. Such a system will not evolve automatically, however. Before the promise of ITS becomes a reality, ITS deployments must be integrated into an overarching policy and institutional framework aimed at promoting sustainable communities.

Elements of sustainability

Sustainable Development

Before describing possible linkages between ITS and sustainable communities, it is necessary to provide some background on the "sustainability" concept. Since the WCED's 1987 definition of *sustainable development* as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs," over 70 definitions of sustainable development have entered the policy literature (Tryzyna,1995). Despite its promise as a measure of progress and as a mobilizing vision, the concept of sustainable development remains controversial and difficult to define, and is particularly difficult to translate into practical action. Indeed, Ruttan (1993) correctly notes that the popularity of the WCED definition stems in part from it being "so broad that it is almost devoid of operational significance." Take the notion of ecological sustainability with respect to a lake, for example. "Sustaining" a healthy lake as a stable aquatic ecosystem means reversing the natural process of eutrophication that slowly turns lakes into marshes, and marshes into forests. In such instances, it is ecological integrity that must be sustained, not necessarily a particular ecosystem.

Despite their limitations, sustainability concepts provide useful frameworks for thinking about the future. Given that almost 200 international conferences, professional meetings, and scientific associations have used sustainability as the theme of their gatherings in recent years (Hempel 1995), it is not surprising that the transportation community is now discussing about sustainability.

Sustainable Communities

Utilizing the WCED's definition of sustainable development, we offer the following as a "synthetic" definition of the various strands considered under the rubric of *sustainable communities*:

> *Sustainable communities have levels of pollution, consumption, and population size that are in keeping with regional carrying capacity; their members share an ethic of responsibility to each other and to future generations; their goods and services reflect the full social and environmental costs of their provision; their system of governance and civic leadership encourages democratic deliberation; and their design of markets, transport, land use, and architecture enhances neighborhood livability and environmental quality.*

As highlighted in Figure 2 below, sustainable communities consist of three basic interrelationships: 1) the psychological and physical relationships between the quality of human life and the quality of the natural environment (the biosphere); 2) the social and political relationships between the quality of individual human life and the quality of community engagement and collective self-governance; and 3) the local-global relationship between community planning and governance and the health of the planet. Sustainable communities in our view are made possible by this set of forces operating in a mutually enhancing fashion.

Figure 2: Model of Sustainable Community

A MODEL OF SUSTAINABLE COMMUNITY

Quality of Human Life: *Health, freedom, access to resources.Fulfillment of individual potential.*

Civic Engagement: *Social equity, sense of place and participation in governance.*

Quality of Biosphere: *Biological diversity, carrying capacity, life support,and renewable resource base.*

"Communities" represent the social and physical expression of interdependence. While they can be organized for both good and ill ends, communities connect individuals with each other, and collectively with the bioregion that envelops them. When designed to promote cooperation for mutual benefit, they provide what Robert Putnam (1993) calls "virtuous circles" or self-reinforcing stocks of "social capital: [which includes] cooperation, trust, reciprocity, civic engagement, and collective well-being." Communities do for people what ecosystems do for nature, they bring a measure of stability and common purpose to the lives of individual organisms.

Another key element of sustainable communities is concern for ecological "carrying capacity." Ecological carrying capacity depends on at least three key factors: 1) the assimilative capacity of ecosystems and bioregions (e.g., the ability of marshes to absorb and break down certain harmful pollutants); 2) the regenerative capacity of natural systems (e.g., forest regrowth after fires), and 3) the technological expansion or substitution effect, whereby man-made artifacts can be used in place of damaged natural amenities (e.g., growing food hydroponically in order to cope with topsoil erosion). Physical indicators such as emission levels of CO, CO_2, the level of paved surface area, etc., can suggest the threshold level for sustainability (Hempel,1995). Perhaps more than anything else, it is concerns about the earth's carrying capacity that spur investigation into the concept of sustainable transportation.

Sustainable Transportation and ITS

The link between ITS and sustainable transportation stems from ITS's ability to create a transportation system rich in information, or what might be called an "information-intensive" transportation system. An "information-intensive" transportation system raises two prospects. First, it means using information instead of new lanes, roads, and highways as a way to increase the capacity of the transportation system. In this sense, ITS "substitutes information for stuff,"[2] resulting in capacity enhancements that use fewer material resources, consume less open space, and reduce the noise and community disruption related to new roads. ITS thus support an underlying premise of "sustainability thinking:" that the Earth's resource base has limits, that some of those limits are being approached, and sustainable development depends on accommodating economic growth while consuming fewer resources.

Beyond potentially substituting for physical elements of the transportation system, the information provides may also enhance the system's performance. It is critical, however, that "enhanced performance" be defined broadly to include greater traffic efficiency *and* a reduction in the transportation system's negative externalities. ITS can contribute to this broader notion of enhanced performance by providing information that allows for greater operational control of the transportation system. Achieving more control of the system, in turn, increases the opportunities to address specific purposes, including broad social, economic, and environmental goals.

Figure 3 illustrates ITS applications that facilitate greater control of the transportation system by channeling information to system managers and users. "Remote sensing,"[3] for example, can generate emission data and assist air quality officials in targeting "gross polluters." Another example is "congestion pricing," or charging drivers a fee that varies with the level of traffic on a roadway.[4] Congestion pricing conveys information (in the form of price signals) that alerts

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[2] We take the phrase "substituting information for stuff" from Robert B. Shapiro, chairman and CEO of Monsanto Company. In a 1997 interview published in a *Harvard Business Review* article entitled "Growth Through Global Sustainability," Shapiro underscored the indispensable role of information in promoting sustainable development due to its ability to substitute "information for stuff:" "Using information is one of the ways to increase productivity without abusing nature... A closed system like the earth's can't withstand a systematic increase of material things, but it can support exponential increases of information and knowledge. Sustainability and development might be compatible if you could create value and satisfy people's needs by increasing the information component of what's produced and diminishing the amount of stuff" (p.882).

[3] "Remote sensing" refers to technologies that can measure the exhaust emissions from vehicles as they pass a roadside detector.

[4] While "congestion pricing" is a policy and not an "ITS application" *per se*, two ITS technologies, advanced vehicle identification (AVI) and electronic toll collection (ETC), enable congestion pricing by allowing automobiles to pay for tolls without stopping at toll booths. Other ITS technologies measure congestion levels and allows toll amounts to vary with congestion levels.

drivers to the overall social and environmental costs of driving, making them aware that driving imposes external costs while encouraging more environmentally benign travel behavior.[5]

Figure 3: ITS-Generated Information and Sustainability

ITS Category	*Application*	*Flow of Information*	*Contribution to Sustainability*
Traffic Management	--Traffic signal synchronization	--traffic information to traffic managers allows re-timing of signals to optimize traffic flow	--reduces energy usage and emissions related to "stop & go" traffic and congestion
	--Incident detection	--incident (i.e., freeway accident) information to traffic managers allows faster emergency response, re-timing of ramp meters, etc.	--reduces energy usage and congestion-related emissions
Traveler Information	--Pre-trip traveler information	--traffic information to traveler allows for shift in travel time, route, or mode	--reduces energy usage, congestion-related emissions and/or the number of trips/ SOVs
	--En-route traveler information	--traffic information to driver allows shift in route	--reduces energy usage congestion-related emissions

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[5]Estimates of the external costs of the U.S. transportation system (measured in the costs associated with loss productivity, damage to human health, damage to agriculture, and extinction of plants and animals) range from between $10 to $200 billion per year (OECD,1995). One study of congestion pricing, for example, found that fees of between $.10 and $.15/mile could reduce travel during that period by 10 to15 percent (NRC,1994), thus reducing congestion-related emissions and perhaps leading to a net reduction in automobile use.

Figure 3: ITS-Generated Information and Sustainability (cont.)

ITS Category	*Application*	*Flow of Information*	*Contribution to Sustainability*
Other	--Congestion-sensitive road tolls (i.e., congestion pricing)	--information to drivers (in the form of price signals) that relays full social an environmental costs of driving	--reduces energy usage and emissions by reducing number of trips/SOVs, reducing congestion, and perhaps encouraging less auto-dependent land use patterns (i.e., less sprawl)
	--Remote sensing of emissions	--vehicle emissions information to drivers and/or air quality managers	--aid in targeting 'gross polluters' (10% of vehicles responsible for roughly 50% of emissions)
	--Demand-responsive transit services	--information to transit managers and transit riders on supply/demand/status related to transit	--reduces emissions and energy usage by encouraging use of transit; helps create more equitable distribution of transportation services to under-served populations (i.e., handicapped, elderly)

ITS, Sustainable Communities and ISTEA

Integrating transportation policy with efforts to improve mobility and accessibility, reduce air pollution, manage land use patterns, and promote social equity is an application of the sustainability framework. ITS systems, by providing information on the performance of the transportation system, provide a technological means of moving toward the sustainability ideal. But this promise cannot be realized without a transportation policy framework that goes beyond the traditional emphasis on mobility and traffic efficiency. Crucial to the creation of a sustainable transportation system is a transportation policy guided by a vision of sustainable communities.

Such a vision was behind major transportation legislation passed in 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA). ISTEA marked an evolution in the U.S. transportation policy, shifting the focus away from highway construction projects. ISTEA is the first comprehensive federal transportation legislation to explicitly endorse the idea that transportation can serve a broad range of social and environmental goals (Dunno, 1994). The law instructs transportation planners to analyze "the overall social, economic, energy, and environmental effects of transportation" [CFR, 450.316(a)(13)]. In conjunction with the 1990 CAAA ISTEA further integrates transportation policy with efforts to control air pollution and manage land use patterns. ISTEA also mandates that the benefits of the transportation system be extended to poor and minority communities and others "traditionally under-served by the transportation system" [CFR, 450.316(b)]. Camph (1994) characterizes the new program and policy directions in ISTEA as follows:

- *Emphasis on a systems approach*, with increased focus on alternative modes, environmental protection, and mobility of persons and goods;
- *A holistic approach to planning*, which expands concepts of system performance to include mobility and access, equity, reliability and external impacts and stipulates a cooperative partnership for planning between local and State governments;
- *Flexibility*, unprecedented flexibility in moving money between modes (i.e., roads, transit, bikes, and pedestrians), making funding decisions clearly a part of the planning process;
- *Linkage to air quality and environment*, in both funding and planning;
- *Emphasis on performance*, with a focus on preservation, maintenance, and management of the existing roads and highways through management systems;
- *Emphasis on aesthetics*, with both planning requirements and funding set-asides for scenic byways and easements, historic preservation and other features;
- *Focus on safety*, on the roads and in communities, for users and non-users; and
- *Emphasis on public involvement*, which moves the nation toward a participatory model of decision making, with an informed citizenry playing a key role.

ISTEA has thus made regional transportation planning a more comprehensive, participatory process, and one in which planners are increasingly required to balance the goal of traffic efficiency with broad social and environmental concerns.[6] This process differs significantly from traditional transportation planning, when policy makers had "few incentives to include urban renewal, social regeneration, and broader transportation objectives in their programming" (Rose, 1990, p.96). ITS provides a new set of tools to implement the holistic vision of transportation policy embodied in ISTEA, but it is critical that these tools be properly directed in relation to

[6] Initiatives in Albany, New York, and Portland, Oregon, provide examples of the comprehensive transportation planning mandated by ISTEA. In Albany, the Capital District Transportation Committee (CDTC) is charged with preparing the long-range plan and transportation improvement program for the Albany, Schenectady, and Troy areas of Upstate New York. The CDTC enlisted the help of over a hundred agency personnel, municipal and county officials, business people, public interest groups, citizens and neighborhood groups in a series of topical task forces. These task forces addressed issues such as goods movement, quality of life, and least cost planning measures. The result, according to CDTC staff, is a broad involvement and understanding of key transportation issues by community leaders and a better reflection of the social, economic, and environmental impacts of transportation (Dittmar, 1996). The transportation plan for Portland, developed by Metro (i.e., the region's metropolitan planning organization), extends to the year 2040, and focuses on light rail investment, multiple centers of growth, and continued creation of a mixed use, transit-oriented center city.

sustainable communities. ITS systems *per se* are neither all “good” or all “bad;” what matters is that they be integrated into a policy and institutional framework aimed at achieving this vision.

SCENARIOS

Methodology for ITS and Environment Scenarios

The purpose of this part of the PATH project was to develop a methodology for evaluating the role and impact of ITS technologies on the environment. Since there are so many uncertainties associated with ITS deployment in the future, scenarios provide a framework for assessing and ranking technologies according to their environmental impacts. The modeling scenarios include baseline data for a ten-year period for a particular region to be modeled, including: population, VMT, and air quality attainment status. Other data include land use (i.e., employment and commercial activity data) and transportation infrastructure developments planned for the modeled region and corridor. We selected the Santa Monica Freeway (I-10) Corridor (also known as the SMART Corridor) in Southern California as the region and corridor to be modeled in this project. Included in this section of the report is a description of the Southern California region and the SMART Corridor. Further details of the SMART Corridor are given in the following section, "Modeling of ITS Technologies with INTEGRATION V2.0".

To develop the scenarios we used a Delphi method, which relied upon the knowledge and understanding of experts in the ITS field to create a forecast for ITS deployment for a ten-year period (i.e., 1995-2005). First, we interviewed experts in Washington, DC, and Los Angeles, CA, to abstract expert opinions about the future of ITS technologies and their market penetration over a ten-year period. Next, we used expert interview data collected in the summer of 1997, to develop our initial scenarios.

The four scenarios that we developed for this study include: 1) a status quo, 2) an industry-dominated approach, 3) a government-dominated approach, and 4) a public-private partnership approach. These scenarios provided a context for establishing deployment rates and user acceptance for various types of technologies that may surface over the next ten years. For instance, an industry-world scenario relies heavily on private sector firms to finance and operate the ITS technologies. All of the scenarios have implications for the market for the various ITS technologies that will be deployed and the individuals that will purchase these technologies.

Finally, in the Fall of 1997, we held two expert scenario workshops, the first in Washington, DC, and the second in Davis, CA, to refine the initial status quo, industry, government, and the public-private partnership scenarios and develop market penetration estimates for each of the ITS technologies included in these scenarios.

A summary of the scenario analysis is contained in this section of the report. The complete set of interview and scenario materials are contained in Appendix D at the end of this document. Appendix D contains copies of the interview questionnaires and the interview and expert workshop summaries.

Scenario Approach

Part I. A region and corridor were selected for this evaluation: Southern California, Santa Monica Freeway (I-10) Corridor.

Part II. Baseline data for the selected region were gathered to begin constructing the basic framework for the scenario analysis. Drawing from David Albright's[7] Systems Engineering for Transportation (SET) approach, we constructed a base case description of this region that reflects the baseline data and three additional components: 1) the system users, 2) ITS technologies, and 3) supporting infrastructure and the surrounding environment in the project's selected region. This base case or status quo scenario served as the preliminary system from which the alternative-world scenarios and future forecasts were developed.

We used the baseline data and SET approach to describe the region in which we will model the selected ITS technologies will be modeled , including: 1) electronic toll collection, 2) signal coordination, 3) en-route vehicle traffic information (i.e., dynamic), and 4) en-route vehicle guidance systems (i.e., static). Interviews were conducted to collect data that helped us to create three alternative-world scenarios for the Washington, DC, expert scenario workshop participants to review. These scenarios emerged from the SET interviews and the base case for the I-10 corridor, including the demographic and emissions baseline data. The modeled scenarios are limited by the set of technologies selected for analysis in this study.

Baseline Data/Description for the Modeled Region

- Population projections for ten-year forecast;
- VMT projections for ten-year forecast;
- Land use inventory forecast, e.g.,, residential zones (housing density), commercial and industrial zones (by type of establishment), and parking spaces;
- Emission projections for criteria pollutants (i.e., from the emissions budget) and carbon dioxide for ten-year forecast (e.g., derived from fuel consumption estimates);
- Infrastructure/land-use changes in region for ten-year forecast;
- Description of system use and population characteristics in the region and along corridor (e.g., user acceptance and level of service);

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[7] David Albright works for the Alliance for Transportation Research in Albuquerque, New Mexico. He drafted a paper titled: "Systems Engineering for Transportation," in the Spring of 1997. He has not yet published this paper. The Systems Engineering for Transportation (SET) approach consists of three critical elements: the user, vehicle or technology, and infrastructure or surroundings. Each of these elements must be included in the representation of a system.

- Description of ITS technologies (i.e., 1) electronic toll collection, 2) signal coordination, 3) en-route traffic Information, and 4) en-route vehicle guidance systems); and

- Description of supporting infrastructure and surrounding environment in the selected corridor.

Part III. Three interview questionnaires were developed for gathering quantitative and qualitative data for each of the three scenarios; i.e., a separate questionnaire for the government, industry, and public-private partnership interviews. To some extent, there was overlap in the interview questionnaires. For each ITS technology, we gathered user acceptance and market penetration estimates in the individual interviews. We used these estimates to create two deployment scenarios, i.e., one for the first five years (2000) and another for the second five years (2005) of the modeling effort. We have assumed that the vehicle fleet characteristics will remain stable to reflect the current regulatory and political environment (e.g.,, ZEV mandate) and the timeframe for the modeling exercise (i.e., 1995 to 2005). Finally, the political context was captured by the interviews (given each particular scenario), which could impact the deployment of ITS technologies and user acceptance. Such political factors might include political initiatives (e.g.,, the NAAQS amendments), global warming, or an oil crisis. Finally, we asked questions regarding the economic context in each of the interviews, which have been captured in the resulting scenarios described over the next ten years. All of these data will be used to differentiate from the base case or status quo scenario for the modeled region/corridor.

Part IV. Two expert scenario workshops were conducted in the fall of 1997. Present synthesized results from the DC and LA expert interviews (Part III) to workshop participants in the form of descriptive scenarios and summary tables of market penetration estimates. After the DC workshop participants reviewed initial scenarios in September 1997, we revised the scenarios to reflect the alternative worlds created by the DC participants. At the California workshop, we presented the scenarios developed by the DC experts to the California experts. The final scenarios, and corresponding market penetration estimates, that will be used in the modeling exercise in this project are the product of our modified Delphi approach and the final round of expert reviews in November 1997.

Parts I and II: SMART Corridor (Santa Monica Freeway (I-10) Corridor) Baseline Description

Regional overview

The SMART Corridor lies in the heart of Southern California, one of the largest, most traveled, and most environmentally challenged regions in the nation. The South Coast "region" includes six counties--Los Angeles, Orange, Ventura, Riverside, San Bernardino, and Imperial--and extends over 3,500 square miles. Its total population exceeded 14.6 million in 1990, and is expected to reach 20.5 million in 2010. Los Angeles County--the region's "center" and the portion through which the SMART Corridor extends--contained nearly 8.9 million residents in 1990, and the population will reach nearly 11.3 million in 2010. Between 1995 and 2005, the region's population and household growth rates are expected to be 1.4 and 1.6 percent, respectively.

Economic Forecast

Some of the region's economic characteristics and projections are shown in Table 9 below.

Table 9: Economic Characteristics and Projections for Southern California

Southern California Region: Select Economic Characteristics and Projections, 1995-2005 (1995$)				
		2005		
	1995	***Low***	***Moderate***	***High***
Per Capita Personal Income	$22,597	$26,198	$27,416	$29,082
Average Household Income	$69,263	$78,416	$82,064	$87,051
Total Personal Income (millions of 1995$)	$360,297.1	$478,686.4	$500,953.7 (represents growth of 39% over 1995)	$531,397.8

Land Use and Travel

The region's urban form is best described as widely distributed low- and medium-density communities. While the entire region is experiencing population and employment growth at a rate exceeding the national average, that growth is occurring fastest in the "outlying" counties of Riverside and San Bernardino. Moreover, employment centers continue to disperse. For example, the region contained 10 employment centers in 1980 (defined as an area with 20,000 or more jobs and a density of at least 20 jobs per acre), and these centers contained roughly 17 percent of the region's employment. In 1990, 12 such centers existed, but they contained only 14.4 percent of regional employment. The trend of population decentralization and workplace dispersion is likely to continue over the next ten years.

This scattered urban form ensures that southern Californians do a lot of driving, yet in many respects their travel patterns resemble those in other urban areas. The region's traffic congestion is among the nation's worst, with Los Angeles County alone accounting for over 85 million daily VMT and eight of the nation's ten busiest freeway interchanges. Shown below are select statistics on the region's travel (Table 10), as well as a comparison with travel in other urban centers (Table 10)

Table 10: Select Statistics on Travel in Southern California

Southern California Travel Characteristics, 1990	
Daily Person Trips	48,867,000 --23% work-related --77% non-work related
Daily Vehicle Trips	33,416,000
Daily VMT	294,169,000
Average Speed	32.5 mph
Daily Hours delay	2,152,000

Table 11: Comparison of Travel Characteristics in Southern California with Other Urban Areas

Southern California and Large Metropolitan Area Travel Characteristics, 1990		
	All Metro Areas With >2 Million Population	Southern California Region
Percentage of Households with >1 Vehicle Per Driver	76%	82%
Share of Person Trips by Mode, all Vehicle Trips:		
Private Vehicle Driver	61.1%	63.4%
Private Vehicle Passenger	21.4%	23.9%
Transit	3.7%	1.7%
Walk	10.6%	8.3%
Other	3.1%	2.7%
Private Vehicle Trip Length, by Trip Purpose (in miles):		
To Work	11.4%	12.3
To Shop	4.1%	3.5
Social or Recreational	9.6%	9.2
Persons per Vehicle		
Work Trips	1.12	1.20
Nonwork Trips	1.63	1.64

Air Pollution

The region's transportation system is one reason southern California has the nation's worst air pollution. In 1989, the region exceeded federal air quality standards on 219 days. Yet improvements in auto emission reduction technologies contributed to 1995 air pollution being the lowest on record: the region experienced 13 stage-one smog alerts, compared to 23 in 1994, and the high of 127 in 1977. Nevertheless, increases in population and economic activity tend to undermine the trend toward better air quality. Displayed below in are statistics on Southern California emissions (Table 12) and emissions budgets (Table 13) related to the NAAQS.

Table 12: Mobile Source Emissions in Southern California

Emissions from Mobile Sources (tons per day); Southern California Air Quality Management District (SCAQMD)*				
	1993	***2000***	***2006***	***2010***
VOC	790	462	342	284
NOx	1,040	769	634	593
CO	6,946	4,233	3,466	3,145
SOx	56	48	53	57
PM-10	42	31	30	30

* The Southern California Air Quality Management District covers over 12,000 square miles, and includes all of Orange County and the non-desert portions of Los Angeles, Riverside, and San Bernardino Counties

Table 13: Southern California Air Quality Management District Emissions Budgets

SCAQMD Emissions Carrying Capacity (Emissions Budgets) Estimations (tons per day)	
Carbon Monoxide Attainment Strategy (2000)	
Emission Category	*CO*
Stationary	294
On-Road	3125
Off-Road	1549
Overall Control Strategy to Meet NAAQS	4958

Table 13: Southern California Air Quality Management District Emissions Budgets (cont.)

SCAQMD Emissions Carrying Capacity (Emissions Budgets) Estimations (tons per day)				
PM_{10} Attainment Strategy (2006)				
Emission Category	*VOC*	*NOx*	*SOx*	*PM_{10}*
Stationary	341	96	13	271
On-Road	187	350	16	14
Off-Road	95	189	37	16
Overall Control Strategy to Meet NAAQS	623	635	66	301
Ozone Attainment Strategy (2010)				
Emission Category	*VOC*		*NOx*	
Stationary	268		88	
On-Road	81		278	
Off-Road	64		164	
Overall Control Strategy to Meet NAAQS	413		530	

SMART Corridor (Santa Monica Freeway (I-10) Corridor)

The Santa Monica Freeway Corridor was the location for the Pathfinder in-vehicle information system project conducted in 1990. This freeway is one of the most traveled freeways in the country with an average daily traffic count of almost 250,000 vehicles. The study area consists of approximately 11 miles of freeway with associated ramps (i.e., 26 on-ramps and 26 off-ramps in each direction), five parallel arterials (i.e., Olympic Boulevard, Pico Boulevard, Venice Boulevard, Washington Boulevard, and Adams Boulevard), and a network of other surface streets. The corridor also includes four connector on-ramps and four connector off-ramps. The SMART Corridor is described in more detail in the following main section of this report "Modeling of ITS Technologies with INTEGRATION V2.0".

Part III: Expert Interview Materials

This section of the report is a summary of the scenario research findings, which are based on expert interviews that were conducted in Washington, DC, and Los Angeles in the summer of 1997, and the expert scenario workshops that were held in Washington, DC and Davis, CA, in the Fall of 1997. The final section of this summary contains a table that presents the final or "model" scenarios that were developed through our modified Delphi expert interview and workshop research process (described earlier). The "model" scenarios are the actual ones that will be modeled with INTEGRATION in this study. In the next step of this research project, the INTEGRATION modeling results will be evaluated and then prioritized according to the energy and environmental criteria specified in "Ranking of ITS Technologies Based on Energy and Environmental Impacts," which is a subsection of the next section of this report: "Modeling of ITS Technologies with INTEGRATION V2.0."

The following four tables summarize the results from the Washington, DC, and Los Angeles expert interviews. The summary findings are listed in two table formats: 1) general findings and 2) market penetration estimates. Please note that the interview protocols and summaries for both the DC and LA interviews can be found in Appendix D at the end of this report.

<u>Comparison of DC and LA Expert Interview Perspectives: Future Markets for ITS Technologies</u>

It is interesting to note the similarities and differences between the DC and California expert perspectives on the future market for ITS technologies and systems. Our evaluation of expert responses are grouped into six main question areas. See Tables 14 and 17 for the interview summaries presented from three different world views or perspectives: 1) industry, 2) government, and 3) public-private partnership.

Most Likely Technologies

There was a significant difference between the LA and DC experts in response to this question. The LA respondents, from all three sectors, highlighted three main technologies in their reply to this question: vehicle information systems, ETC, and ATSC.

In contrast, DC experts commented on the same technologies, but they often had different reactions to deployment rates. There was agreement among the industry, government, and public-private partnership experts that ATSC would be widely deployed and that en-route vehicle information services would have a low market penetration (i.e., less than 10 percent). CMS was described as an expensive and inefficient information tool by industry. The public-private partnership experts predicted a 25 to 50 market penetration rate for this technology, while government experts estimated a 100 percent market penetration rate. Based on this summary, it is evident that there was a vast difference in the perspectives of the industry and government experts on the cost-effectiveness and value of CMS technology.

Finally, industry experts expressed more interest in en-route traffic information; they predicted that there would be a 20 to 25 percent market penetration level for this service by the year 2005. Government experts agreed that these rates were reasonable, but they predicted a much lower usage rate (less than 10 percent). In contrast to both of these groups, the public-private partnership experts predicted a very low market penetration for these technologies over the next two to seven years.

Initiatives Having Most Influence on ITS Deployment

Responses to this question varied greatly between the DC and LA. DC experts, from all of the expert sectors, discussed the role of the Telecommunications Act. Both industry and public-private partnership experts from DC discussed the role of NEXTEA in future ITS deployment. And, both the industry and public-private partnership experts emphasized the role of the private sector independently or in partnerships with the government in promoting ITS technologies.

Overall, the LA experts revealed a range of different perspectives. Industry experts noted the importance of public-private partnerships (as did the DC industry experts) to ITS deployment and the need for higher quality data. The government experts focused on the role of NEXTEA in funding ITS and the need for implementing agency support and cooperation for ITS projects/deployment. Finally, the public-private partnership experts focused on air quality and global warming.

To summarize, responses to this question revealed a difference between a national and State perspective to ITS. The DC experts all focused on the role and impact of legislation, and many of the DC experts discussed the need for stronger coordination between the public and private sectors. In contrast, the LA experts focused on issues of a more regional perspective, such as air pollution and the need for local agency coordination.

Broad Factors (Social, Economic, Environmental, Technological) Exerting Most Influence on ITS Deployment

Similar to the last question, responses from DC experts reflected common themes, and responses from the LA experts reflected more diverse and regional interests. For example, all of the DC expert summaries focused on the role of the aging population on ITS deployment in the future.

Expert from industry and government focused on the economy. Not surprisingly, there were also several differences in the responses of these groups. For example, industry experts noted the role of ITS in promoting and enabling urban sprawl. Government experts noted the potential impact of environmental concerns on ITS deployment. And, the public-private partnerships experts commented on the issue of political acceptance (e.g.,, privacy and congestion pricing) and the impacts of growing congestion on future ITS deployment.

In contrast, LA experts focused on different issues that likely reflect their concerns about the LA region, including the need for continuing financial support from the government for ITS and the impact of energy and environmental concerns on ITS deployment. Experts from industry and government also commented on the need for financial support. And, the public-private partnership experts focused exclusively on the impact of energy and environmental concerns on ITS Deployment.

Major Barriers Facing ITS Deployment

There was a notable similarity in the responses of the DC and LA experts to this question. Top issues included: 1) political and social acceptance (e.g.,, privacy and the need for integrated coordination); 2) the need for better data and dissemination methods; and 3) costs/funding for ITS technologies.

Another trend appeared in the responses of the public-private partnership experts from DC and LA. Experts from both these regions mentioned the need for/lack of perceived benefits (i.e., mainly economic) of ITS to society and the environment. The other expert sectors (i.e., industry and government) focused on the three top issues, listed above. Since there are many similar barriers to ITS deployment throughout the nation, it is not surprising that there was more consistency in the responses to this question than were identified previously.

Which Groups Benefit Most or Least

Responses to this question varied significantly between the DC and LA experts. LA experts mentioned that more affluent customers would benefit from ITS deployment, and the less affluent customers (or "have nots") would benefit the least. In contrast, DC experts focused on various segments who would benefit from ITS deployment. The industry experts mentioned fleets, business travelers, and higher income consumers. The government experts focused on benefits to the general public (including tourists), fleets, and industry. And, finally, the public-private partnership experts focused on the broad public and business travelers as beneficiaries of ITS, while noting some inequity in benefits for the less affluent.

Perhaps this vast difference in perspective between the DC and LA experts is representative of the strong role and vision of the national government towards ITS deployment.

Broad ITS Deployment Outlook in A Typical Urban Corridor

Responses to this question varied significantly between the DC and LA experts. LA experts focused on integration of ATSC between freeways and major arterials, incident detection, SMART shuttles, remote sensing for emissions, and on-board emissions diagnostics. These responses reflect the regional perspective of LA, specifically their environmental concerns, the need for paratransit services, and the presence of the "State-of-the-art" SMART (I-10) corridor.

DC experts noted many similar technologies in their response to this question, including: commercial vehicle operations (CVO), pretrip information services, advanced public transportation systems (APTS), incident management, MayDay technologies, and collision avoidance systems. Overall, there was a great similarity in the responses to this question from each of the expert segments. Notably, both government and public-private partnership experts focused on APTS, while industry experts mentioned the deployment of SMART cards for payment. Although SMART cards can and will likely be used to support transit operations, industry experts appeared to be much less interested in ITS-based transit operations and systems, at least in the absence of public-private partnerships.

Table 14: Summary of Expert Interviews (Washington, DC)

	INDUSTRY WORLD	GOVERNMENT WORLD	PUBLIC-PRIVATE PARTNERSHIP WORLD
Most likely technologies	-ATSC will be on the freeways; full coordination of signals can be expected by the year 2005 in the I-10 corridor. One-third coordination can be expected on a typical urban corridor by the year 2005. -En-route traffic information will be at the 20 to 25 percent market penetration level by the year 2005 in a typical urban corridor. -CMS is expensive. Transportation agencies will have purchased as many of these units as they will acquire by the year 2000. -En-route guidance systems will have less than a 10 percent market penetration rate by the year 2005 in a typical urban corridor. This market will be determined by the auto manufacturers. Dynamic systems will be more useful. People will only use these systems when they are in unfamiliar areas.	-ATSC will be on the freeways by the year 2000. Full coordination of these freeways can be expected on a typical urban corridor by the year 2005. En-route traffic information will be at the 25 percent market penetration level by the year 2005 on a typical urban corridor. System usage will be less than 10 percent, unless cell phones are widely available, and the payment for this service is high. -CMS will be on 100 percent of all freeways by the year 2000. -Highway Advisory Radio (HAR) is not useful. -En-route guidance systems will have less than a 10 percent market penetration rate by the year 2005. It is important to note that the penetration rate will vary by market segment.	-ATSC will be on one half to three quarters of the freeways and be fully coordinated by the year 2005 in a typical urban corridor. -En-route traffic information will have a very small market penetration rate in the years 2000 and 2005. System use will be low, but this depends on the meaningfulness of the information. -CMS will be on 25 to 50 percent of the freeways and arterials across the country by the year 2005. -HAR will have a market penetration rate between 15 to 25 percent between the years 2000 and 2005. -En-route guidance systems market penetration will depend upon the cost. Meaningfulness of data is critical to this market.

Table14: Summary of Expert Interviews (Washington, DC) (cont.)

	INDUSTRY WORLD	GOVERNMENT WORLD	PUBLIC-PRIVATE PARTNERSHIP WORLD
Initiatives having most influence on ITS deployment	-Wireless technologies are emerging, and they will have a significant impact on the ITS industry. -The Telecommunications Act is likely to improve the communications backbone. This could help promote more information technologies. -NEXTEA funds should aid in ITS deployment. -Public-private partnerships will facilitate the privatization of many ITS services.	-The government could try to leverage communications for the public sector through the Telecommunications Act, especially when industry wants to use an existing right-of-way to lay down fiber optic cable. -The Telecommunications Act should stimulate innovation and lower costs; this should boost ITS. -Road capacity constraints are likely to foster technological solutions, including ITS.	-The Telecommunications Act will help to increase ITS deployment and portfolio diversification. -Internet access will promote ITS information technologies. -NEXTEA is still uncertain, but it is likely to affect ITS deployment. CMAQ funds might lead to more advanced traffic signal coordination technologies. -The private sector profit motive may be a driving force promoting ITS technologies, especially ETC and vehicle information services.
Broad factors (social, economic, environmental, technological) exerting most influence on ITS deployment	-The economy must be robust for people to invest in a new technology. Hence, the State of the economy will have a large impact on ITS deployment. -The aging of the population might stimulate some new product development. -Continued sprawl could be important to the ITS industry. ITS could make it easy for individuals to live in rural areas due to the availability of information technology and telecommuting.	-A good economy will tend to aid ITS. -Telecommuting from the home will become more popular. -With the graying of the population, we are likely to see a reduction in the number of "congestion" drivers. -Environmental concerns might increase and be maintained due to the climate change threat. This could spur the market for environmentally beneficial ITS technologies.	-A good economy will tend to aid ITS. -Telecommuting from the home will become more popular. -With the graying of the population, we are likely to see a reduction in the number of "congestion" drivers. -Environmental concerns might increase and be maintained due to the climate change threat. This could spur the market for environmentally beneficial ITS technologies.

Table 14: Summary of Expert Interviews (Washington, DC) (cont.)

	INDUSTRY WORLD	GOVERNMENT WORLD	PUBLIC-PRIVATE PARTNERSHIP WORLD
Major barriers facing ITS deployment	-Political and public acceptance issues (e.g.,, acceptance of ITS may be impossible in some areas). -If ITS requires significant behavioral change, this could represent a strong barrier. -There is a need for public sector spending for data collection. A lack of funds for data collection is a major barrier. Information quality and dissemination can present barriers. -There could be significant institutional (e.g.,, lack of standards) and cultural barriers (e.g., privacy issues) to ITS. -Dollars and technology are two significant barriers.	-ETC deployment has huge political and social barriers. Public trust can be a barrier. -There are cost barriers for many ITS technologies, e.g., in-vehicle information systems. -A limit on operational funding could present a barrier. -A lack of coordination in public-private partnerships could present a barrier. Data delivery requires extensive coordination. -Data needs to be reliable. -Standards should not be a big barrier, but this area still needs some effort. -Institutional barriers outweigh the technical barriers. A lack of jurisdictional control is an important issue.	-ETC deployment has huge political and social barriers. -Political barriers could be large because some sectors of society will benefit disproportionately from public investment in ITS. -At present, municipalities are not convinced of the economic benefits of ITS.

Table 14: Summary of Expert Interviews (Washington, DC) (cont.)

	INDUSTRY WORLD	GOVERNMENT WORLD	PUBLIC-PRIVATE PARTNERSHIP WORLD
Which groups benefit most or least	-Fleets will benefit most from private-sector investment in ITS. -Business travelers benefit because of their high value of time. -High income groups and early adopters will benefit. -Consumers benefit from a greater diversity of products, pricing, and quality services.	-The general public and service industries would benefit the most from ETC deployment. -Fleet and service vehicles would benefit from route guidance systems. -ATSC would benefit everyone. -Guidance systems benefit tourists. -Information systems have wide benefits to many market segments.	-Business travelers could benefit most from pricing and tolling services. There will be inequities in benefits between the higher and lower income classes. -The broad public could benefit from ITS services and environmental benefits. -The big winners are business travelers, fleets, and other high-value users.
Broad ITS deployment outlook in a typical urban corridor	-Commercial Vehicle Operations (CVO) -More wireless communication technologies -SMART cards for payment -Pretrip information services	-CVO -Advanced Public Transportation Systems (APTS) -Pretrip information services -Incident management and collision avoidance systems	-CVO -MayDay technologies -APTS -Pretrip information services -Collision avoidance systems

Table 15: Future ITS Market Penetration Estimates: Washington, DC

	Electronic Toll Collection			Automated Signal Coordination			Vehicle Information Systems			Vehicle Navigation Systems		
Public-PrivateWorld	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**
Bob Noland the US EPA	**ETC** **OEM**	N.C. No	N.C. No	**Freeways** **Arterials**	100% N.C.	100% 100%	**Have** **Use**	50% 10%	50% 10%	**Have** **Use**	.001% 90%	.001% 90%
Don Chen STPP	**ETC** **OEM**	1 lane	2 lanes (poss.) Not likely but some transponder ports by 2010	**Freeways** **Arterials**	100% 50-75%	100% 100%	**Have** **Use** **CMS** **HAT** **HAR**	1-2% 5-10% 25% 10%(use) 15%(use)	3-4% 5-10% 50% 10%(use) 25%(use)	**Have** **Use**	1-5% Usage would depend on functions - higher if parking info. avail.	10-20% Same
Michael Replogle EDF	**ETC** **OEM**	2 out of 5 lanes, if hot lanes	Same Perhaps 30% penet. by 2005, 80% by 2010	**Freeways** **Arterials**	100% 100%	100% 100%	**Have** **Use** **CMS**	5-10% 10-20% On freeways	20-25% 40-50% On freeways	**Have** **Use**	10% Regularly, if good info. on congestion	10% Regularly, if good info. on congestion

Table 15: Future ITS Market Penetration Estimates: Washington, DC (cont.)

	Electronic Toll Collection			Automated Signal Coordination			Vehicle Information Systems			Vehicle Navigation Systems		
Industry World	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**
Carol Zimmerman Battelle	**ETC**	10-15% of facilities	25-30% of facilities	**Freeways** **Arterials**	100% 0%	100% 100%	**Have** **Use**	5% 75%	25% 75%	**Have** **Use**	1-2% 75%	10-15% 75%
Craig Roberts Kenny Faunteroy ITS-America	**ETC**	All hot lanes ETC	All hot lanes ETC	**Freeways** **Arterials**	100% small %	100% 100%	**Have** **Use** **CMS**	1% 1% 0%	1-3% 1-3% 0%	**Have** **Use**	1% 1%	5% 5%
Erin Bard Booz-Allen & Hamilton	**ETC**	Not likely to have hot lane on I-10	Not likely to have hot lane on I-10	**Freeways** **Arterials**	10% 33% (higher for I-10 corr.)	15% 33% (higher for I-10 corr.)	**Have** **Use** **CMS**	10% 100% All over	20% 100% All over	**Have** **Use**	1% 1%	5% 5%
Sergio Ostria Apogee, Inc.	**ETC** **OEM**	Not much change from today	ETC in most facil., 1-2 lanes out of 4 Just starting in 2005, barcodes by 2010	**Freeways** **Arterials**	100% not yet	100% 10 largest metro areas would have full coord.	**Have** **Use** **CMS**	Not many	Not many On every major freeway	**Have** **Use**	N.C.	Only for CVO, rental cars, and luxury cars

Table 15: Future ITS Market Penetration Estimates: Washington, DC (cont.)

	Electronic Toll Collection			Automated Signal Coordination			Vehicle Information Systems			Vehicle Navigation Systems		
Government World	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**
Joe Peters Toni Wilbur FHWA	**ETC**	100% of hot lanes	100% of hot lanes	**Freeways** **Arterials**	Response N/A	Response N/A	**Have** **Use** **CMS**	1% 1% 0%	1-3% 1-3% 0%	**Have** **Use**	1% 1%	5% 5%
George Beronio FHWA	**ETC**	Hot lane would be ETC	poss. 2 lanes ETC	**Freeways** **Arterials**	50% 0%	100% 100%	**Have** **Use** **CMS**	20% 30% 100% (on freeway)	40% 30% 100% (on freeway, some arterials.)	**Have** **Use**	2%	5%
Brian Gardner FHWA	**ETC** **OEM**	30-50% of lanes	30-50% of lanes 10% of new veh.	**Freeways** **Arterials**	Almost all Almost all	100% 100%	**Have** **Use** **CMS** **HAR** **HAT**	N.C. N.C. 100% (on freeway) low usage 10-20%	N.C. N.C. 100% (on freeway) low usage 10-20%	**Have** **Use**	Small %	5-15% 80-100%

Table 15: Future ITS Market Penetration Estimates: Washington, DC (cont.)

	Electronic Toll Collection			Automated Signal Coordination			Vehicle Information Systems			Vehicle Navigation Systems		
Government World	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**
Richard Schoenberg FHWA	**ETC** **OEM**	2 lanes, ETC	2 lanes, ETC 40% of new veh.	**Freeways** **Arterials**	100% 0%	100% close parallel routes	**Have** **Use** **CMS**	25% most, if HAT 100% (on freeway)	50% most, if HAT 100%, 30% (on close routes)	**Have** **Use**	5%	10%
Cecilia Ho FHWA	**ETC** **OEM**	Poss. 50% of facilities	Same 10-20% in 2005-2010	**Freeways** **Arterials**	See below Arterials coord, poss. with ramps as well	Same	**Have** **Use** **CMS**	People would try if free service High % on freeways, only about 5% on arterials.	Same Same	**Have** **Use**	10-15% High %	Poss. more

Notes:
N.C. = no comment.
N/A= not applicable.
OEM = original equipment manufacturer (inclusion of transponder or bar code functionality in new vehicles).
Have = % of drivers who have the system in question.
Use = of those who have system, % that use it regularly.

Table 16: Summary of Expert Interviews (California)

	INDUSTRY WORLD	GOVERNMENT WORLD	PUBLIC-PRIVATE PARTNERSHIP WORLD
Most likely technologies	-Vehicle information systems and vehicle navigation systems are the most likely bundles. -ETC and signal coordination are largely stand-alone systems. -Incident detection/emergency notification are being pushed strongly by private sector and likely to be bundled with information/navigation systems under any scenario.	-Same	-Same
Initiatives having most influence on ITS deployment	-In California, private-public partnerships such as the Southern California Economic Partnership (advocating and organizing for both greater public and private use of ITS) are influential. -Private sector development of products/devices is an important initiative, but these products often lack quality information	-How ITS fares in ISTEA reauthorization is an influential issue. -There is a great deal of focus on "systems integration" (i.e., looks like ISTEA reauthorization could have up to $100 million for systems integration), focusing on TMC-to-TMC communications. -Degree to which implementing agencies push for ITS deployment is critical.	-Continued new information on the effects of air pollution on human health is influential. -Greater acceptance of global warming scenarios is an influential factor on ITS deployment.
Broad factors (social, economic, environmental, technological) exerting most influence on ITS deployment	-Market acceptance of ITS; especially, how quickly ITS products/services will reach broad market (not just upper-end car buyers), keeping in mind the slow turnover in vehicle fleet (less than 10% per year). -Government funding: will it continue, or will ITS funds be cut in larger push to eliminate "corporate welfare".	-The combined financial support for ITS by federal, State, and local governments is an influential issue.	-In the LA area, the major transportation issue by 2005-2010 is likely to be goods movement in an efficient and environmentally acceptable way (i.e., estimated 300% increase in truck traffic from airport expansion; 400% increase in truck traffic from port expansion). -Energy conservation efforts (especially related to oil consumption) will become a more salient initiative after the year 2005

Table 16: Summary of Expert Interviews (California) (cont.)

	INDUSTRY WORLD	GOVERNMENT WORLD	PUBLIC-PRIVATE PARTNERSHIP WORLD
Major barriers facing ITS deployment	-Privacy issues are important barriers to ITS deployment. -Deployment fragmentation: government implementation has been piecemeal and uncoordinated, leaving large gaps in the information quality/availability. -Technology: current information gathering techniques (i.e., loop detectors) are not ideal; better traffic information feedback mechanisms are needed (most promising is equipping vehicles to be data gathering mechanisms, but privacy becomes an issue).	-A lack of commitment from implementing agencies to install, operate and maintain ITS infrastructure is a major barrier. -Lack of communication/coordination between agencies is a significant barrier. -Inadequate infrastructure (esp. lack of fiber optic cable in place) is an important barrier to ITS deployment.	-Important barriers include difficulty in meeting air quality standards (especially tightened PM standards under CAAA); SCAG draft RTP, for example, exceeds SIP-allocated emissions budget. -A major question is how ITS is perceived (as a net benefit or net cost to the environment)
Which groups benefit most or least	-Better off consumers will benefit the most initially (those than can afford more expensive in-vehicle information systems). -Less affluent customers will benefit the least (another dimension along the information have/have-not divide in society).	-Same, although less distinction between technology "haves and have-nots" (due to relatively less effort by automakers in marketing in-vehicle systems).	-Same, although less distinction between technology haves and have-nots (due to relatively less effort by automakers in marketing in-vehicle systems).
Broad ITS deployment outlook in a typical urban corridor	-Santa Monica Freeway SMART Corridor, which integrates freeways and arterials, is a good indication of the future through the year 2005 (i.e., 20 potential SMART Corridors currently identified in LA and Orange County alone). -We will see continuing penetration of in-vehicle information/route guidance and incident detection systems, led by the high-end car market.	-No "typical" corridor in the year 2005 time frame; most urban areas will have technologies, but to what degree and how sophisticated will vary greatly (i.e., LA and Orange County far advanced in deploying technologies that generate/disseminate traffic information, but Riverside/San Bernardino counties has almost no such capacity currently).	-Under "environmental" scenario, the following ITS-related deployments may take on greater importance: -SMART shuttles, advanced signal coordination, remote sensing of emissions, and on-board emissions diagnostics.

Table 17: Future ITS Market Penetration Estimates: California Experts

	Electronic Toll Collection			Automated Signal Coordination			Vehicle Information Systems			Vehicle Navigation Systems		
	System	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**
Public-Private Partnership World												
Transportation Professional	**ETC**	2-3 lanes	2-3 lanes	**Freeways** **Arterials**	25%	50% 15%	Have Use CMS	75% (some form of info) 50% more CMS than now	75% (some form of info) 50% more CMS than now	Have Use	10% 75%	30% 75%
Transportation Professional	**ETC**	1/2 of lanes on new toll roads	1/2 of lanes on new toll roads	**Freeways** **Arterials**	40% most (in SoCal)	60% most (in SoCal)	Have Use CMS	2% 10% 35% of freeways	5% 25% 50% of freeways	Have Use	2% 10%	5% 25%
Gov-World												
Government Professional	**ETC**	1/3 of lanes	1/3 of lanes	**Freeways** **Arterials**	50% 50%	75% 75%	Have Use CMS	small % small %	small % small %	Have Use	small % small %	small % small %
Government Professional	**ETC**	40% of lanes	40% of lanes	**Freeways** **Arterials**	75% most major arterials (SMARTC)	100% 100% of major arterials (SMARTC)	Have Use CMS	>5% <25% every 2 miles on I-I-10	10% <25% same	Have Use	>5% <25%	10% <25%
Market-World												
Private Sector Representative	**ETC**	20-25% of lanes	1/3 of lanes	**Freeways** **Arterials**	20%	40-50%	Have Use HAT		40% 20% of trips 70% (have) 20% (use)	Have Use		40% 20% of trips
Private sector representative	**ETC**	all new toll facilities, but some lanes will always be non-ETC	all new toll facilities, but some lanes will always be non-ETC	**Freeways** **Arterials**	50% <50% depends on what is "advanced"	80% <75% depends on what is "advanced"	Have Use CMS	2%	10%	Have Use	2%	10%
Private sector representative	**ETC**	1-2 lanes	1-2 lanes	**Freeways** **Arterials**	100% for SMART Corridor majority of major arterials	100% for SMART Corridor all major arterials	Have Use CMS	2% 10% 100%	5% 10% 100%	Have Use	5% 20%	10-15% 10%

Part IV: Expert Scenario Workshops

This section presents a summary of the expert scenario workshop process and results. To prepare for the expert scenario workshop in Washington, DC, ITS-Davis researchers developed an outline of the initial future scenarios for the modeling exercise (Status-Quo World Industry World, Government World, and Public-Private Partnership World). The steps in this process were:

-- Define a focal issue around which the exercise is based;

-- Develop a list of driving forces that impact the future of ITS; and

-- Create a group of four scenarios.

The scenarios created by ITS-Davis researchers served as "drafts" for the expert workshop participants. The workshop brought together a group of experts to improve and extend the initial scenarios, which were later modified and presented to the California experts the following month.

In the one-day workshop, experts retraced all of the steps in the process of developing a scenario, in order to examine the validity of the scenarios and to expand upon each of the scenario worlds. Below follows a list of scenario steps.

Step One: Identify Focal Issue

In this step, participants identify the focal issue for the scenarios. ITS-Davis researchers developed the following focal issue for this workshop: "What is the market for specific ITS technologies and systems over the next ten years?" (The list of ITS technologies is the same as that used in the expert interviews.) This focal issue served as the initial "model" for the workshop. Participants discuss modifying the focal issue with input from the workshop facilitator and organizers. It is important that participants do *not* change the focal issue too much, so that it still responds to the goals of the Partnership for Advanced Transit and Highways "ITS and Environment" project. In these worlds, it is critical that researchers estimate market penetration for the ITS technologies in each of these scenarios.

Step Two: Key Forces in the Local Environment

Participants identify critical facts that decisionmakers will want to know when making key choices. For instance, what key issues will decisionmakers want to know about customers, suppliers, competition, government support, etc.? Below we list some of these key questions (the answers to which would be the "key issues") that emerged from our expert interviews in Washington, DC.

Some Key Issues from DC Expert Interviews:

What is/are the…?

- Impact of the Telecommunications Act on data quality and costs;
- Response of public to pricing policies;
- Impact of global warming and air quality on the ITS market;
- Impact of baby boomers (e.g., concern for safety);
- Impact on economy;
- Potential for behavioral change (e.g., mode shift);
- Potential for lower data collection costs;
- Role for Internet, smart cards, cell phones in the ITS market;
- Impact of NEXTEA;
- VMT projections;
- Land-use trends (e.g., continued sprawl and urban renewal);
- Impact of information technologies on commercial markets;
- Impact of ITS on transit systems;
- Need for operation funds (e.g., impact if funds are not available);
- Impact of consumer acceptance;
- Role of public/private partnerships; and
- Impact of standards on architecture and ITS deployment.

Step Three: Driving Forces

In this step, participants identify driving forces behind the key issues identified in Step 2. Not surprisingly, some forces are very structured, such as demographics, and others are highly uncertain, e.g., public acceptance. Driving forces generally include social, economic, political, technological, and environmental factors.

Driving forces identified in the DC expert *interviews* are listed in the description of each of the scenario worlds below. The four scenarios include:

1) status-quo world,

2) industry world,

3) government world, and

4) public/private partnership world.

Step Four: Rank by Importance and Uncertainty

Next, participants rank key factors and driving forces based on two criteria:

1. Degree of importance for the success of the focal issue or decision identified in Step One.
2. Degree of uncertainty surrounding those factors and trends.

Participants identify two or three factors or trends for each scenario that are *most important* or *uncertain.*

Step Five: Scenario Logic

Organizing scenarios according to some logic is crucial to creating each world or story. First, participants decide upon crucial uncertainties. Next, the group decides whether or not to present each scenario relative to these particular uncertainties (e.g., economy, customer acceptance) along one axis, a matrix (i.e., two axes), or in a volume (i.e., three axes). These axes can help participants to identify and elaborate upon different scenarios. To summarize, these logical structures should help characterize significant scenario drivers. In this project, experts were unable to organize the scenarios according to some logic or scenario matrix. This was in part due to the complexity of the focal issue and the topic of ITS.

Step Six: Expanding the Scenarios

While the most important forces will determine logic of each scenario, other lesser forces and trends can be used to flesh out each scenario.

- How would the world get from here to there?
- What events might be necessary to make the end point of each scenario possible?

Step Seven: Implications

After participants develop scenarios in some detail, then the experts will return to the focal issue (Step One) to explore the implied future.

- How does the future look in each scenario?
- What vulnerabilities have been revealed?
- Which technologies and customers predominate the market in each of the scenarios?

Step Eight: Selection of Leading Indicators and Responses

After each of the scenarios have been elaborated and implications for the focal issue have been determined, then participants identify a few key indicators that can be used in monitoring the future. Further, participants identify a few alternative responses that government agencies and private companies might take, if signposts for each scenario begin to emerge. Finally, participants review a set of ITS market penetration estimates for each scenario. The DC expert workshop participants ran out of time and were unable to complete this scenario step. The California workshop participants generated these market penetration estimates. In the final step of scenario development in this project, all of the expert interview and workshop participants reviewed these numbers. The final estimates will be used in the modeling exercise in this project. These final estimates appear in Table 21 on page 124 of this report.

Step Nine: Developing Scenarios Matrix

After participants develop scenarios in some detail, then the DC experts generate a set of market penetration estimates for the years 2000 and 2005 for each scenario, specifically for the four technologies listed below:

- Electronic Toll Collection
- Advanced Traffic Signal Coordination
- Vehicle Information Systems
- Vehicle Navigation (Route Guidance) Systems.

Below follows the initial scenarios that were developed by ITS-Davis researchers, based on the DC and California expert interviews. The DC expert scenario workshop participants modified the initial scenarios. The California expert workshop participants modified these scenarios further. These final or “model” scenarios were mailed to all of the expert interview and workshop participants for final review. The scenarios were revised, based on the comments received. These final scenarios and market penetration estimates serve as the basis for the ITS modeling exercise in this project.

Table 18: Initial Scenarios Based on Interviews on the Future Development of ITS Technologies

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Status-Quo World	• ITS deployment continues along a steady and incremental trajectory. • There are no major changes in the economy, social acceptance, and rates of increase in ITS-technology usage. • There are no technology breakthroughs, and information quality and collection methods do not change. • Standard-setting and protocols receive some attention from government.	• NEXTEA passes with support for ITS programs. • Market acceptance of ITS technologies is limited. • Private-sector investment continues at a slow rate. • Public-sector investment continues at a moderate rate.	• Market acceptance (low) • Willingness-to-pay (low) • Private-sector investment (low, increasing to moderate) • Public-sector investment (moderate and stable) • Information availability (low) • Information quality (low, focused on broadcast of information to a general public market)

Table 18: Initial Scenarios Based on Interviews on the Future Development of ITS Technologies (cont.)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Industry World	• ITS deployment, especially information-based technologies, explodes. • The market for information-based technologies soars. Consequently, the public sector benefits from high, quality information gathered by industry. • Technology breakthroughs allow for inexpensive and high-quality information collection and dissemination. • Entrepreneurial efforts by industry outpace government efforts at ITS management (i.e., standard setting and deployment). • Short to medium-term market chaos; often incompatibility between competing products.	• Technology breakthroughs. • Industry and government standards promote information acquisition and exchange. • Market acceptance of Internet, Web TV, PDAs, and cell phones aid in willingness-to-pay and market demand for new information technologies. • Private-sector investment high.	• Market acceptance (high) • Willingness-to-pay (high) • Private-sector investment (high) • Public-sector investment (low to moderate) • Information availability (high, largely directed to specialized, paying market) • Information quality (high, focused on a specialized, paying market)

Table 18: Initial Scenarios Based on Interviews on the Future Development of ITS Technologies (cont.)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Government World	• ITS deployment, in terms of information collection, dissemination, and traffic signal coordination, high. • Information is gathered and distributed to meet the needs of the general public, e.g., traffic information available through highway advisory telephone and CMS. • Market for specialized information technology is low. • Technology continues to evolve largely through government investment. Government investment in ITS outpaces private-sector investment. • Government actively engaged in development of private market for ITS.	• Architecture standards promote government information acquisition and dissemination. • Market acceptance of "free" information services is high. • Private-sector investment drops and is diverted to other high-tech applications. • Public-sector investment continues due to increasing VMT and congestion, and concomitant energy and air quality impacts. • Environmental and social concerns (e.g., equity) play a key role.	• Market acceptance (moderate, yet increasing) • Willingness-to-pay (low) • Private-sector investment (declining) • Public-sector investment (high) • Information availability (moderate to high, but limited to public market) • Information quality (moderate to high, focused on general public market)

Table 18: Initial Scenarios Based on Interviews on the Future Development of ITS Technologies (cont.)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Public-Private Partnership World	• ITS deployment is high in both traveler information and traffic management arenas. • Information is used to meet both the needs of the general public and specialized users. • Market for specialized information technology is high. • Public and private sectors work together to create seamless transportation network and services. • Technology development slow. • Government actively working with industry to develop markets for ITS.	• Market acceptance of new technologies and information services is high. • Public acceptance of new pricing policies is high, which facilitates ETC. • Private-sector investment in ITS is moderate; it is increasingly directed at other high-tech applications (e.g., emission control technologies) • Public-sector investment increases. • Barriers to ITS deployment drop. Cooperative efforts increase. • Environment plays a large role.	• Market acceptance is increasing for traveler information and traffic management technologies, including ETC (moderate and increasing) • Willingness-to-pay (high) • Private-sector investment (moderate) • Public-sector investment (moderate) • Information availability (high, focused on both public and specialized markets, shared between public and private sectors) • Information quality (high, focused on general public and specialized markets)

Next follows the four scenarios developed by the expert scenario workshop participants in Washington, DC These scenarios were presented to the California experts for review and revision. Overall, the DC experts accepted the "draft" scenarios developed by ITS-Davis researchers, with a few minor changes. The DC experts greatly expanded the scenario descriptions from those that they were presented in the "draft" or initial scenarios. In this modified Delphi approach, it is important to note that the expert participants did not significantly change the scenarios from the initial ones created by ITS-Davis researchers, which were developed based on the results, from the DC and LA expert interviews.

Table 19: Modified Scenarios on the Future Development of ITS Technologies (DC Expert Workshop)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Status-Quo World	• ITS deployment continues along a steady and incremental trajectory. • There are no major changes in the economy, social acceptance, and rates of increase in ITS-technology usage. • There are no technology breakthroughs, and information quality and collection methods do not change. • Standard-setting and protocols receive some attention from government.	• NEXTEA passes with support for ITS programs. • Market acceptance of ITS technologies is limited. • Private –sector investment continues at a slow rate. • Public-sector investment continues at a moderate rate.	• Market acceptance (low). • Willingness to pay (low). • Private-sector investment (low, increasing to moderate). • Public sector investment (moderate and stable). • Information availability (low). • Information quality (low, focused on broadcast of information to a general public market).

Table 19: Modified Scenarios on the Future Development of ITS Technologies (DC Expert Workshop) (cont.)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Industry World	• Private, multi-technology world. • NEXTEA gets only one-year re-authorization and some of infrastructure is sold to private sector. • Government funds basic research and gets involved in limited partnerships. • Government focused on telecommunications deregulation versus transportation regulation. • Major competition worldwide in several sectors: ITS technologies become more important. • Growing market for ITS. • General Motors orders 400,000 embedded vehicle navigation units. • UPS strike encourages more companies to develop fleet management technologies for consumer market. • Three major MPOs spur herd mentality and major investment in ITS. • Congestion pricing based on VMT (e.g., flat fees for road pricing as a first step). • Fare collection using debit cards and ETC; payment services will bring financial institutions into ITS.	• Out-sourced services. • Invisible technology. • Satellite technology unveils new detection methods. • Globalization creates wider dispersion of manufacturing. • Federal government plays diminished role in infrastructure funding. • ITS dominated by Big Players: AT&T, Intel, and Microsoft. • Deregulation of telecommunications benefits private competition, innovation and profits. • Induced demand for ITS technologies.	• Market acceptance (high). • Willingness-to-pay (high). • Private-sector investment (high). • Public-sector investment (low to moderate). • Information availability (high, largely directed toward a specialized, paying market). • Information quality (high, focused on a specialized, paying market).

Table 19: Modified Scenarios on the Future Development of ITS Technologies (DC Expert Workshop) (cont.)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Government World	• Focus on public infrastructure rather than in-vehicle technologies; i.e. electronic toll collection and signal coordination versus information and navigation systems. • World peace spreads: defense-funding declines. • NEXTEA passes with $32 billion; there is a 25 to 30% increase in infrastructure expenditures. • Lockheed Martin signs $2 billion contract to help fund and build infrastructure (i.e., fee-for-service); this is one of many government contracts awarded in the year 2000, for the $20 billion available per year investments. • Government mandates embedded vehicle navigation systems from Detroit and subsidizes the Big Three with $20 billion due to a United Auto Workers strike. • Stagflation: US industry less competitive in global markets.	• Satellite imaging allows full detection, complete information. • Ubiquitous communications networks solidified. • Protectionism; high import duties. • Regulation issues emerge: privacy and governmental policy. • "Lock in" to particular ITS technologies as a by-product of the national architecture. • Political influences on standards. • Cheaper information and communications technology.	• Market acceptance (moderate, yet increasing). • Willingness-to-pay (low). • Private-sector investment (declining). • Public-sector investment (high). • Information availability (high, but limited to public market). • Information quality (high, but focused on general public market).

Table 19: Modified Scenarios on the Future Development of ITS Technologies (DC Expert Workshop) (cont.)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Public-Private Partnership World	• Public and private sectors work together to create Intermodal transportation network and services, but question remains as to who will generate quality data. • DOTs negotiate the right-of-way for telecommunications infrastructure, as mandated by NEXTEA. • Financial institutions offer electronic payment systems to public agencies (i.e., VISA taken on buses). • Satellite detection regulated by government. • Established standards facilitate ability to exchange data. • Congestion pricing on a limited scale through HOT lanes and peak-hour pricing. • Public agencies have a new face: operations management; they become less capital-intensive. • Movement to a paperless society.	• General telecommunications de-regulation enables public/ private partnership, e.g., FM Rebroadcast. • Rich, broad data comes out of public infrastructure and is readily traded from public to private sectors in exchange for contracting opportunities. • More federal mandates; allow companies to make money by reselling traveler information. • Traveler information explosion (Metro, ETAK). • Rise of MPOs in transportation decision-making and ITS deployment. • Rise of mobility company conglomerates to serve public needs.	• Market acceptance is increasing for traveler information and traffic management technologies, including ETC (moderate and increasing). • Willingness-to-pay (high). • Private-sector investment (moderate). • Public-sector investment (moderate). • Information availability (high, focused on both public and specialized markets, shared between public and private sectors). • Information quality (high, focused on general public and specialized markets).

In Davis, CA expert scenario workshop, it is notable that the scenario modifications were primarily a refinement of the DC scenarios. The CA experts noted that some of the descriptions and possible axes developed by the DC expert workshop were either a bit "extreme" (i.e., not very likely) or they were somewhat contradictory in nature. To summarize, the CA experts reviewed and modified the scenarios developed by the DC experts. Their changes represented minor refinements and "checks" to the consistency of each scenario.

In addition, the CA experts developed a set of market penetration estimates to complement the final or "model" scenarios. As mentioned earlier, after this workshop, the final scenarios and market penetration estimates were sent out to the expert interview and workshop participants for one final review. Researchers incorporated the minor changes received to these materials.

The final scenarios and market penetration estimates appear in their final format, below. The "model" scenarios will be used in the modeling exercise to supply modelers and researchers with assumptions, market penetration estimates, and context for the microsimulation exercise. After the modeling is completed, researchers will apply the energy and environmental criteria to the results for each of the modeled scenarios and rank each of the modeled technologies for each scenario.

Table 20: Final Scenarios on the Future Development of ITS Technologies (California Expert Workshop)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Status-Quo World	• ITS deployment continues along a steady and incremental trajectory. • There are no major changes in the economy, social acceptance, and rates of increase in ITS-technology usage. • There are no technology breakthroughs, and information quality and collection methods do not change. • Standard-setting and protocols receive some attention from government.	• NEXTEA passes with support for ITS programs. • Market acceptance of ITS technologies is limited. • Private –sector investment continues at a slow rate. • Public-sector investment continues at a moderate rate.	• Market acceptance (low). • Willingness to pay (low). • Private-sector investment (low, increasing to moderate). • Public sector investment (moderate and stable). • Information availability (low). • Information quality (low, focused on broadcast of information to a general public market).

Table 20: Final Scenarios on the Future Development of ITS Technologies (California Expert Workshop) (cont.)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Industry World	• FHWA (and the U.S. Congress) will authorize the conversion of the Federal InterState system to toll facilities. • In the year 1999, an open architecture information management system will start to be installed in automobiles. This system will encompass in-vehicle information and navigation functions—to the exclusion of single service technologies that are incompatible with the architecture. • Multiple, new start-up companies will provide information services. • Satellites provide ample bandwidth for multiple in-car services by the year 2000. • Since proprietary, single function information technologies are not favored in this world, the existing example of General Motors ordering 400,000 embedded in-vehicle navigation units is stricken from the scenario description. • Noted that the "Big Players" listed in the sixth driving force are not, as of now, big players in ITS.	• ITS is a "splash" market for the information industry—a market that can be captured at little additional cost because the necessary technology and systems are already being developed for other applications. • Invisible "push" technologies will drive ITS. Push technologies are those that take information about users, create customized information packages, and narrow-cast, or push, that customized information back to users. • Information management systems will produce and provide high quality, personal data. • Information management systems will be built to communication and computer industry standards, not automotive industry standards.	• Market acceptance (high). • Willingness-to-pay (high). • Private-sector investment (high). • Public-sector investment (low to moderate). • Information availability (high, largely directed toward a specialized, paying market). • Information quality (high, focused on a specialized, paying market).

Table 20: Final Scenarios on the Future Development of ITS Technologies (California Expert Workshop) (cont.)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Government World	• Focus on public infrastructure rather than in-vehicle technologies; i.e., electronic toll collection and signal coordination versus information and navigation systems. • World peace spreads: defense-funding declines. • NEXTEA passes with $32 billion; there is a 25 to 30% increase in infrastructure expenditures. • Lockheed Martin signs $2 billion contract to help fund and build infrastructure (i.e., fee-for-service); this is one of many government contracts awarded in the year 2000, for the $20 billion available per year investments. • Government mandates embedded vehicle navigation systems from Detroit and subsidizes the Big Three with $20 billion due to a United Auto Workers strike. • Stagflation: US industry less competitive in global markets. • Government becomes more competitive.	• Satellite imaging allows full detection, complete information. • Ubiquitous communications networks solidified. • Protectionism; high import duties. • Regulation issues emerge: privacy and governmental policy. • Political adoption of open standards. Purpose of National Architecture is to eliminate closed architectures. • Leveraging open standards to produce efficient information management and dual use—public and private. • Government focuses on simplifying and improving operations, a by product of which is information beneficial to end users • Cheaper information and communications technology.	• Market acceptance (moderate, yet increasing). • Willingness-to-pay (low). • Private-sector investment (declining). • Public-sector investment (high). • Information availability (high, benefits end user). • Information quality (high, benefits end user).

Table 20: Final Scenarios on the Future Development of ITS Technologies (California Expert Workshop) (cont.)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Public-Private Partnership World	• Public and private sectors work together to create Intermodal transportation network and services, but question remains as to who will generate quality data. • DOTs negotiate the right-of-way for telecommunications infrastructure, and share data with private sector. • Financial institutions offer electronic payment systems to public agencies (i.e., VISA taken on buses). • Satellite detection regulated by government. • Established standards facilitate ability to exchange data. • Congestion pricing on a limited scale through HOT lanes and peak-hour pricing. • Public agencies have a new face: operations management; they become less capital-intensive. • Movement to a paperless society.	• General telecommunications de-regulation enables public/ private partnership, e.g., FM Rebroadcast. • Rich, broad data comes out of public/private partnerships and is readily traded from public to private sectors in exchange for contracting opportunities. • More federal mandates; allows companies to make money by reselling traveler information. • Traveler information explosion (e.g., Metro, ETAK). • Rise of MPOs in transportation decision-making and ITS deployment. • Rise of mobility company conglomerates to serve public needs.	• Market acceptance is increasing for traveler information and traffic management technologies, including ETC (moderate and increasing). • Willingness-to-pay (moderate to high). • Private-sector investment (moderate). • Public-sector investment (moderate). • Information availability (high, focused on both public and specialized markets, shared between public and private sectors). • Information quality (high, focused on general public and specialized markets).

Table 21: Final Scenario Market Penetration Estimates (Developed in Davis, CA Workshop)

Scenario Worlds	**Electronic Toll Collection**			**Advanced Traffic Signal Coordination**			**Vehicle Information Systems**			**Vehicle Navigation Systems**		
Status-Quo World	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**
Smart Corridor	**ETC** **OEM**	0 No	0 No	**Freeway** **Arterials**	100% 50%	100% 75%	**Have (Gen)**[8] **Use** **CMS**	10% 75% 100%	25% 75% 100%	**Have** **Use**	1% 100%	5% 100%
Typical Urban Corridor	**ETC** **OEM**	10-15% No	25-30% No	**Freeway** **Arterials**	10% 33%	15% 33%	**Have** **Use** **CMS**	5% 75% 25%	20% 75% 50%	**Have** **Use**	1% 100%	5% 100%
	System	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**
Industry World[9]	**ETC** **OEM**	10-15% No	20-25% No	**Freeway** **Arterials**	100% 33%	100% 33%	**Have** **Use** **CMS**	15% 80% 25%	30% 80% 50%	**Have** **Use**	1% 100%	10% 100%
	System	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**
Government World	**ETC** **OEM**	30% No	60% No	**Freeway** **Arterials**	100% 40%	100% 50%	**Have** **Use** **CMS**	10% 75% 100%	25% 80% 100%	**Have** **Use**	1% 100%	2% 100%
	System	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**System**	**2000**	**2005**
Public-Private Partnership World	**ETC** **OEM**	33% 11%	66% 16%	**Freeway** **Arterials**	100% 40%	100% 60%	**Have** **Use** **CMS**	95% 30% 100%	95% 40% 100%	**Have** **Use**	2% 100%	15% 85%

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[8] Developed for general public, so the traveler information is not specifically designed for individual users nor does it provide dynamic updates based on a drivers location.

[9] Market penetration estimates for each of the scenario worlds are for the Smart Corridor (per PATH's advice and request).

MODELING OF ITS TECHNOLOGIES WITH INTEGRATION V2.0

This section of this report describes the database obtained and modified for the modeling of the energy and environmental impacts of ITS technologies with the INTEGRATION simulation model. A discussion of the proposed model runs is provided, followed by some detail of the specific ITS technologies which are to be modeled.

Background

The "Modeling Tools" section of this report has detailed various simulation tools suitable for modeling ITS technologies. Reasons were presented for the selection of the INTEGRATION simulation model as the tool for this study. Appendix C of this report is a slightly modified version of the "Technologies to be Modeled" section from the report submitted to PATH at the end of the first year of this project. This section discusses the selection of four specific ITS technologies for the modeling effort within the scope of this research. The selected technologies are:

- adaptive traffic signal coordination,
- electronic toll collection,
- en-route driver information, and
- route guidance.

A subsection of Appendix C exists reasons for our decision to focus (at least initially) on the modeling of *individual* technologies, rather than on bundled or packaged technologies. These reasons include the desire to *rank* individual technologies and the absence of previous attempts to model bundled technologies, resulting in uncertainty about the model's capabilities to manage this.

A discussion about the scale of analysis is also presented, leading to our decision to model a transportation corridor rather than attempt to model a larger region. This decision was based on the much larger effort required to model a region (project resources were limited), the plausibility of modeling each of the selected technologies within the bounds of a corridor, and the expected magnitude of impact for a corridor versus the impacts at a regional level. Impacts that might be significant at the corridor level may not be noticeable at the regional level.

Appendix C also contains a section from the first year report, which describes data needs for modeling ITS technologies and potential data sources, namely, Mitretek's Urbansville database and the UC Berkeley SMART Corridor (Santa Monica (I-10) Freeway Corridor) database. Advantages and disadvantages of these databases are presented. The project team obtained the Urbansville database and began work with that to identify and extract a corridor for the current modeling effort. This proved to be a very difficult assignment and was readily abandoned when the SMART Corridor database became available in July 1997.

The SMART Corridor Database

The road network selected for the modeling efforts was the SMART Corridor (Santa Monica (I-10) Freeway Corridor). This corridor had been the focus of a previous modeling study by Bacon *et al*. (1995) in which the INTEGRATION model was applied to assess the impacts of various ATIS strategies. This study did not incorporate any environmental measures of effectiveness.

The Santa Monica Freeway Corridor was the location for the Pathfinder in-vehicle information system project conducted in 1990. This freeway is one of the most traveled freeways in the country, with an average daily traffic count of almost 250,000 vehicles.

The SMART Corridor database was developed for a section of the Santa Monica Freeway Corridor from I-405 to I-110. The study area consists of approximately 11 miles of freeway with associated ramps (i.e., 26 on-ramps and 26 off-ramps in each direction), five parallel arterials (i.e., Olympic Boulevard, Pico Boulevard, Venice Boulevard, Washington Boulevard, and Adams Boulevard), and a network of other surface streets. The corridor also includes four connector on-ramps and four connector off-ramps.

The following table shows the characteristics of the INTEGRATION database for the SMART Corridor before modification in the current research effort.

Table 22: Magnitude of Original SMART Corridor Database

Feature	Total
Mainline freeway links	85
Arterial links	1060
Expanded intersection links	1672
Zone connector links	314
Total links	3286
Origin nodes	111
Destination nodes	111
Total zones	118
Total nodes	1747

Source: Bacon *et al.* (1995).

The primary advantages of the SMART Corridor database for the current study are:

- good documentation,
- developed for use with the INTEGRATION model,

- extensively tested and calibrated, and
- only California-based corridor database available.

The main disadvantage of this database is that it was created for use with INTEGRATION version 1.5. The current model available from and supported by Michel Van Aerde (developer of INTEGRATION) is version 2.0, and there have been some significant changes to the internal logic of the model and the format of the input data files required. The following section details many of the changes necessary to update the database obtained from UC Berkeley such that it could be used for model runs with INTEGRATION V2.0.

Modifications to the Database

The INTEGRATION models uses a set of ASCII files to store input data for model runs. These files include the following:

- Master Control file,
- Link file,
- Node file,
- Signal file,
- Demand file, and
- Incident file,

There are three optional input files: 1) a lane striping file; 2) a detector location file; and 3) a screen capture frequency file.

Each file in the bulleted list above and the lane striping file is described briefly below. For details of the format of these files and the parameters contained in them, the reader is referred to Van Aerde (1995). Following the description of each file is a discussion of the modifications that were made to update the files for use with INTEGRATION V2.0. The majority of this discussion is focused on the link file since most changes necessary were the result of modifications required there. The presentation here is meant to reflect the extensive effort required to make these updates, while attempting to not present unnecessary detail. It is intended that enough detail be provided, so that our steps can be retraced at a later date.

The full listing of each of the final versions of the INTEGRATION V2.0 input data files for the Santa Monica Freeway Corridor network will be included in a Technical Appendix to the final report. The macros developed as part of this study also will be made available upon request.

Master control file

This file stores simulation control values, the names of input data files to be used, the location of these files, the location where output files should be written, and the names of optional output data files. This file also allows the user to define characteristics of the five INTEGRATION vehicle types, including the update frequency of information provided to the vehicles/drivers and a measure of the error inherent in the information provided (information quality indicator).

Node file

The node file defines the characteristics of all the zones and nodes in the network, including the X and Y coordinates and whether the zones/nodes are origins, destinations, both, or intermediate nodes.

The node file was modified in response to changes made to the link file. The end points of each link are defined by a node, consequently, the addition, removal, or change in length of a link generates a necessary adjustment to the node file. Modifications to the node file include:

- addition of new nodes in the center of signalized intersections (see next section on modifications to link file for explanation of this); and

- removal of old upstream node numbers of outbound links from signalized intersections (see next section for explanation).

Link file

This file contains the data fields that define the characteristics of each link in the network. These include: The modifications necessary to update the link file required the most substantial effort. The changes were primarily due the differences between the way the two versions of INTEGRATION simulate signalized intersections.

In version 1.5 of the INTEGRATION model there is no distinction between the individual lanes of an intersection approach. Hence, the approach (or inbound) links act as "pipes," and if one of the movements (through, left, or right) at the intersection is delayed, vehicles making that movement will block the "pipe" and cause all the movements to be delayed. Bacon *et al.* (1995) describe in detail how they used a solution proposed by Van Aerde (1985) to overcome this problem. One-node intersections were expanded to eight-node intersections with twelve *appended* links (i.e., for intersections with four inbound and four outbound links). Figure 4 shows these appended links for a typical intersection. Each appended link represents a turning movement from one of the inbound links (which were made slightly shorter) to one of the outbound links. This *expansion* of intersections was only done to those intersections with high observed traffic flows or those where unrealistic queues were observed during model runs.

Version 2.0 of the INTEGRATION model implemented a feature that enables the user to specify the lane striping configuration of links. This allows the lanes and lane usage to be coded for inbound links at signalized intersections. Hence, the vehicles arriving at the intersection are allocated to the lane(s) appropriate for their particular turning movements. This means that where there is an exclusive left turn lane, vehicles with path trees that make the left turn are moved into the left turn lane and consequently do not block other vehicles (e.g., through traffic) that are released from the signal in a different phase.

To take advantage of this improved model capability, the link file was edited to change the configuration of each *expanded* intersection from that shown in Figure 4 to that shown in Figure 5. This involved removing all the appended links, adding a new center node, connecting the main inbound links to the new center node with new appended links, and extending the upstream end of the outbound links back to the new center node (discarding the original upstream nodes of the outbound links).

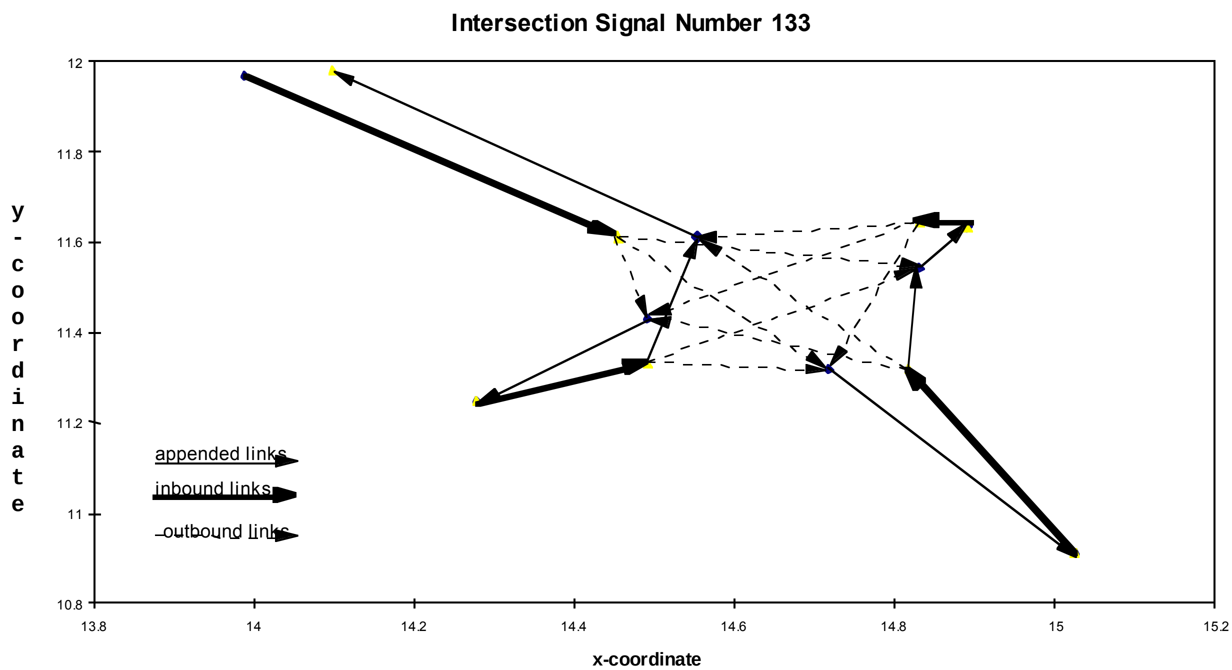

Figure 4: Expanded Intersection (Eight Nodes/Twelve Links) from Original Database

In the original link file, all the data for controlling signal number, first and second phases in which each link discharges, turn prohibition data, and the first and second links opposing the flow of each link were coded in the appropriate fields for the appended links (not the main inbound links), as the appended links represented each turning movement at the signal. Simply removing all the appended links would result in the loss of all this data, so the relevant data were transferred back to the main inbound link. This was a temporary "holding place" since these data were ultimately required to be coded to the new appended links when they were added.

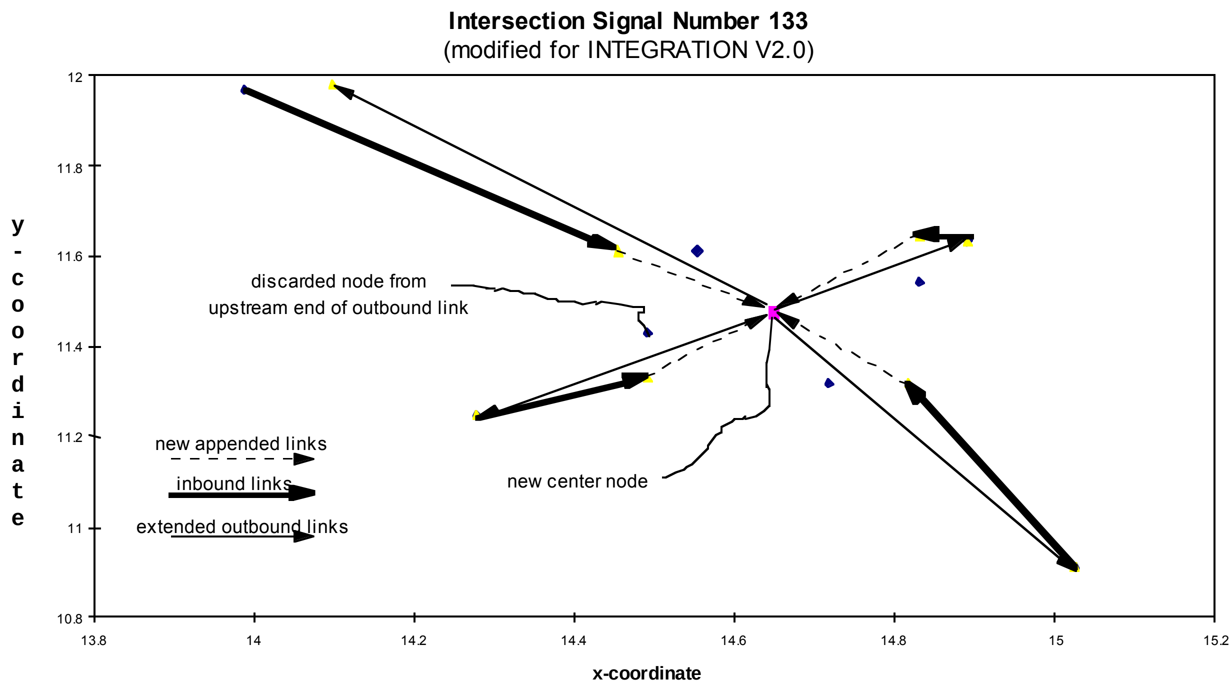

Figure 5: Modified Intersection (Five Nodes/Four Links) for INTEGRATION V2.0 Database

The large number of links (i.e., 3286 in the original database obtained from UC Berkeley) made this exercise a very time consuming effort. Microsoft Excel spreadsheets were used to manipulate the data and a series of Visual Basic macros were written to minimize the amount of time to complete this task. The first macro collected all the relevant data from the appended links and transferred it to the appropriate cells in the record for the corresponding main inbound link. The macro also made changes to the data to reflect new approaches in the model to various characteristics of signalized intersections (e.g., right-turn-on-red, RTOR, permission is coded in V2.0 by assigning a negative value to the signal number; this feature did not exist in earlier versions of the model). It was assumed, based on a conversation with the UC Berkeley team, that all the intersections being considered (i.e., expanded intersections) permitted RTOR movements. The macro did not transfer the two data values representing the discharge phases of each appended link. These were assessed by hand to determine the correct way to code the values from *all turning movement links* for a given inbound link into the appropriate fields on just *one* link.

INTEGRATION V2.0 distinguishes between protected and permitted left turn phases by allowing the user to assign a negative value to the discharge phase number if that phase represents a protected left turn. In earlier versions of the model an algorithm would check if the discharge phase number of the left turn was the same as the discharge phase number as the opposing through movement. If so, it would model the traffic flow as a permitted left turn. Otherwise it would be treated as a protected left turn. The use of the negative value in the INTEGRATION V2.0 model allows more information to be stored in fewer fields. Hence, it was possible to recode all the phasing information stored in the two fields of each appended link (i.e., where all three movement types existed) to the two appropriate fields of one link. However, there were many different conditions that had to be checked, so this part of the data transfer from the appended links was carefully performed without the use of a macro. Once the data were transferred to the main inbound links the appended links were deleted before adding the new center nodes and new appended links, to fill the gap created by the removal of the original appended links.

The first step in the process of adding the new center nodes and new appended links was to create a file named MODIFIER.XLS, which contains all the relevant data for each intersection to be modified. A section of this file is presented below in Table 23. MODIFIER.XLS was a working file in which data were gathered from the original link data file and node file, before being used to update those files. These data include:

- signal number,
- inbound link numbers,
- outbound link numbers,
- upstream and downstream node numbers for each inbound and each outbound link, and
- x- and y-coordinates of all nodes.

Table 23: Section of Working File MODIFIER.XLS

	signal #	inbound/ outbound	link #	up node	x up coord	y up coord	down node	x dn coord	y dn coord	new node #	new node x coord	new node y coord
1	133	in	587	120	14.279	11.243	697	14.492	11.328	703	14.648	11.474
2	133	in	685	763	13.989	11.965	698	14.454	11.609			
3	133	in	595	122	14.891	11.631	699	14.83	11.642			
4	133	in	693	121	15.024	10.906	700	14.817	11.316			
1	133	out	588	703	14.83	11.542	122	14.891	11.631			
2	133	out	686	704	14.717	11.316	121	15.024	10.906			
3	133	out	596	701	14.492	11.428	120	14.279	11.243			
4	133	out	694	702	14.554	11.609	759	14.099	11.977			
1	153	in	285	125	17.566	11.794	705	17.773	11.88	711	17.906	12.017
2	153	in	744	655	17.745	12.05	706	17.705	12.05			
etc	…	..	…	…	…	…	…	…	…			

The signal number, in- and out-bound links numbers, and link node numbers were obtained from MOD_SUPP.XLS; this is an Excel file that is essentially a copy of the original link data file provided by UC Berkeley (SCF14_2.DAT) with comments and flags. The macro UNEXPANDED was written and saved in the MOD_SUPP.XLS file to collect these data and enter them into the appropriate place in the working file MODIFIER.XLS mentioned above. The upstream node number of the first outbound link at each signal was selected as the number for the *'new' center node*. This node number could be re-used since the upstream nodes of each outbound link were to be moved to the new center node, rendering the original outbound link upstream node numbers obsolete (see "discarded nodes" in Figure 5).

Another macro named GETCOORDINATE was created and saved in MODIFIER.XLS to extract the X- and Y-coordinates from the node file NODE1.DAT for each node listed in MODIFIER.XLS and subsequently entered them into the appropriate place in MODIFIER.XLS. The coordinates of the new center node were calculated by taking the average of the coordinates of all outbound link upstream nodes at the intersection under consideration. This was the most efficient way to place the new node in the approximate center of the intersection configuration.

The macro UNEXPANDED functioned well for "standard" intersections - those with four inbound links to the signal and four outbound links from the signal. Intersections that were T-junctions and/or where one-way links existed, were more complicated. Where no main inbound link existed for a particular leg of the intersection (or potential leg), the nodes and links could not be traced by the macro to identify the corresponding outbound link (on the opposite leg). Hence, the macro would respond as if there was no outbound link on that leg, where in fact one may exist. Such problems could be identified by plotting the coordinates of all nodes at an intersection and connecting them with links to view the configuration of the intersection. This was a very time consuming process and hence an alternative method was sought. To deal with the cases of T-junctions and one-way links another macro named TSECCASE was written and stored in MODIFIER.XLS. The way this macro functions is difficult to explain without the aid of detailed diagrams, but we made an attempt to do this here. This macro obtains the downstream node number of all left and right turn appended links and compares them with the downstream node number of all "through" movement appended links. Where a downstream node associated with a left or right turn link could not be matched with the downstream node of a through movement link, this node was flagged as the upstream node of an outbound link that was not previously identified by the UNEXPANDED macro.

Once all the necessary data were collected for each of the 167 intersections that needed to be modified, the following steps were taken to update the link data file, LINK2.DAT:

1. *New* appended links were added to connect the downstream end of each inbound link to the new center node (these links were later given lane striping data where known).

2. The relevant data (i.e., controlling signal number, first and second phases in which each link discharges, turn prohibition data, and the first and second links opposing the flow of each link) that were temporarily coded to the main inbound links were transferred to the corresponding new appended links (removing it from the main inbound links as these terminated prior to the signal).

3. The opposing link numbers (which at this point referred to main inbound links) were changed to the appropriate numbers for the corresponding new appended links.

4. Information was retrieved from the APPROACH.DAT and EXPLODE.DAT files contained in the Technical Appendix of Bacon *et al.* (1995) to update some of the characteristics of the appended links that were different to those of the corresponding main inbound links (e.g., number of lanes and free flow speed).

The first three steps were carried out with the help of the macro ADDNL stored in MODIFIER.XLS. The macro assigned a new link number to each new appended link, assigned the downstream node number of the main inbound link as the value of the new link's upstream node, and the new center node number as the value of the new link's downstream node. The node number of all outbound links was also changed to the new center node number to complete the network connectivity. To correct the opposing link numbers, the associations between main inbound links and appended links were stored so that the values in the opposing link fields could be updated from the numbers of main inbound links to their corresponding appended links.

Before the fourth step was carried out, the data from APPROACH.DAT and EXPLODE.DAT (in the Technical Appendix of Bacon *et al.* (1995)) were entered into two Excel data files, APPROACH.XLS and EXPLODE.XLS. The electronic versions of these files were not obtained from the UC Berkeley team. The EXPLODE.DAT/XLS file listed the characteristics of each intersection by the INTEGRATION node number of the intersection (i.e., the node number when the intersections were represented by only one node, before they were expanded by the UC Berkeley team). The information stored in these records had to be matched to the link numbers and node numbers after the intersections were expanded. The problem is that the node numbers in this list did not exist after the intersections were expanded. However, careful study of a column of comments in the node file revealed that the comments contained the original node number around which each set of new nodes (i.e., eight in the case of the standard intersection shown in Figure 4) had been built. A macro named GETSIGNALNO (stored in EXPLODE.XLS) was created to obtain the first of the new node numbers and search for that node in the file MODIFIER.XLS. Once the node was found, the number of the signal at which that node existed could be determined. The signal number was then entered back in the EXPLODE.XLS file alongside the corresponding INTEGRATION node number.

The fourth step above was then carried out by the macro UPDATENL, which is also saved in EXPLODE.XLS. The EXPLODE.DAT/XLS file contains fields that store the number of a predefined approach type, for each approach link. The APPROACH.DAT/XLS file contains data that defines each of these approach types including the number of lanes, basic saturation flow rate, free flow speed, and lane configuration (e.g., number of exclusive left turn lanes, shared left/through lanes, etc.).

During this recoding process for the link data file, a number of errors and inconsistencies were identified in the link data. The resolution of these inconsistencies was made difficult since the UC Berkeley team was unable to provide a detailed map of the network region or drawings of specific intersections. Most of the problems were resolved by phone calls to members of the UC Berkeley team or other individuals familiar with the corridor.

Signal file

The signal file stores the signal timing plans for each signal in the network for the period of the simulation. The signal timing plans are specified by initial, minimum, and maximum cycle length; and the offset of the start of the first phase, number of phases, effective green time, effective lost time, and the optimizer frequency for each phase.

No changes were necessary to update the signal file, since the format of this file was unaltered between the two versions of INTEGRATION. However, modifications will be made to the signal file to create different model runs for the scenarios in which ATSC will be simulated. The main parameters that will be modified are the signal offsets and optimizer frequencies.

Demand file

The demand file contains the O-D demand matrix for the network. The O-D matrix provided by the UC Berkeley team is for the morning period 6:00am - 10:00am. Bacon *et al.* (1995) details the difficulty encountered during attempts to calibrate the full morning period and a midday period (10:00am - 2:00pm). Calibration of the morning peak period from 8:00am - 10:00am was attempted by both the UC Berkeley team and the model developers, but it was unsuccessful after attempts for eight months. The four half hour time slices between 6:00am and 8:00am were calibrated successfully, and the demand pattern for this period was mirrored for the remaining two hours from 8:00am - 10:00am; (i.e., the demand pattern was symmetric about 8:00am).

The format of this file did not change between V1.5 and V2.0 of INTEGRATION, hence, no updates are necessary for that reason. However, the file will be edited to reflect the market penetration rates of the route guidance and en-route traveler information systems for the scenarios in which they will be modeled. One of the following section discusses the proposed modeling runs. The O-D file may also be edited to remove the 8:00am - 10:00am portion of the morning period, if it is found that model runs require an unrealistically long time to complete. (Time is a required function of network size, model capability, and computer power; see section on Proposed Model Runs.)

Incident file

The incident file allows the user to introduce incidents into the simulation by specifying the number of the link on which an incident occurs, the effective number of lanes blocked by the incident, and the simulation start and end time of the incident.

The format of this file for INTEGRATION V2.0 is the same as for V1.5. Modifications will be made to the file obtained from UC Berkeley to represent the incidents introduced into various modeling scenarios for this study, particularly scenarios involving en-route traveler information.

Lane striping file

The lane striping file is a feature added to INTEGRATION V2.0 that allows the user to specify the lane configuration and lane use on any given link. This is particularly useful at intersections (i.e., exclusive left turn lanes, shared left turn and through movement lanes, etc. can be specified). Additionally, each of the five vehicle types that can be defined in the INTEGRATION master control file can be allowed or prohibited access to any or all of the lanes. The following information is included in the lane striping file: link number, number of lanes, permitted turning movements for each lane, and vehicle type prohibition for each lane. A portion of the lane striping file created is shown below in Table 24.

Table 24: Portion of Lane Striping File for Appended Links at Intersections

SMART Lane Striping File									
488									
1631	3	100	010	011		00000	00000	00000	
1632	3	100	010	011		00000	00000	00000	
1633	3	100	010	011		00000	00000	00000	
1634	2	100	011			00000	00000		
1635	4	100	010	010	011	00000	00000	00000	00000
1636	3	110	010	001		00000	00000	00000	

Since this file is a new feature of the INTEGRATION2.0 model from the version used by the team at UC Berkeley, it did not exist as part of the database obtained. It was important to create this file to specify lane configurations for the *new* appended links that had been added, as described in the above section for the link file.

Detailed information about the lane configurations for each approach type is contained in the comment column of the APPROACH.DAT file in the Technical Appendix of Bacon *et al.* (1995). Another macro, LANESTRP, was written to extract this information and insert it in the appropriate fields of the lane striping file. A three integer code is used to represent the turning movement permissions of each lane. The integer one represents permission and zero represents prohibition for left, through, and right turning movements respectively. For example, the code 100 for a given lane would represent and exclusive left turn lane, whereas 110 would represent a lane with shared left and through movements.

Vehicle type prohibition for each lane is defined by a five integer code in which the integer one represents prohibition of a certain vehicle type and the integer zero represents permission. Hence, the code 01000 would represent prohibition to vehicle type two for a given lane with permission for all other vehicle types. No prohibitions have been assigned to the lanes of any of the appended links at this stage.

Some additional work is necessary to complete the lane striping file. Some data were missing from the EXPLODE.DAT file and they will have to be obtained from another source before completion of this input file.

Summary of database modifications

The SMART Corridor INTEGRATION database was obtained from the team that created it at UC Berkeley. This database was developed for version 1.5 of the INTEGRATION model. The format of some of the input data required for version 2.0 of the INTEGRATION model were modified along with the functionality of the model. Since V2.0 is to be applied for the current study, it was necessary to update many of the fields in some of the input data files.

The major effort required to modify the database was directed toward the link file. This work has been undertaken since mid-July 1997. The update process has been a very detailed and time consuming process, requiring substantial care and cross-checking to avoid mistakes when working with such a database with tens of thousands of data fields. It was difficult to estimate the total time required to complete this task. The project team completed the necessary updates and began actual model runs in 1998.

Proposed Model Runs

Model runs will be established for a subset of all possible runs in the matrix defined by: the four scenario 'worlds' (i.e., status quo, government, private, and public-private partnership); the four technologies (i.e., electronic toll collection, advanced traffic signal coordination, en-route driver information, and route guidance); and the three model run years (i.e., 1995, 2000, and 2005). Clearly this three dimensional matrix has many cells representing potential model runs. The opportunity to obtain results for all of the potential runs is beyond the scope of this project, given time and budget constraints.

Since the final results of the scenario development process were finalized in time for submission in this report, there has not yet been opportunity to review them with the specific goal of selecting the most useful scenarios to model. However, the team intends to begin the modeling efforts with runs based on the following scenarios (unless careful review and discussion with the project sponsors recommends otherwise):

(1) Status Quo World in 1995 and 2005 for each technology, and

(2) Public-Private Partnership World in 2005 for each technology.

The project team will discuss additional potential model runs with the project sponsors to help determine which runs will be given priority for further work. Substantial effort is expected to be directed toward the identification of specific model runs in the near future, as model formulation is nearing completion.

Model runs will be performed for the morning period for which the O-D demand file was created by the UC Berkeley team. As described in the Demand file section of the Modifications to the Database section, this morning period is from 6:00am - 10:00am; however, it was only calibrated for the first two hours. The last two hours were made a mirror image of the first two hours. For the current project, simulations may be carried out only for the period 6:00am - 8:00am, depending on the actual time the model takes to complete a run. Bacon *et al.* (1995; p. 140) Stated that INTEGRATION runs for the first two time slices (6:00am - 7:00am) were able to be completed overnight; however, runs for all eight morning time slices would have taken approximately six days to complete. It is expected that simulation runs for this current study will take somewhat less time, due to the use of faster computer technology. However, the INTEGRATION model has been modified and in several aspects is more microscopic requiring additional processing--this will counteract the gains achieved by greater computer power to some extent.

The market penetration rates used for the "worlds" and run years to be modeled will be *based* on the results from the expert interviews and workshops (see Scenarios section, particularly Table 21 at the end of that section). Although these results will be used as a basis, some variation will be allowed to conduct a sensitivity analysis during the modeling effort.

Each model run will be analyzed on the basis of the output related to the following performance measures:

- average link and trip speeds,
- average link and trip travel times,
- total link and trip fuel consumption,
- total link and trip hydrocarbon (HC) emissions,
- total link and trip carbon monoxide (CO) emissions,
- total link and trip nitrous oxide (NOx) emissions, and
- total link and trip carbon dioxide (CO_2) emissions,

The performance measures will be assessed at both the link and trip level where appropriate. The link based statistics will pertain more to the analysis of scenarios involving ATSC and ETC, while the trip-based statistics will also pertain to the analysis of scenarios involving ATIS technologies. These results will be extracted from the default INTEGRATION output files and also the optional output files 11 and 12. Probe vehicles will be introduced into the model runs to assess the impact of certain scenarios along specific routes. The results of these tests will be obtained from output files 15 and 16.

Technologies to be Modeled

The following section provides some additional details about the four specific technologies to be modeled in the initial modeling effort:

- advanced traffic signal coordination (ATMS),
- electronic toll collection (ATMS),
- en-route driver information (ATIS), and
- route guidance (ATIS).

The modeling exercise will focus on each individual technology in the initial phase for the reasons presented in the “Technologies to be Modeled” section in Appendix C. However, the project team hopes to have opportunity to test the ability of the INTEGRATION model to simulate the interactions between multiple technologies in an integrated intelligent transportation system.

Advanced traffic signal coordination (ATSC)

ATSC is the dynamic optimization of signal cycle times and phases to synchronize signals along selected arterial routes. If all the signal controllers along a route are assigned a common cycle time, users can experience a progressive green wave along the route. An ATSC system can also incorporate dynamic actuation of traffic signals to respond to changes in traffic demand.

All traffic signals in the SMART Corridor study area are linked to the Los Angeles Department of Transportation ATSAC (Automated Traffic Surveillance and Control) System. ATSAC is an interconnected and coordinated signal system which monitors and manages surface street traffic. Traffic is monitored by detectors and traffic surveillance cameras and various timing programs are automatically implemented in response to fluctuating traffic demands.

Characteristics of an ATSC system can be specified within the signal input file described in the section above (“Modifications to the Database”). A set of signal input files will be created to represent the alternative scenarios being modeled, as discussed in the section “Proposed Model Runs.” The UC Berkeley team did not intend to simulate ramp metering; consequently, they did not code any of the ramp meters in the Santa Monica Freeway Corridor into the link file. In addition, the INTEGRATION model has not been previously tested with regard to its ability to model ramp metering. As a result, ramp metering is not likely to be directly included in the scope of the modeling effort for the current research project.

Electronic toll collection (ETC)

The ETC technology makes use of a pocket-sized tag containing a radio transponder that is placed inside a vehicle's windshield. The transponder transmits radio frequencies to an electronic antenna as the vehicle passes through the toll collection lane, and the appropriate fare is deducted automatically.

Such systems have the capacity to move five times as many vehicles as conventional toll lanes, reducing congestion, fuel consumption, and air pollution at toll plazas. As well as saving travel time for motorists, ETC systems are viewed as very convenient (i.e., no need to change, stop, lower window, etc.).

No ETC facilities currently exist along the SMART Corridor. Since the Corridor is only 11 miles long, it would only be feasible to deploy one ETC facility(in a modeling scenario). Recent discussion regarding the implementation of ETC and the modeling of this technology for this project have centered around the issue of HOT lanes (i.e., HOV lanes converted to allow SOV users to pay, via ETC, to access the HOV lane and avoid high levels of congestion). It has been argued that this is the most reasonable application of ETC within the Santa Monica Freeway Corridor. It is not yet clear whether the INTEGRATION model is capable of simulating the deployment of HOT lanes. This will be determined shortly through continuing discussions with the model developers.

An ETC facility can be modeled within INTEGRATION by changing the characteristics (e.g., reducing the capacity or free-flow speed) of a link or links on the network at the location of the ETC facility. Prohibitions can also be assigned to certain vehicle types for use of certain links or lanes (i.e., by use of the lane striping file; see earlier section).

En-route driver information

En-route driver information consists of real-time information about traffic conditions, incidents, construction, transit schedules, and weather conditions, which are provided to drivers once travel begins. Real-time traffic conditions can be obtained from surveillance stations (i.e., from cameras or inductive loops) or from probe vehicles that drive through the network and transmit data back to the control center. The primary travel behavior impact of such a system would be caused by drivers choosing better routes to their destination or changing their destination or both. Mode choice and trip chaining formation may also be influenced.

Information can be provided via in-vehicle displays or voice messages or both, via Highway Advisory Radio (HAR), or externally via CMS.

This study will attempt to model the impact of in-vehicle information and also CMS. HAR may also be contrasted to CMS. The INTEGRATION model allows the user to define five different vehicle types in terms of the frequency of information that they receive and a measure of the error likely to be inherent in the information received. The parameters for these vehicle types are defined in the master control file, as described in an earlier section. Nodes within the network will be coded to act as information nodes that transmit traveler information to vehicle types that are coded to receive it.

Route guidance

Route guidance systems provide simple instructions to a user to follow a suggested route in order to reach a specified destination. Such information can be provided at the start of a trip (pre-trip) or throughout the trip or both with regular updates to an in-vehicle device. Real-time route guidance systems update directions based on real-time traffic conditions, status of transit systems, and road construction/closures. The directions consist of simple instructions for turns or other upcoming maneuvers.

The effectiveness of a route guidance system is a function of the market penetration levels of in-vehicle or hand-held route guidance devices, the quality of the information provided, and the response of users to the information provided (i.e., partly related to information quality).

This study will model en-route route guidance systems within the context of the scenarios that have been developed.

Ranking of ITS Technologies Based on Energy and Environmental Impacts

The criteria on which the modeled ITS technologies will be ranked are the following:

1) Vehicle Miles Traveled (VMT): To what extent does the technology reduce VMT?

2) Travel Time: To what extent does the technology reduce travel time?

3) Energy Consumption: To what extent does the technology reduce energy consumption?

4) Emissions reduction: To what extent does the technology reduce emissions (i.e., of CO, HC, NOx, and CO_2)

The focus of this research is of course on the energy and environmental criteria (3 and 4). However, VMT and travel time impacts will also be taken into account. Two caveats apply to these criteria. First, they are somewhat narrow to be classified as "sustainability" criteria. We are attempting to rank the technologies based on criteria that are either directly related to or can be derived from the modeling effort. And second, we make no attempt to judge the relative importance of each of the four criteria. This is because the relative importance of the criteria will vary depending on the region, environmental regulation, or other context-specific factors in which the ITS technology is being deployed (i.e., in some regions, reductions in VMT may be deemed more important than emissions reduction, or vice versa).

SUMMARY AND CONCLUSIONS

This report has presented research conducted by Institute of Transportation Studies at Davis and Claremont Graduate School researchers for the project titled "Identification and Prioritization of Environmentally Beneficial Intelligent Transportation Technologies."

This report presents an extensive review of literature related to the importance of considering the environment in ITS deployment plans. The reviews focus on the impact of ITS technologies, and in particular on energy and environmental impacts. Since the first year interim report, the policy context section of this document has been revised and updated to reflect the current regulatory arena in which ITS technologies will be deployed.

In addition, the scenarios section of the report has been substantially expanded to reflect the outcome of work conducted in Year Two of this project. In 1997, the scenario analysis was the focus of significant project effort. This scenario section includes a discussion of the scenario methodology, summaries from expert interviews, and the results of two expert scenario workshops (i.e., held in Washington, DC, and Davis, CA, in the Fall of 1997). Furthermore, this section provides the final scenarios and market penetration estimates developed to provide the framework for the modeling efforts in this project..

The INTEGRATION model was selected after a review of several different modeling tools for the following primary reasons:

- It is the most advanced model, capable of simulating the broadest range of different ITS technologies;
- It is the most widely applied model, therefore it has many of the 'bugs' identified and corrected;
- There are existing databases and networks available for the INTEGRATION model; and
- Several supporting models have been developed for use with INTEGRATION

A large section of this report is devoted to a description of the INTEGRATION database for the SMART Corridor, obtained from researchers at UC Berkeley and being updated for use with INTEGRATION V2.0 in this study. The effort required to update this database due to changes between this version (i.e., V2.0) of the model and the version (i.e., V1.5) for which the database was originally developed has been extensive. Modeling with a detailed microsimulation model such as the INTEGRATION model is extremely data intensive and requires substantial time and personnel resources.

The end of the modeling effort section discusses proposed work. The *initial* modeling effort will focus on a subset of ITS technologies, namely, advanced traffic signal coordination, electronic toll collection, en-route driver information, and vehicle navigation/route guidance. Specific modeling runs will be based at first on the following scenarios: (1) Status Quo World in 1995 and 2005 for each technology; and (2) Public-Private Partnership World in 2005 for each technology.

Modeling results will be analyzed and assessed within the policy context detailed in this report and within the context of the scenarios on which the runs are based. ITS technologies will be ranked in terms of their environmental impacts.

FUTURE WORK

A large knowledge base has been developed regarding the environmental benefits of ITS technologies. The focus of future work will be to add to this knowledge the results of our simulation modeling effort for a subset of ITS technologies, within the context of the scenarios developed.

The *initial* modeling effort will focus on the following ITS technologies and user services:

- adaptive traffic signal coordination (ATMS),
- electronic toll collection (ATMS),
- en-route driver information (ATIS), and
- route guidance (ATIS).

After finalizing the modification to the database for the SMART Corridor, the project team will direct efforts to modeling specific scenarios for each of the four ITS technologies identified in this report. Model runs will be established for a subset of all possible runs in the matrix defined by: the four scenario "worlds," the four technologies; and the three model run years (see section "Proposed Model Runs"). The initial model runs will be based on the following scenarios:

(1) Status Quo World in 1995 and 2005 for each technology, and

(2) Public-Private Partnership World in 2005 for each technology.

Subsequent model runs will be developed by a careful review of the findings of the interviews and workshops, and in consultation with the project sponsors. Further details of the proposed modeling effort and the technologies to be modeled are given in the last subsections of the section "Proposed Model Runs."

The results of the modeling work will be assessed within the context of the scenarios upon which they were based and the broader policy context described in this report. The modeled technologies will be ranked according to their energy and environmental benefits. Recommendations will be made for planners and decisionmakers to help advise them in their efforts to demonstrate attainment and conformity with air quality standards.

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APPENDIX A

This appendix presents summaries of the two interviews of energy and environmental policy experts, conducted in year one of this research. The first interview was with Professor Daniel Sperling, Director of the Institute of Transportation Studies, and Professor of Civil and Environmental Engineering and Environmental Studies at the University of California, Davis. The second interview was with Professor Monty Hempel of the Claremont Graduate School.

Expert Interview with Daniel Sperling on Environmental and Energy Trends Affecting Future ITS Deployments; 9-15-96

Introduction

This interview focuses on the expected changes in the regulations and monitoring enforcement of environmental issues, especially the future of air quality regulations. Several individuals have been interviewed using a standardized set of questions. This summary reflects an interview with Daniel Sperling, an expert in the energy and environmental regulations arena and a professor at the University of California, Davis.

Regulatory Changes

Many regulatory acts have been passed by the government in the past three decades. Many of these regulations specified goals for the future and may require amendments due to technology or population trends. The CAA of 1990 currently include standards for six criteria pollutants, including PM-10 and ozone. There most definitely will be a tightening up of the PM-10 standards, and a new set of standards are likely to be developed for PM-2.5. The ozone standards will likely be changed from a one-hour to an eight-hour standard, as well.

To achieve attainment of current and new standards, vehicle technology will play an important role, especially in the area of propulsion technology. Expect to see rapid growth in electric fuel cell technology and many hybrid vehicles in the near future. VMT controls will only play a minor role in achieving attainment.

At present, the future of ISTEA is uncertain. There is a debate whether the federal government should give the States more responsibility in terms of funding and taxes. As a consequence of this, the federal government will likely cut back on funding for transit. In general, there is likely to be continued support for ITS deployment, which was one of the main goals of ISTEA. No changes are expected in EPA and CEQA.

The ZEV Mandate of 1990 requires that ten percent of all motor vehicles sold in California by 2003 must have zero tail pipe emissions. D. Sperling expects a breakdown in the mandate. He forecasts that the mandate will be revised to call for only three-five percent ZEV sales in 2003.

Achievement of the mandate strongly depends on technology, how people will react to new vehicles, marketing of vehicles, and the cost of buying and owning such vehicles. The Partnership for a New Generation of Vehicles (PNGV--clean cars) also depends on technology. Hybrid and fuel-cell vehicles are the driving force for this partnership. PNGV is intended to help with the ZEV mandate.

The International Climate Change Accord along with a Persian Gulf War might change the popular perception. In terms of ITS technology, it will only affect the area of propulsion technology. It will provide support for station cars and NEVs. It also may provide support for specialized vehicles.

Market Attributes of ITS

In the next ten years, consumers will be the driving force for the implementation of ITS, not the government. Hence, ITS will become decentralized. The main concerns of most drivers are safety and security. If ITS can provide an increased level of safety and security, consumers will be willing to pay for these services. The ITS technologies of interest are collision avoidance, emergency notification, and to a lesser extent traveler information. Congestion pricing is predicted to emerge very slowly and only in certain situations with new projects.

Energy Security Issues

In the future, oil imports are likely to increase. Worldwide oil supply will increase, but the demand for oil worldwide also is increasing. The world will have a secure supply of oil for the next twenty years. Disruptions, such as wars, are the only issues to contend with in energy security.

Market for Sustainable Energy Technologies

The market for sustainable energy technology (high efficiency and low environmental impact) is growing. The deregulation of the electricity industry will cause new investments in more efficient electricity generation to proceed slowly, however. Nevertheless, electricity is still considered a sustainable source of energy because of the inexpensiveness of producing electricity from natural gas. In terms of vehicles, there will be a slow growing trend towards electric drive vehicles.

Technological Changes in Vehicles

Vehicle technology is expected to change in the future. The main change will be to reduce emissions from all types of vehicles. Fuel efficiency is expected to increase in all vehicles, not necessarily fuel economy. The light truck share of the market is expected to increase from 40 to 50 percent, making light trucks the major vehicle type on the road, which could cause fuel economy to remain the same. The number of freight trucks on the road also will increase, resulting in increased fuel consumption--even though the trucks are expected to be more fuel efficient.

Land Use and Urban Structure

No changes are expected in land use and urban structure over the next ten years.

American Values and Culture

The values and culture of the public are most definitely going to change over the next ten to twenty years. People are more sensitive to the future and the environment. If choices are available, people will choose the more environmentally friendly one. In terms of transportation, people will be more willing to drive electric vehicles if the technology is available. Transit usage will decrease because land use will be widely dispersed. Intelligent paratransit use may increase.

Congestion Reduction from ITS

ITS will reduce congestion minimally. People will use ITS technologies because of the tremendous latent demand for transportation. People will travel more efficiently by changing their time of travel. However, someone will inevitably take the spot of the person who is now traveling more efficiently.

Some will telecommute, and this will help to reduce congestion. Flatter travel patterns both spatially and temporally will emerge as a result of widespread ITS. The result will be a better use of infrastructure and a safer and more secure transportation system.

Expert Interview with Prof. Monty Hempel on Environmental and Energy Trends Affecting Future ITS Deployments; 9-20-96

Introduction

Professor Hempel highlighted three trends related to environmental and energy policy that may influence ITS deployments over the next ten to twenty years; 1) environmental policy changes in California and elsewhere; 2) trends in energy consumption; and 3) the international regime governing greenhouse gas emissions. A summary of the interview is provided below:

Environmental Policy Trends: California and Elsewhere

General California Trend

Professor Hempel believes that environmental quality is less of a policy priority in California than it was prior to California recession. As a result, environmental regulations have and may continue to loosen. An exception is the SMOG CHECK II program, which is aggressively targeting gross polluters, but Professor Hempel believes that this program may be scaled back over time (i.e., people seem very leery of excessive government intervention in their lives, or literally "taking away their cars").

From "single media" to "multi-media" approaches to environmental policy; and from command and control to market based approaches

According to Professor Hempel, approaches to environmental policy are becoming more "integrated." This increased integration takes the form of mandating "ecosystem management" and "sustainable communities:" i.e., air, water, and land use issues are considered together rather than separately. In addition, as environmental policy is increasingly subsumed under "sustainable development," policies protecting the "environment" may make greater efforts to balance economic, social, and environmental concerns. Balancing multiple goals is extremely complex, according to Professor Hempel, and policies must be informed by large amounts of technical information and data. New technologies, such as Geographic Information Systems (GIS) and ITS, can help generate this information and data to assist policymakers in taking such an integrated approach to environmental protection.

In addition to more integrated approaches, another trend in environmental policy is the increasing use of market-based approaches, with the latest example in California being the energy deregulation scheme. Professor Hempel believes that excessive reliance on market approaches raises environmental concerns. If price is the final arbiter of what is deemed "environmentally acceptable," policymakers must be sure that those prices reflect full social and environmental costs. Fully reflecting these costs is not always possible, however. For example, when asking "what is the price of a tree" (i.e., valued in terms of wood input), this price will not reflect the full value of the tree because the real value is in its "ecological inter-connection" (i.e., the tree's role in preventing soil erosion, preventing against floods, absorbing CO2). Nature, according to Professor Hempel, is not just a resource component and cannot always be reduced to a separable level.

Greenhouse Gases (GGs)

Major Trends Related to GGs

Professor Hempel highlighted trends in both science and politics. With respect to science, scientists seem increasingly convinced that global warming is a "real" phenomenon, and they are tending to call for stronger limits on GG emissions. Only a small group (i.e., maybe 12) of well-regarded scientists remain outspoken critics of the theory of global warming.

With respect to policy and politics, there is increasing international momentum to move from "frameworks" to "protocols" in governing GG emissions. The current GG regulatory regime remains the international Framework Convention on Climate Change (FCCC). The FCCC created the goal and expectation (but **not** the requirement) that each signatory nation's GG emissions in the year 2000 be at or below its 1990 levels. Since the FCCC, there have been two meetings of the "Conference of Parties" (i.e., among nations who signed the accord). At the latest meeting in Berlin, it was decided that specific GG emission targets and timetables should be considered, although the U.S. opposes specific mandates.

With respect to transportation and ITS, Professor Hempel believes that while the trend is toward more demanding controls on GG emissions, he foresees no "bite the bullet" scenario in the near future.

Trends in Energy Consumption

Short-term versus. Long-term Supply/Demand

While Professor Hempel sees no energy supply problems in the short-term (i.e., barring unforeseen political instability), the long-term prospects appear different. Perhaps in 25 years, oil prices could "sky-rocket" due to a huge increase in demand. One scenario, according to Professor Hempel, is that China, India and other rapidly developing countries (with huge populations) could be competing with the U.S. for oil imports. If such competition occurs, a big question is how soon alternative energy sources (especially electric propulsion technologies and fuel cells) become available and viable for large-scale use.

APPENDIX B

Regional Ten-Year Forecasts

Below follows regional forecasts for three major areas in California: the South Coast, San Francisco, and Secramento. We collected these data in Year One of this project t keep us prepare and select a modeling region for this study. We include this data on our Year Two appendices because they contain valuable data to MPOs interested in gathering data to create a scenario framework and the baseline data needed for an ITS modeling study.

I. *South Coast Forecast*

The South Coast area's population is approximately 14 million people. By 2006, a projected two million more people will reside there (AQMD, 1996a). This area is also expected to experience job growth. By 2015, approximately 3,000,000 new jobs will be created since 1990 (SCAG, 1994). A minimum of 350,000 to 400,000 of these new jobs will support industries that produce and support new transportation technologies (SCAG, 1994). This will increase the total number of jobs in the area to approximately 10.3 million by 2010 (SCAG, 1994).

Congestion is a major problem in the South Coast area. The majority of the population is a commuter society, which relies heavily on single occupancy vehicles. Currently, the average vehicle ridership is 1.38 persons per car (SCAG, 1994). Transit accounts for a very small proportion of this area's travel with only 5.62 percent of the population using this mode (SCAG, 1994). Each person, on average, makes 3.4 daily trips and drives an average of 20.48 miles per day (SCAG, 1994).

In 1993, the average vehicle miles of travel was approximately 291,800,000 per day. In 2006, this average is expected to increase to 378,610,000 (AQMD, 1996a). This represents an increase of almost 30 percent. In 2006, the number of vehicle trips is projected to increase by 7,740,000 or by 26 percent (AQMD, 1996a).

Not surprisingly, poor air quality is a major problem associated with this area. Emissions from vehicles account for most of the pollutants emitted. Nevertheless, air quality is improving in this area. The baseline figures for VOC, NOx, CO, PM-10, and SOx are all decreasing. (See Table B-1 below.)

Table B-1: Southern California Forecast				
	1993	**2000**	**2006**	**2010**
Population	13,800,000	14,900,000	*16,040,000*[1]	16,800,000
VMT (daily)	291,800,000	325,600,000	*378,610,000*	385,500,000
VHT (per capita)	0.631	*0.777*	*0.902*	0.985
Vehicle Trips	29,800,000	36,100,000	*37,540,000*	38,500,000
Emissions (tons per day)				
VOC	857	521	388	318
NOx	1,134	823	677	626
CO	8,563	4,927	3,952	3,520
SOx	76	72	79	83
PM-10	46	37	36	37

[1] All values in italics are linearly interpolated

Source: SCAG (1994) and AQMD (1996a)

Attainment status depends on two sets of standards, the federal standard and the State standards (see Table B-2 below).

Table B-2: Attainment Status and Target Dates		
	Federal	**State**
NOx	Met	Met
CO	2000	2000
PM-10	2006	Post-2010
Ozone	2010	Post-2010
SOx	Met	Met

Source: AQMD (1996b)

In terms of NOx and SOx, federal and State standards are met. By 2000, federal and State standards for CO will be attained. For PM-10 and ozone, current federal standards will be met in 2006 and 2010, respectively. The State standards for these pollutants will be achieved post-2010 (AQMD, 1996b).

II. *San Francisco Bay Area Forecast*

The San Francisco Bay Area is expected to experience significant change within the next ten years. The Bay Area population is expected to grow to 7.3 million people by 2005 which is an increase of 1.3 million people from 1990 (MTC, 1994). Surprisingly, immigration into the Bay Area is projected to decline; however, births will account for about 80.4 percent of the new population (MTC, 1994). The job market is estimated to grow at a rate of 1.4 percent per year between 1990 and 2010, which is slightly slower than the 2.3 percent growth rate of the 1980s (MTC, 1994). Tables B-3 and B-4 (below) show the growth in jobs and employed residents by county.

Table B-3: Growth in Employed Residents by County

County	1990	2010	Net Growth	Rate of Growth (%)
Alameda	648,461	776,600	128,139	20
Contra Costa	409,351	565,300	155,949	38
Marin	127,578	145,400	17,821	14
Napa	52,683	68,400	15,717	30
San Francisco	391,292	441,600	50,308	13
San Mateo	353,626	401,700	48,074	14
Santa Clara	812,345	967,900	155,555	19
Solano	162,219	252,700	90,481	56
Sonoma	194,387	269,500	75,113	39
Region	**3,151,943**	**3,889,100**	**737,157**	**23**

Source: ABAG Projections (1994)

Table B-4: Growth in Jobs by County				
County	**1990**	**2010**	**Net Growth**	**Rate of Growth (%)**
Alameda	617,320	796,240	178,920	29
Contra Costa	305,140	430,120	124,980	41
Marin	102,240	129,540	27,300	27
Napa	47,590	72,260	24,670	52
San Francisco	582,010	667,570	85,560	15
San Mateo	319,120	393,540	74,420	23
Santa Clara	864,110	1,046,360	182,250	21
Solano	119,300	194,760	75,460	63
Sonoma	153,600	240,990	87,390	57
Region	**3,110,430**	**3,971,380**	**860,950**	**28**

Source: ABAG Projections (1994)

With the increase in population and employment, an increase in travel volume is also expected. Indicators of travel volume are person trips, vehicle trips, and VMT. The total travel volume is projected to increase at similar rates to those of population and employment. For instance, growth in work trips parallels projected growth in residents employed and total employment (MTC, 1993) (See Table B-5 below).

Table B-5: Bay Area Forecast					
	1990	**1995**	**2000**	**2005**	**2015**
Population	6,020,147	6,492,950	6,931,300	7,296,250	
VMT (daily)	113,389,582	123,666,922	*133,900,459*[1]	144,133,996	
Person Trips	16,783,360	17,391,725	*19,990,206*	20,278,927	
Vehicle Trips	15,854,266	16,992,313	*18,448,036*	19,903,760	
Emissions (tons per day)					
NOx	337.2	256.96	222.28	187.6	
Particulates	44.48	*44.72*	*45.06*	*45.36*	45.94
ROG	325.4	219.6	159.5	99.4	
CO	3467.57	2267.1	1664.3	1061.4	
VOC	321.9	217.2	157.7	98.3	

Source: ABAG Projections (1996); MTCFCAST, MTC (1996)

[1] Data in italics are interpolated

The greatest growth will be in commercial vehicle trips at 44 percent (MTC, 1994). Linked transit trips will grow at 17.6 percent. This rate is significantly lower than the population growth rate which is due to increased auto ownership and developments occurring farther away from the urban core (MTC, 1994).

Overall travel time increases at a slower rate than growth in travel volume (MTC, 1994). Still, the average travel time in the year 2010 will increase slightly, except for the travelers in the Almanden, Gilroy, and Morgan Hill areas (MTC, 1994). The average work trip length will increase from 10.4 miles in 1980 to about 11.2 miles in 2010, i.e., an eight percent increase (MTC, 1993).

The above statistics are for single occupancy drivers. Figures for other modes of transportation are also available, such as buses and intercity rail. The transit share is expected to decline from 10.6 percent to 9.3 percent for commute trips and from 5.7 percent to 5.1 percent for other trips between 1990 and 2010 (MTC, 1994). The decline can be attributed presumably to an increase in auto ownership and a trend in individuals choosing to live farther away from the urban core that is not well serviced by public transit (MTC, 1994). With the population increase, ridership is expected to increase by 24 percent between 1990 and 2010 (MTC, 1993). Rail transit is served by Amtrak, which operates this intercity service. The rail service of most interest to the Bay Area is the Capitols Lines that runs between San Jose and Auburn. Current ridership is 20,000 passengers per month on a service that operates three daily round trips. Service is expected to expand to six daily trips (MTC, 1994). The increase in number of trips should improve the convenience of rail transit.

The Bay Area is very concerned about air quality. There are three major pollutants used to measure the quality of air. (See Table B-5 above.) These pollutants are ozone, CO, and particulates, e.g., PM-10. The Bay Area is in attainment for the federal ozone standards, but in non-attainment for State standards (Dyett, 1996). At present, this area is classified as non-attainment for CO, although this area has demonstrated attainment for both federal and State standards in the past two years (Dyett, 1996). Attainment certification is pending.

Particulate standards are met on the federal level; however, the State standards have not yet been satisfied (Dyett, 1996). To aid in obtaining attainment in all three pollutant areas, a Bay Area Clean Air Plan was adopted. This plan calls for: 1) an average vehicle ridership of 1.4 persons during weekday commute hours by 1999, 2) no net increase in motor vehicle emissions after 1997, and 3) a significantly reduced rate in the increase of vehicle trips and VMT (MTC, 1994). Air quality improvements can be attributed to cleaner burning engines and the turnover rate of fleet vehicles (Dyett, 1996).

III. *Sacramento Area Forecast*

The Sacramento Metropolitan region is expected to grow in population and employment opportunities over the next ten years. This region is expected to absorb another 700,000 people, and employment is projected to increase between 40 and 50 percent (SACOG, 1996). A majority of this growth will be in Sacramento County. In fact, downtown Sacramento can expect a 38 percent increase in employment and a 37 percent growth in population (SACOG, 1996). Job growth is projected to be strong in the: 1) I-80 corridor between Roseville and Rocklin, 2) I-5 corridor around North Natomas, 3) Rancho Cordova, and 4) West Sacramento. Strong residential growth is expected in Franklin/Laguna, the Vineyard Area I-5/Route 99 corridor, Roseville/Rocklin corridor, and the North Natomas (SACOG, 1996).

Many transportation issues arise with an increase in demographics. One issue that will affect many people is congestion. With the growth in population and employment, vehicle trips will increase by approximately one third (SACOG, 1996). Daily VMT will increase from 36,212,000 miles in 1996 to 22,202,000 miles in 2005 (SMAQD, 1994). With the increased demand on the freeway network, it is predicted that congestion will increase four fold (SACOG, 1996). Along with the increased travel due to residents living in the metropolitan area, many long distance travelers, passing through the area, will also contribute to congestion in the region (SACOG, 1996).

In addition, suburb to suburb travel is rising quickly. In fact, suburb to suburb trips are increasing at a faster rate than suburb to downtown trips (SACOG, 1996). Many of these trips were not anticipated by transportation planners as the area's transportation system is not designed to carry the large volume of suburb to suburb trips (SACOG, 1996). As a result, many of the corridors are congested. At present, other travel mode choices are very limited, and public transit most often requires that individuals make transfers (SACOG, 1996).

Currently, this region supports a light rail and bus system. Many critics have Stated that there is a lack of public transit in this region. Many citizens would like to expand the light rail system and provide more express buses (SACOG, 1996). The goal of increased transit is to reduce congestion and increase the mobility of those who cannot drive by making public transportation more convenient. In a survey distributed in Sacramento and Yolo counties, the respondents preferred improvements to public transit over street widening (SACOG, 1996).

Air pollution is directly related to vehicle emissions. Currently, the Sacramento Metropolitan Area is classified as severe non-attainment area for ozone under the federal standards (SACOG, 1996). Other measurements of air quality include PM-10 and CO. In Sacramento, both of these pollutant also are classified as non-attainment (Hoffacker, 1996). The baseline figures for the pollutants are given in Table B-6 below. Most of the pollutants decrease over time, with the exception of NOx and PM-10. Specifically, PM-10 increases slightly, and NOx remains constant (SMAQD, 1994).

Table B-6: Sacramento Projections

	1990	**1995**	**2000**	**2005**
Population	1,548,523	1,800,494	1,985,450	2,204,800
Vehicle trips (Daily)	3,769,185	4,383,134	4,956,538	5,497,663
VMT (Daily)	22,202,000	26,550,000	30,795,000	36,212,000
No. of Vehicles	830,690	965,970	1,092,332	1,211,575
Emissions (tons per day)				
Oxides of Nitrogen (NOx)	66.69	50.07	50.77	50.87
PM (PM10)	9.69	8.85	9.84	11.30
Reactive Organic Gases (ROG)	70.55	52.18	34.76	25.95
Carbon Monoxides (CO)	449.20	368.78	254.00	199.89
Total Organic Gas (TOG)	76.10	56.71	37.96	28.16

Source: SACOG (1995); Sacramento Metropolitan AQMD (1994)

APPENDIX C

This appendix contains sections from the project Year One report that are an integral part of the modeling work and are referred to in the section "Modeling of ITS Technologies with INTEGRATION V2.0." The sections below have been left essentially intact to provide background and easy reference to some of the work that led to decisions about which technologies to model, whether to model individual technologies or bundled technologies, and the scale of the network in which to conduct the modeling. This final section provides a discussion on some of the data needs for modeling ITS technologies.

Modeling ITS Technologies

The principal aim of this project is to provide a detailed review of the environmental impacts of a wide range of ITS technologies and user services. However, it is not within the scope of this project's timeframe and resources to conduct a detailed quantitative evaluation of each and every technology/user service. The number of ITS equipment packages totals over 100. The US DOT (1995c) approach specifies 38 individual technologies, grouped into eight different bundles based on their expected impact on emissions, resulting from changes in traffic operations and travel demand.

The Year Two project work plan listed the following ITS technology functional areas from which the modeled technologies would be selected:

- Advanced Traveler Information Systems (ATIS),
- Advanced Traffic Management Systems (ATMS), and
- Advanced Public Transportation Systems (APTS).

Three specific technologies were listed as part of the proposed ATMS-related investigations; namely, ATSC, ETC, and AVI--one use of which is as a part of an ETC facility. Demand responsive public transport systems were identified as being the focus of the efforts in the APTS area.

The selection of technologies to be part of the modeling effort depends on several factors:

- modeling capabilities,
- availability of required data,
- the technologies that are currently deployed or set to be deployed in short term, and
- the technologies that are likely to have a significant impact on the environment.

At a workshop hosted by Mitretek on March 14, 1995, representatives from Mitretek, the architecture contractor teams, and other interested parties discussed which of the services defined by the architecture "could potentially be modeled with tools available now or in the next few years" (Glassco *et al*., 1996). The participants of this discussion defined user services as those that: 1) can be directly addressed, 2) can be indirectly addressed, and 3) those that can not be addressed by traffic simulation modeling. The following three lists show the result of this exercise (Glassco *et al*., 1996). A question mark is shown where there was not substantial agreement among workshop participants.

The user services that can be *directly addressed* are those whose impact can be explicitly modeled with traffic simulation tools:

- en-route driver information,
- route guidance,
- pre-trip travel information, and
- traffic control (including adaptive traffic signal control).

The user services that can be *indirectly addressed* have primary characteristics that cannot be modeled with traffic simulation tools, but whose secondary impact on traffic flows can be assessed in some meaningful way:

- emissions testing and mitigation,
- incident management,
- emergency notification and personal security,
- emergency vehicle management,
- ride matching and reservation,
- demand management and operations,
- traveler services information, and
- electronic payment services (tolls).

The user services that can *not* be *addressed* have primary characteristics and secondary impacts that cannot be modeled with current traffic simulation tools in a meaningful way:

- public transportation operations (i.e., four services),
- commercial vehicle operations (i.e., six services), and
- advanced vehicle control and safety systems (i.e., seven services).

It is important to note that the workshop was focused on the ability of tools to model the *traffic* impacts of ITS services, and not on the secondary energy and environmental impacts that are of interest to this project. The ability of available modeling tools is even less promising for environmental evaluations.

Based on the information presented above, discussions with various experts, resource and time limitations, modeling limitations, and the abilities of the project team, a decision was made to focus the *initial* modeling efforts on the following list of technologies:

- advanced traffic signal coordination (ATMS),

- electronic toll collection (ATMS),
- en-route driver information (ATIS), and
- route guidance (ATIS).

The final list of technologies that will be modeled do not differ from the list above. It should be noted that the exclusion of technologies from specific modeling efforts does not mean that additional environmentally beneficial ITS technologies cannot be identified and prioritized. Another likely candidate for inclusion beyond this initial list is incident management. In the second year of this project, we continued to collect results from other studies and FOTs, and we combined those findings with those already obtained in this report.

Individual technologies vs. bundled technologies

The modeling efforts will focus on the evaluation of *individual* technologies, rather than attempting to evaluate the impacts of various technology bundles. There are obvious justifications for and against this approach. First, it is clear that in the field, individual technologies will not often be deployed in isolation. Many of the technologies rely on input and feedback from other technologies or are designed to provide information to other technologies or both. For example, a traveler information system that provides real-time information about congestion levels and incidents must be linked to technologies such as incident management/clearance systems and freeway management systems. In fact, the optimal strategy for any implementation of ATIS and ATMS technologies is likely to be a combination of technologies from each system group.

Despite this argument for considering technology bundles, rather than individual technologies, there are at least two reasons why the project team has chosen to focus on the evaluation of individual technologies.

1. There is substantial interest in the transportation community about the environmental impacts of ITS technologies. This interest is not only in whether ITS technologies are environmentally beneficial, but it is also in which ones have the greatest potential for providing environmental benefits; and conversely, which technologies are the greatest threat to the environment. MPOs have an interest in understanding the relative impacts of a range of technologies (i.e., the order of ITS technologies and user services ranked by their potential environmental impact). This is particularly important in relation to the project-level conformity process (e.g., CO and ozone emissions) and the need to demonstrate that individual projects will not cause an exceedance of the air quality standards. Additionally, it would be very useful for a region that is trying to reach attainment of the ambient air quality standards to have a "suite" of environmentally beneficial technologies from which to select, understanding the relative benefits of each.

The large number of differing factors that define and affect each technology will make it difficult to provide a decisive ranking, but it is expected that some useful guidance can be provided.

2. No modeling efforts have attempted to simulate the combined impacts of multiple technologies, and it is yet unclear whether existing models are capable of achieving this. The INTEGRATION model claims to be able to simultaneously represent various combinations of ATIS and ATMS strategies. However, this functionality has not been thoroughly tested by real-world application. Although there is no reason to doubt this claim, it is not the *purpose* of this project to evaluate the ability of INTEGRATION to simulate integrated technologies.

Scale of analysis

The project team has discussed at length the appropriate scale of analysis for the modeling effort, and has decided to confine the scope of the modeling effort to *corridor-based* studies. The primary reasons for this decision follow.

- The effort required to simulate a network is directly proportional to the size (i.e., both temporal and spatial) and complexity of the network--an often-repeated observation of Bacon *et al*. (1995).

- Each of the technologies selected for the initial modeling effort is suitable for application within the boundaries of a transportation corridor, and has been deployed in this manner in practice.

- The magnitude of energy and environmental benefits for a corridor analysis is likely to be greater for a given technology than for the same technology deployed system-wide. Since the ranking scheme (i.e., for the prioritization of environmentally beneficial technologies) will be based on the relative magnitudes of the appropriate measures of effectiveness, a multi-criteria framework will be better able to distinguish between technologies and scenarios at the corridor level.

Despite the focus on the corridor level for modeling efforts, the results of the modeling will be assessed with regard to their implications for system-wide deployments and the resulting impacts.

Data Needs for Modeling

The experience of Bacon *et al*. (1995) highlighted the difficulties associated with coding and calibrating the various aspects of a transportation network. Since the focus of this current research project is on evaluating the energy and environmental impacts of various ITS deployment scenarios, and not on calibrating a network or testing simulation models, it is highly desirable to make use of an existing calibrated network. As the selected simulation model is INTEGRATION, it is also desirable to have a network already coded for this model. In this light, the choices include: 1) the Urbansville and Thruville networks (already obtained from Karl Wunderlich of Mitretek); 2) the Smart Corridor (or at least that part of it calibrated by Bacon *et al*. (1995)); and 3) the TravTek Orlando network (although the calibration of this network was based on freeway flow data only).As mentioned earlier, we have selected the I-10 smart corridor for our simulation modeling exercise in this project. The main advantages of the Smart Corridor network are that it is partly calibrated, and it is the only California-based network of these options.

There are advantages to using the Urbansville and Thruville networks, not the least of which is that they are already available to the project team. However, the work by Mitretek has been somewhat conceptual in nature and has not consisted of the calibration of an *actual* traffic network. The Urbansville network is a *representation* of Detroit, Michigan and its suburbs, consequently, it cannot be correctly calibrated with real-world measured traffic flows.

Is it essential to have an accurately calibrated network to simulate the *relative* impacts of various ITS strategies involving a range of technologies/user services? It can be argued that if the same network is used for each scenario, the degree of calibration may not be critical, but the use of a calibrated network is likely to make the results of the study more credible.

In addition to the requirement for a carefully coded network for simulation efforts, there is a need for information about the specific operational characteristics of the technologies to be modeled. The literature reviews and collection of FOT data that has occurred over the last year has provided the project team with much of this necessary information. One of the useful products of this research may be the *specification of data needs* from FOTs in order to be able to conduct detailed assessments of environmental benefits. This was addressed as an important issue by the ‘Expert Panel’ meeting held by Apogee in Washington, DC. (Apogee Research, 1997a; 1997b).

APPENDIX D

Expert Interviews

The following sections present the interview protocols, and the interview summaries from Washington, DC, and the Los Angeles, conducted in July and August of 1997.

Interview protocols

Government World Interview

Imagine that "the government" ("the government" refers to federal, State, and local governments) made ITS deployment a high priority for two time periods, i.e., the years 2000 and 2005. Imagine as well that the private sector continued to invest in ITS products and services at roughly the same rate at which that investment is taking place today. And finally, imagine that the degree of policy and public concern for the environment continued at roughly the same level as today.

Given this scenario, please answer the following questions:

1) To what degree would the following ITS technologies be deployed in a typical urban corridor in the years 2000 and 2005?

a) electronic toll collection
  - What proportion of lanes at a given toll facility would operate using ETC?
  - Would you expect vehicles to be manufactured with OEM ETC functionality by 2005 and/or 2010?
  - If so, what proportion of on-road vehicles would be likely to have OEM ETC?

b) advanced signal coordination
  - What proportion of all traffic signals are part of a coordinated route?
  - What proportion of signalized arterial routes would be coordinated?

c) en-route traffic information
  - What proportion of system users receive in-vehicle traffic information?
  - What proportion of receivers use this information?
  - What proportion of routes have changeable message systems (CMS), highway advisory telephone (HAT), and highway advisory radio (HAR)?

d) en-route vehicle guidance systems
  - What proportion of system users have in-vehicle navigation system?
  - What proportion of individuals with in-vehicle navigation systems regularly use this information?

2) It is likely that some ITS technologies will be deployed in “bundles” (i.e., deployed simultaneously and/or coupled to work together). Among the four ITS technologies listed above, which would most likely to be deployed in bundles in the years 2000 and 2005?

3) Which, if any, government-led initiative(s) would have the most influence on the degree of ITS deployment in the years 2000 and 2005?

4) Still operating under the “gov-world” scenario, what factors (i.e., economic, social, technological, political, environmental, etc.) are likely to exert the most influence on ITS deployment in the years 2000 and 2005? What impacts would these factors have on the four ITS technologies listed above in the years 2000 and 2005?

5) What would be the major barriers facing ITS deployment for the four technologies listed above in the years 2000 and 2005? In other words, what ITS-related activities would the government find particularly difficult to accomplish without significant assistance from the private sector and support from the environmental community for the four ITS technologies in the years 2000 and 2005?

6) Which group(s) of transportation system users and technologies (e.g., business travelers, fleets, and public users) would benefit most from government taking the lead in ITS deployment in the years 2000 and 2005, for the four ITS technologies listed above?

7) Over the next five to ten years, do you expect that the nation’s roadways will be instrumented with in-road detection? How rapidly do you think this may occur? How do you think traffic data will be collected over the next ten years (e.g., using vehicles with transponders as probes)?

8) How will recent changes in the Telecommunications Act impact the communications network/infrastructure for the public and private sectors over the next five to ten years?

9) Considering the whole universe of ITS technologies, what technologies (and to what degree) will be deployed in a typical urban corridor in the years 2000 and 2005?

10) Among the technologies that you listed, which would most likely be deployed in bundles in the years 2000 and 2005?

11) Still operating under the “gov-world” scenario, what factors (i.e., economic, social, technological, political, environmental, etc.) are likely to exert the most influence on ITS deployment in the years 2000 and 2005? What impacts would these factors have on the ITS technologies you listed in the years 2000 and 2005?

12) What would be the major barriers facing ITS deployment of the technologies you listed above in the years 2000 and 2005 (e.g., NAAQS)? In other words, what ITS-related activities would the government find particularly difficult to accomplish without

significant assistance from the private sector and support from the environmental community for the technologies you listed in the years 2000 and 2005?

13) Which group(s) of transportation system users and technologies (e.g., business travelers, fleets, and public users) would benefit most from the government taking the lead in ITS deployment in the years 2000 and 2005, for the ITS technologies you listed?

14) Do you have any additional comments that you would like to make on the proposed framework/modeling exercise or on future ITS deployment?

Industry World Interview

Imagine that the private sector aggressively invested in and marketed ITS products and services for two time periods, i.e., the years 2000 and 2005. Imagine as well that "the government" ("the government" refers to federal, State, and local governments) continued to invest in ITS infrastructure at roughly the same rate at which that investment is taking place today. And finally, imagine that the degree of policy and public concern with the environment continued at roughly the same level as today.

Given this scenario, please answer the following questions:

1) To what degree would the following ITS technologies be deployed in a typical urban corridor in the years 2000 and 2005?

a) electronic toll collection

What proportion of lanes at a given toll facility would operate using ETC?
Would you expect vehicles to be manufactured with OEM ETC functionality by 2005 and/or 2010?
If so, what proportion of on-road vehicles would be likely to have OEM ETC?

b) advanced signal coordination

What proportion of all traffic signals are part of a coordinated route?
What proportion of signalized arterial routes would be coordinated?

c) en-route traffic information

What proportion of system users receive in-vehicle traffic information?
What proportion of receivers use this information?
What proportion of routes have changeable message systems (CMS), highway advisory telephone (HAT), and highway advisory radio (HAR)?

d) en-route vehicle guidance systems

What proportion of system users have in-vehicle navigation system?
What proportion of individuals with in-vehicle navigation systems regularly use this information?

2) It is likely that some ITS technologies will be deployed in “bundles” (i.e., deployed simultaneously and/or coupled to work together). Among the four ITS technologies listed above, which would most likely to be deployed in bundles in the years 2000 and 2005?

3) Which, if any, industry-led initiative(s) would have the most influence on the degree of ITS deployment in the years 2000 and 2005?

4) Still operating under the “industry-world” scenario, what factors (i.e., economic, social, technological, political, environmental, etc.) are likely to exert the most influence on ITS deployment in the years 2000 and 2005? What impacts would these factors have on the four ITS technologies listed above in the years 2000 and 2005?

5) What would be the major barriers facing ITS deployment of the four technologies listed above in the years 2000 and 2005? In other words, what ITS-related marketing activities would the private sector find particularly difficult to accomplish without significant assistance from the government and support from the environmental community for the four ITS technologies in the years 2000 and 2005?

6) Which group(s) of transportation system users and technologies (e.g., business travelers, fleets, and public users) would benefit most from the private sector taking the lead in ITS deployment in the years 2000 and 2005, for the four ITS technologies listed above?

7) Over the next five to ten years, do you expect that the nation’s roadways will be instrumented with in-road detection? How rapidly do you think this may occur? How do you think traffic data will be collected over the next ten years (e.g., using vehicles with transponders as probes)?

8) How will recent changes in the Telecommunications Act impact the communications network/infrastructure for the public and private sectors over the next five to ten years?

9) Considering the whole universe of ITS technologies, what technologies (and to what degree) will be deployed in a typical urban corridor in the years 2000 and 2005?

10) Among the technologies that you listed, which would most likely be deployed in bundles in the years 2000 and 2005?

11) Still operating under the “industry-world” scenario, what factors (i.e., economic, social, technological, political, environmental, etc.) are likely to exert the most influence on ITS deployment in the years 2000 and 2005? What impacts would these factors have on the ITS technologies you listed for the years 2000 and 2005?

12) What would be the major barriers facing ITS deployment for the technologies you listed above in the years 2000 and 2005 (e.g., NAAQS)? In other words, what ITS-related activities would the private sector find particularly difficult to accomplish without

significant assistance from the government and support from the environmental community for the technologies you listed in the years 2000 and 2005?

13) Which group(s) of transportation system users and technologies (e.g., business travelers, fleets, and public users) would benefit most from the private sector taking the lead in ITS deployment in the years 2000 and 2005, for the ITS technologies you listed?

14) Do you have any additional comments that you would like to make on the proposed framework/modeling exercise or on future ITS deployment?

Public-Private Partnership World Scenario

Imagine that concern for the environment significantly influenced ITS deployment for two time periods, i.e., the years 2000 and 2005. Imagine as well that "the government" ("the government" refers to federal, State, and local governments) continued to invest in ITS infrastructure at roughly the same rate at which that investment is taking place today. And finally, imagine that the private sector continued to invest in ITS products and services at roughly the same level as today.

Given this scenario, please answer the following questions:

1) To what degree would the following ITS technologies be deployed in a typical urban corridor in the years 2000 and 2005?

a) electronic toll collection
What proportion of lanes at a given toll facility would operate using ETC?
Would you expect vehicles to be manufactured with OEM ETC functionality by 2005 and/or 2010?
If so, what proportion of on-road vehicles would be likely to have OEM ETC?

b) advanced signal coordination
What proportion of all traffic signals are part of a coordinated route?
What proportion of signalized arterial routes would be coordinated?

c) en-route traffic information
What proportion of system users receive in-vehicle traffic information?
What proportion of receivers use this information?
What proportion of routes have changeable message systems (CMS), highway advisory telephone (HAT), and highway advisory radio (HAR)?

d) en-route vehicle guidance systems
What proportion of system users have in-vehicle navigation system?
What proportion of individuals with in-vehicle navigation systems regularly use this information?

2) It is likely that some ITS technologies will be deployed in "bundles" (i.e., deployed simultaneously and/or coupled to work together). Among the four ITS technologies listed above, which would most likely to be deployed in bundles in the years 2000 and 2005?

3) Which, if any, initiative(s) would have the most influence on the degree of ITS deployment in the years 2000 and 2005? What possible "event" (e.g., oil crisis, new data on global warming, etc.) might significantly influence ITS deployment for the four technologies listed above in the years 2000 and 2005?

4) Still operating under the "public-private partnership-world" scenario, what factors (i.e., economic, social, technological, political, environmental, etc.) are likely to exert the most influence on ITS deployment in the years 2000 and 2005? What impacts would these factors have on the four ITS technologies listed above in the years 2000 and 2005?

5) What would be the major barriers facing ITS deployment of the four technologies listed above in the years 2000 and 2005? In other words, which of the four ITS technologies would be promoted if environmental quality was made a high priority in the years 2000 and 2005?

6) Which group(s) of transportation system users and technologies (e.g., business travelers, fleets, and public users) would benefit most from the environment being a leading ITS deployment priority in the years 2000 and 2005, for the four ITS technologies listed above?

7) Over the next five to ten years, do you expect that the nation's roadways will be instrumented with in-road detection? How rapidly do you think this may occur? How do you think traffic data will be collected over the next ten years (e.g., using vehicles with transponders as probes)?

8) How will recent changes in the Telecommunications Act impact the communications network/infrastructure for the public and private sectors over the next five to ten years?

9) Considering the whole universe of ITS technologies, what technologies (and to what degree) will be deployed in a typical urban corridor in the years 2000 and 2005?

10) Among the technologies that you listed, which would most likely be deployed in bundles in the years 2000 and 2005?

11) Still operating under the "public-private partnership-world" scenario, what factors (i.e., economic, social, technological, political, environmental, etc.) are likely to exert the most influence on ITS deployment in the years 2000 and 2005? What impacts would these factors have on the ITS technologies you listed in the years 2000 and 2005?

12) What would be the major barriers facing ITS deployment of the technologies you listed above in the years 2000 and 2005 (e.g., NAAQS)? In other words, which of the ITS

technologies that you listed would be promoted if environmental quality was made a high priority in the years 2000 and 2005?

13) Which group(s) of transportation system users and technologies (e.g., business travelers, fleets, and public users) would benefit most from the environment being a leading ITS deployment priority in the years 2000 and 2005, for the ITS technologies you listed?

14) Do you have any additional comments that you would like to make on the proposed framework/modeling exercise or on future ITS deployment?

Washington, DC expert interview summaries

Interview Subject(s): Bob Noland

Subject Affiliation: US EPA

Interview Date: Wednesday, July 23, 1997

Interview Location: Washington, DC

Scenario: "Public-Private Partnership World"

Interviewer(s): Susan A. Shaheen
Timothy E. Lipman

Question 1:

a) ETC: Where there are toll facilities, most will be ETC by the year 2005.

OEM: OEMs will not tend to include ETC functionality during the proposed timeframe.

b) ATSC: Since freeways are 100 percent coordinated, at present, they will obviously be in the year 2000, and full coordination of arterials and freeways will be expected by the year 2005.

c) En-Route Traffic Information: By the year 2000, about 50 percent of people will be receiving HAR, HAT, or CMS or both, and there will be no change by the year 2005 (this includes radio based systems). Usage rates will be low, perhaps about 10 percent, since information is of limited use once an individual is already in route.

d) En-Route Guidance: By the year 2000, only about .001 percent will have systems and not much more by the year 2005. Of those who have systems, about 90 percent will use them.

Question 2: There would be some advantages to bundling systems c and d.

Question 3: The new National Ambient Air Quality Standards (NAAQS) regulations could have some effect on ITS deployment; however, Los Angeles is already out of attainment. With regard to PM 2.5, induced travel from ITS deployment could generate more health costs than the benefits of improved flow.

The climate change issue could slightly impact ITS on the fringe, depending on what emission reduction strategies/agreements are adopted--lack of knowledge about impacts of climate change prevents much action.

Road pricing and Corporate Average Fuel Economy (CAFE) changes are very unlikely, and even if something were to develop in these areas, they probably would not impact ITS.

Question 4: NEXTEA reauthorization is uncertain. "Consideration of projects with long-term benefits" language could encourage more innovative approaches, but it is unclear if this language will survive, or what the impacts would really be on ITS deployment.

Increases in Congestion Mitigation and Air Quality (CMAQ) funds might lead to more advanced traffic signalization.

Question 5: ETC would have broad benefits, but it is unlikely to happen where toll facilities do not already exist.

There are no large benefits associated with information systems.

Signalization systems could be improved, but benefits would be marginal.

Question 6: Business travelers could benefit from ETC if pricing/tolling were to occur, but this is unlikely within the next ten years. There might be some “hot lanes” by the year 2005, but it is an important decision to take an HOV lane or build a new lane. Overall, there probably would be no benefits from “hot lanes” because the relieved capacity on the other lanes would quickly fill in. However, “hot lanes” could begin to get people used to paying for transportation services. In the case of a “hot lane,” an HOV lane takeaway would be preferable to building a new lane.

Question 7: Most freeways would have some form of detection by the year 2005, especially if Operation Timesaver is implemented (with its goal of deploying systems in 75 percent of urban areas that would reduce travel times by 15 percent). People are unlikely to allow transponders to be placed in their cars to collect travel data, but fleets might sell information gathered using transponders.

Question 8: Thus far, the public sector has not been smart about bandwidth. With deregulation, bandwidth should become more competitive. The transportation interests should bid for use of bandwidths along with others, and if the transportation sector cannot bid enough, then transportation agents should not have access to them (some transportation experts seem to feel that they should have free access).

Question 9: Of all ITS technologies, signalization technologies are the primary ones being deployed, at present. Transit applications are potentially very useful, as information could be particularly valuable in this setting from an environmental perspective (more than the efficiency improvements that are being discussed). It is dubious that there will be much emphasis on better feeder services, but perhaps there will be more experimentation.

Commercial Vehicle Operations (CVO) seems to have some environmental benefits, and efforts in this area should continue because they will improve profitability. Mode split impacts of CVO are uncertain between truck and rail, in part because rail is currently at capacity. There is a push for intermodalism, but the rail capacity constraint is an issue. As for information systems (e.g., CMS), people do not use signs now, and it is unlikely that they will respond well to high-tech signage in the future. We can probably do more with better placement and design of regular signs, than we can with high-tech ones.

Question 10: These technologies are generally discrete.

Question 11: Generally the same answers, as above--pricing mechanisms and transit information would offer the biggest environmental benefits. Also, speed governors in cars could be used to reduce speeds in residential areas, and this could improve safety and neighborhood quality of life.

Land use issues are becoming an increasing concern for municipalities. What are the environmental consequences of sprawl? There are opportunities to do things differently and to improve the livability of communities. Transportation impacts are important--for example, flow enhancement has a downside for downtown areas because they become less livable. ITS is generally concerned with improving flow, not livability.

Pricing could influence behavior and land use, and enhance livability, especially when combined with restraints on local roads to keep traffic from shifting to arterials. Traffic calming is inexpensive, and we will probably see a lot more of it over the next ten years, particularly in urban areas and residential zones. Reducing speed limits does not do anything to decrease flow and increase livability; however, various traffic calming efforts would help, such as speed bumps, on-street parking, and narrowing streets. It is unclear if we will do calming on arterials, but in many cases, speed limits should be 25 and not 35 mph. Higher speeds create barriers for pedestrians. There probably will be expenditures to improve facilities for bicycling, but the problem is that bike lanes tend to be used along high speed streets. It would be better to have slower traffic, without dedicated bike lanes. In a sense, bike lanes are a reaction to bad infrastructure and high speeds.

There probably will be very little emphasis on alternative fuel vehicles in the next ten years (some of this will depend on what happens in Los Angeles in the future). There may be some hybrid vehicles, but fuel cells are too far off for the timeframe in this study.

Question 12: Speed governors have political barriers, and people can disconnect them in their vehicles. There are always budgetary constraints, but for things like CVO companies will adopt themselves. CVO could be used to support a government function with electronic manifesting, but most other CVO measures can be developed and implemented privately to improve efficiency.

CMAQ funds will tend to be used to improve flow. A standardized methodology would be helpful to assess impacts before and after deployment and to rank strategies with respect to benefits. TRANSIMS will be used to determine how certain projects will impacts air quality. This model may be available by the year 2003 in some areas, and it could be used to assess CMAQ fund use.

Question 13: Pricing would benefit business travelers, and transit users would benefit from transit information systems.

Comments: ITS cannot be imposed on local areas, it must be integrated into the planning process.

Interview Subject(s): Don Chen

Subject Affiliation: Surface Transportation Policy Project

Interview Date: Wednesday, July 23, 1997

Interview Location: Washington, DC

Scenario: "Public-Private Partnership World"

Interviewer(s): Susan A. Shaheen
Timothy E. Lipman

Question 1:

a) ETC: This area is very uncertain, because we do not yet have a sense of public acceptance for pricing and tolls. The response will depend on demographics and the region. By the year 2005, some systems might be in place in major congested cities (such as the Easy-Pass system in N.Y.C.). There are many different ways to implement ETC--all lanes or high-speed buy-in.

By the year 2000, if systems were in place, a small percentage (about one percent) of people would have transponders, but by the year 2005 perhaps one-third of the population would have them. In the year 2000, there would probably be only one ETC lane, and by the year 2005 this number might increase to two lanes depending on whether other lanes were being tolled.

OEM: By the year 2010, vehicles would include at least a port for a transponder, perhaps a few vehicles classes would have ports by the year 2005 (e.g., luxury cars or California vehicles).

b) ATSC: By the year 2000, one-half to three-quarters of the freeway will be fully coordinated, and by the year 2005, 100 percent of the freeway will be coordinated. Systems that give priority to transit and emergency vehicles would probably complicate the system.

c) En-Route Traffic Information: A very small percentage (one to two percent) of on-road vehicles would have these systems by the year 2000, except for the radio systems that are already there. By the year 2005, this percentage would rise to only three to four percent unless the systems were bundled with other technologies. Of the systems in vehicles, the usage rate would be about five to ten percent (unless bundled with other services) in which case the usage rate might be higher.

Changeable Message Sign (CMS) systems might experience an upsurgance in popularity over the next decade, but it also might drop with the increase of in-vehicle systems.

About 25 percent of freeway and arterial routes would have CMS by the year 2000, and 50 percent of routes by the year 2005. As for Highway Advisory Telephone (HAT), system-wide use would be 10 percent by the year 2000, and about the same in the year 2005. The usage rate could change if cell phones continue to grow in popularity. With Highway Advisory Radio (HAR), a lot of people might check-in occasionally (use would be about 15 percent in the year 2000, and 25 percent in the year 2005).

d) En-Route Guidance: By the year 2000, only one to two percent of the population will have these systems, but by the year 2005, this could increase to 10 to 15 percent, perhaps even up to 20 percent. If the systems could tell where parking is available, these numbers could be even higher.

Question 2: Technologies do not necessarily need to be bundled together; however, this may occur, particularly for highway information and in-vehicle navigation systems together and ETC and ATSC systems together. The government may invest more funding into signal coordination, but ETC will increase as signalization systems are completed. In the year 2000, perhaps two-thirds of investment would be for signals and one-third for tolls, but by the year 2005, perhaps it would be the other way around with one-third of investment for signals and two-thirds of investment for ETC.

As for the second bundle (i.e., traffic information and in-vehicle navigation systems), in the year 2000 people would be willing to spend much more for guidance systems than for information systems, perhaps in ratios of approximately 90:10 percent or 80:20 percent. The government will likely be spending more on information, particularly with respect to CMS, because guidance systems will be more of a private venture. In the year 2005, government investment will be 70:30 percent for information and guidance systems, respectively. Nevertheless, the private sector will be spending more money for guidance, probably on the order of 90:10 percent for guidance and information, respectively. As for user acceptance, some individuals might use route guidance and not traffic information, but, overall, acceptance will probably be about 50/50, with some individuals using both systems and some using only one of the two.

Question 3: Global warming could be a potential driver, but an oil crisis will probably not be a driving force in the future. There may be a greenhouse gas measure in place by the year 2005, and this could change the current focus toward reducing VMT and improving efficiency. This new focus would require dramatic measures, however, such as pricing or taxes. By the year 2000, there may be a weak greenhouse gas control program, but it would be more serious by the year 2005. These measures would slightly affect ITS deployment. In the future, air quality would drive another set of technologies, but over time the connection between congestion and air quality will grow less strong as cleaner vehicles move into the fleet. This trend will probably continue, and vehicle emission technologies and alternative fuels will have a greater impact on air quality than ITS technologies.

Question 4: The welfare reform program is likely to result in a failure, and costs will emerge in different ways. There will be more drivers, but they will represent lower income groups. Therefore, ETC might become more difficult to deploy, and few (i.e., one to two percent) will be able to afford en-route traffic information and guidance systems. The poor are less likely to visit unfamiliar areas, so guidance systems would be of less use to them. ATSC also could be problematic, if it helps the wealthy more.

The fact that baby boomers will begin to reach retirement age could start to be a factor by the year 2005--government budgets for ITS deployment could be tightened. As for NEXTEA, there should be $25 billion dollar total budget, so there will probably be money for these technologies up to the year 2005 and probably beyond.

Question 5: Barriers could be public acceptance and cost, even if measures improve environmental quality. ETC might be beneficial to the environment, if deployed systemwide. However, other ITS technologies are highly uncertain with regard to their impacts. The technological barriers are not serious. Political/equity barriers are potentially serious because some sectors of society will benefit disproportionately. These equity concerns could possibly be a barrier in Los Angeles, but this is not very probable. There also would likely be political arguments over spending toll revenues.

Question 6: The broad public would experience environmental benefits. Business travelers could have more non-commute time. Benefits would be greatest for those who attach high values to time spent in traffic.

Question 7: Over the next five years, not many roads will have detectors; however, in ten years, there will be a lot more detectors in place. In the future, road detector investments could be either publicly or privately dominated.

Question 8: In the future, there is likely to be more private sector involvement in ITS technologies, particularly from telecommunication firms due to the Telecommunications Act, increased ITS technology deployment, and portfolio diversification.

Question 9: The added value of ITS technologies to transit is great. Real-time information and navigation systems could help to mitigate transit unpredictability. Intermodal linkages could also be facilitated. The transit industry has not embraced these technologies yet, so rollout is unlikely to be rapid. The transit industry should be focusing on new technologies, nevertheless. Transit is a good way to achieve disparate goals, and "gelling" of different small drivers will lead to more ITS/transit deployment.

"May-Day" technologies, especially in rural areas, would be useful.

Trip planning technologies would be useful, in order to get information before the trip is started.

AVL systems will become more popular as transit technology deployment expands.

Also, real-time ridesharing and data collection technologies (using ITS to aid travel planning, environmental assessments, and modeling, perhaps with GIS) are likely to be used more.

Comments:

The clean air regulations will be less influential in the long term (post 2010) than greenhouse gas regulations. Most ITS technologies seem to have more to do with energy use (VMT) than emissions. The CMAQ program will survive, potentially with increased funding.

Traffic flow should not be the only goal of ITS deployment. ITS will help existing efforts to help flow, but the greatest impacts will be on transit, especially for specific user groups (e.g., elderly).

It is hard to say if NEXTEA will have "teeth." ISTEA was too harsh in some ways, in that the threats were unreasonable. NEXTEA should have sanctions, but they should be reasonable ones.

There is a need for a framework that can assess modular technologies, which can submit these technologies to a battery of tests for various impacts in a given context.

Interview Subject(s): Carol Zimmerman

Subject Affiliation: Battelle

Interview Date: Thursday, July 24, 1997

Interview Location: Washington, DC

Scenario: "Industry World"

Interviewer(s): Susan A. Shaheen
Timothy E. Lipman

<u>Question 1</u>:

a) ETC: Interest in electronic tolling has been high, and SR-91 in California is a current example of implementation. By the year 2000, 10 to 15 percent of drivers would be using ETC facilities, if there was a toll road or other facility in their region. By the year 2005, this could rise to 25 to 30 percent depending on the expansion of toll facilities. It would be unlikely for there to be more than one ETC, “hot lane” by the year 2000, but there could possibly be two lanes by the year 2005, especially if faster travel was promoted on ETC lanes.

OEM: Tolls are location specific, so automakers would not put transponders in vehicles unless they had another function. Perhaps there would be some of this by the year 2010, but it would be unlikely because of the need for nationwide standards.

b) ATSC: By the year 2000, ramp meters would be implemented on freeways, but the entire corridor would not be equipped. The corridor, including arterials, would be 100 percent coordinated by the year 2005 in the Smart Corridor. For a typical corridor, the percentages would be lower, perhaps 10 percent in the year 2000 and 25 percent coordinated in the year 2005.

c) En-Route Traffic Information: By the year 2000, about five percent of drivers will be receiving information, not including the simple radio systems that are available today. By the year 2005, market penetration could rise to about 25 percent. About 40 percent of users would tend to change routes based on the traffic information, and maybe 75 percent would use the information routinely. CMS systems are still expensive. By the year 2000, transportation agencies will have purchased as many CMS units as they are likely to acquire. Similarly, HAR is not especially useful, and it is not likely to grow in popularity.

d) En-Route Guidance: Guidance systems are expensive now (around $2,000), but simpler systems are being developed. By the year 2000, perhaps one to two percent of drivers will be using such systems, and by the year 2005, this market penetration rate could grow to 10 to 15 percent. People will tend to use these systems a lot, particularly when they were in an unfamiliar area. Perhaps individuals with access to these systems will use them 75 percent of the time, on average. The commercial applications of en-route guidance systems are very clear.

Question 2: Traffic and guidance information could be bundled together, with in-vehicle systems for both. Perhaps 30 percent of systems would be bundled, with the other 70 percent of units being separate. The other systems (i.e., ETC and ATSC) will tend to be publicly funded, and of those technologies, ATSC and CMS systems could be bundled, although only about five percent of these systems would be bundled. ETC systems would not be bundled with anything else.

Question 3: If public agencies invested in traffic management systems, this would help to leverage traffic information and guidance systems. Data are now fragmented, so if centralized information became available, this would increase market penetration for en-route vehicle systems. There is an effort to establish a standardized architecture for ITS; a standardized architecture would enable "plug and play" and allow individuals to use these systems anywhere.

Question 4: The economy needs to be robust for people to invest in new technologies. A recession would slow public sector deployment because it would be hard to justify non-essential expenditures, and there would be fewer private sector purchases.

The environmental links for ITS are not that clear, and ITS can probably only have a slight impact.

The aging of the population might stimulate some new product development, but this factor would not affect the four technologies in this study particularly.

NEXTEA funds should aid ITS deployment, with funds going to municipalities. This might alleviate some barriers to procurement, although these barriers are mainly at the State level. In addition, there may be more funds for operation and maintenance.

Question 5: If behavioral changes are required, this would present a significant problem. Also, there is a need for public sector spending for data collection and integration; without data collection funding, this could be a major barrier to ITS deployment.

Question 6: Fleets would benefit from private-sector investment in ITS deployment because of their concerns about productivity. Business travelers also would benefit because of their high value of time. High income groups would tend to be early adopters, so they would tend to benefit as a group, as well.

Question 7: A perceived problem with loop detectors is that they are hard to maintain especially in cold weather areas. For broader questions of monitoring, systems based on image processing and radar might be more widely used. With regard to deployment, the availability of public funding is the key variable. Vehicles with transponders, which are used as probes, would aid in data collection.

Question 8: There has been less competition resulting from the Telecommunications Act than was expected, but now wireless technologies are emerging. Public-sector interests can request telecommunications access in return when a new cellular tower or fiber network is established on the public right-of-way.

Question 9: There will be more wireless communication (as with personal communication systems) and more satellite and GPS based technologies. This will tend to affect what technologies will be introduced in cars and even for pedestrians.

The internet boom has attracted a lot of attention as an information dissemination device. The network is used for many different things.

In the future, SMART cards for payment will become more popular. Contact and contactless card concepts could be combined, and this would expand usage for transit and financial dealings. Many card uses could be bundled together. Perhaps also there will be more telephone-based systems, with computers, and these could take the place of kiosks. More than one user could be served at a time; it would be safer, and internet security could facilitate expanded services.

A private-sector dominated world would tend to go after markets and profit. Some services will not be as attractive because they might be less profitable than other options. Products would be targeted to the affluent. More expensive vehicles would be the first to incorporate new technologies, and they would filter down slowly to less expensive models. The public sector tends to be concerned about value to all taxpayers; this focus would tend to favor safety issues and environmental concerns.

Question 10: There might not be bundling per se, but rather many linkages between potential uses. There would tend to be a State of flux, with rapidly changing segments having an influence such as the internet.

Question 11: If public sector funds are not available, the private sector will focus on profitable niches. Public expenditures will facilitate broader uses, especially those based on information.

Some more public-private partnerships might occur in a market-driven world. Transit authorities might enter into arrangements where there is privatization, perhaps there will be arrangements with banks to deploy SMART cards, which will improve efficiency.

Question 12: Public funding is the biggest barrier. An important question surrounding federal funding is how much control to allow from Washington, DC, in contrast to how much control to allow from the local level.

The issue of standards is a potential barrier. In the absence of standards, systems might be region ally specific, and there would be less manufacturer interest than there would be with national markets. Standards often are set on an international basis, and this takes a long time.

Question 13: Anyone could benefit, but if costs are high, then this will tend to limit the range of people that will benefit. SMART cards could benefit everyone. ITS technologies are diverse, so it is hard to generalize about benefits.

Interview Subject(s):	Craig Roberts Kenny Faunteroy
Subject Affiliation:	ITS-America
Interview Date:	Thursday, July 24, 1997
Interview Location:	Washington, DC
Scenario:	"Industry World"
Interviewer(s):	Susan A. Shaheen Timothy E. Lipman

<u>Question 1</u>:

a) ETC: Any "hot lanes" would definitely be ETC by the year 2000. Of course, this would be policy driven, not market driven. The facilities could allow cash transactions as well, and then there would be a market-driven push for transponders. Given the potential resistance to "hot lanes," this policy option would be more likely in the year 2005, rather than in the year 2000.

OEM: By the year 2010, there would be either an option for a transponder or a standardized system. This would be possible by the year 2005, but it is unlikely. Transponders might have many functions, for such things as tolls, parking, maintenance needs, and so on. The percentage deployed would depend on many factors.

b) ATSC: Freeways would be coordinated by the year 2000, but only a small percentage of arterials would be coordinated. By the year 2005, however, the full corridor would be coordinated. Signalization includes ramp meters, traffic signals, incident detectors, and CMS.

c) En-Route Traffic Information: Cellular phones are the best devices for getting information, so market penetration for cellular phones would be a determining factor. The Motorola system was going to be display based, but instead it includes cellular information and a "May-Day" system. In the longer term, display penetration will depend on multi-use features, such as their ability to provide business locations, etc. Except for niches, there will not be a lot of in-vehicle systems because of high, near-term costs. See the Apogee report for market penetration estimates. The Apogee report projects a market penetration rate of one percent for personal basic information reception in urban areas by the year 2005, and a three-percent market penetration rate for personal interactive information reception. The source of these estimates is based on "The National Architecture: Evaluation Results," June 1996, which was prepared for US DOT and FHWA by the Joint Architecture Team.

HAR system deployment will depend on data availability.

There will be modest penetration by the year 2005, and more by the year 2010. Some services would result in an 100 percent user rate because they automatically contact the user when there is an incident or congestion. Otherwise, user rates would depend on the circumstances, such as the weather, the importance of the trip, and the cost structure (e.g., per minute charge, a flat fee, free, etc.). See the Apogee report for market penetration estimates. The Apogee report projects a market penetration rate of zero percent for automated road signing in urban areas by the year 2005. The source of these estimates is based on "The National Architecture: Evaluation Results," June 1996, which was prepared for US DOT and FHWA by the Joint Architecture Team.

CMS systems suffer because they are often misplaced or erroneous, so people do not tend to pay attention. Movable CMS systems are becoming increasingly popular. Static systems also will grow, but the growth rate will depend on other factors. Highway departments like these systems. By the year 2000, there will be an increase over CMS use today, and even more in the year 2005. They will start to be used on arterials as well, and in rural areas and national parks. There has been a lot of CMS use in Utah, where I-15 construction is taking place. Perhaps CMS will be used more for events that affect traffic, such as sporting events and concerts.

d) En-Route Guidance: People would only tend to use these systems in unfamiliar areas, unless they were dynamic and could be used to solve problems. Voice systems seem to be favored over visual ones. See Apogee report for market penetration estimates. The Apogee report projects a market penetration rate of five percent for personal route guidance systems in urban areas by the year 2005. The source of these estimates is based on "The National Architecture: Evaluation Results," June 1996, which was prepared for US DOT and FHWA by the Joint Architecture Team.

<u>Question 2</u>: Dynamic guidance and information systems would be bundled in terms of technology, and the services offered. SMART cards might be used for tolls, cellular phones, and other services.

ETC and CMS might also be bundled to provide information to those using paid lanes.

<u>Question 3</u>: The cost of communications will be an important factor, and bandwidth issues could be a big factor with respect to market penetration. Standards are important for consumer acceptance. Safety and security issues seem to matter most when making a big purchase, such as a vehicle, whereas day-to-day travel depends more on travel time.

<u>Question 4</u>: NEXTEA will have a big impact, since it seems likely that Congress will support ITS. The information technology revolution will carry ITS, and this trend will continue. Databases will be used in lots of ways, particularly in shared arrangements for transportation planning, modeling, and environmental policy analysis. VMT growth

projections are made linearly, but VMT patterns are likely plateau. In the past, new groups entered the workforce, but most women and other groups are now employed, so this wave has passed.

There will be continued sprawl, and it will be easier to live in rural areas due to information technology and telecommuting. More people will tend to live in rural areas. Planned communities have appeal, but powerful market forces work against them. Oregon is successfully implementing a few such developments, however. Zoning policy could make a big difference to urban form and transportation demand.

Question 5: Markets are somewhat unpredictable, so this is a barrier. Cellular technology is inexpensive, but in-vehicle navigation systems are expensive and do not have a market, at present. Public-private partnerships could act as a drag on private-sector innovation. Institutional culture could be a barrier, as there is now a lot of expertise in road building and less on information technologies (in the transportation field).

Funding is always a barrier, and if highway user fees begin to be used in the general revenue stream, the public confidence could be corrupted. It is easier to go after tax base than to design new user fees, so this will not happen unless there is no other option. New mechanisms of taxation would require a culture shift, which may not be easy.

Question 6: If the scenario is market driven, consumers will benefit because there will be greater diversity in the offerings, in terms of price and quantity, versus a one-size-fits-all mentality. The downside is for people who will not be able to afford the technology. There is a problem of external costs, and common-property resources, so the general public might lose out in some ways. Toll collection might allow a better allocation of costs, however. Route-guidance systems would tend to benefit fleets, mostly.

Question 7: New vehicles could serve as probes, because in-road systems are expensive. Video cameras will probably be used more than loop detectors and dedicated short-range communications.

Question 8: The Telecommunication Act was supposed to increase competition, but it is hard to say what will happen because of market distortion by large firms. Public interests should be able to get the private sector to lay fibers for public use when companies put them in along public, right-of-way areas.

Question 9: SMART cards are a promising technology, as well as CVO technologies. Most transit agencies and MPOs have been in the dark about SMART cards. ITS can be an enabling technology for a renaissance in transit, with new types of systems that could be developed.

Linked O-D data could enable new niches for transportation services, such as real-time carpooling. A combination of information technologies and pricing schemes could serve to increase vehicle occupancy by encouraging ride sharing.

Interview Subject(s): George Beronio

Subject Affiliation: US DOT, Joint Program Office

Interview Date: Thursday, July 24, 1997

Interview Location: Washington, DC

Scenario: "Government World"

Interviewer(s): Susan A. Shaheen
Timothy E. Lipman

Question 1:

a) ETC: With respect to ETC, there is a big difference between building a new lane and taking a lane. If there were lanes taken by the year 2000. By the year 2005, there would perhaps be two lanes, if the level of service did not drop much as a result of the other lanes. Any toll collection facilities would definitely include ETC.

OEM: It is unlikely that this will happen by the year 2005. Perhaps by the year 2010, transponders will be in new cars. The devices should be inexpensive enough to put them in all cars, not just expensive vehicles. Transponders also could be used for payment inside parking garages and for other payment systems.

b) ATSC: By the year 2000, there will not be much ATSC in a typical corridor, perhaps a 50 percent market penetration could be expected. By the year 2005, however, ATSC should be at 100 percent on freeways. On arterials, there will be no coordination in the year 2000, but there will be 100-percent penetration in the year 2005.

c) En-Route Traffic Information: Dial-up navigation and information services are the first wave of technology for this market, but this is an emerging market and a lot of new systems are being developed. In the year 2000, perhaps 20 percent of the population will have cell phones, and about 40 percent will have cell phones by the year 2005. Of those, less than half of the population with cell phones (perhaps 30 percent) will use an information service. Perhaps there could a six percent usage rate in the year 2000, and a 12 percent usage rate in the year 2005.

CMS should be widespread and on 100 percent of the major freeways by the year 2000. CMS units may begin to spread to arterials, but this will depend on the usefulness of these systems. CMS probably will be seen only on a few arterials by the year 2005, but usage of this technology might be increasing.

d) En-Route Guidance: Navigators and "May-Day" devices should experience a small but growing usage rate, perhaps two percent in the year 2000, and five percent in the year 2005. Static systems probably will not be developed because they will not be very useful. The use of real-time systems requires a constant data stream. Next year, there is expected to be a standard for FM subcarriers, and this should facilitate the use of navigators with real-time data.

Question 2: En-route traffic information and guidance systems are a natural bundle. If there is accurate information, then guidance systems will make more sense.

Question 3: The availability of funds could have a big impact. NEXTEA and other targeted ITS funds have yet to be fully determined. NEXTEA flexibility levels will impact deployment. Trucking regulations could potentially impact CVO deployment. Gas taxes might reduce congestion, and congestion might cause money to be spent on ITS systems rather than infrastructure.

Question 4: There is a latent demand for information, and what some areas have, others may want. Telecommuting from home will become more popular. Sprawl might become seen as a bigger problem, and an emphasis on sustainable development might influence transportation and ITS form. Telecommuting may impact travel in the future, which may shift demand patterns (i.e., spreading demand temporally).

In the recent past, transportation demand increased partly from more women entering the work force, but now the situation has equilibrated. Hence, the number of congestion "drivers" may be slowing, and VMT growth may slow. Environmental concerns will be at least maintained and possibly increased.

Given the current political climate, there probably will not be much support for ETC deployment, particularly congestion pricing. The trend toward more technology should favor the other three technologies (i.e., ATSC, and en-route vehicle guidance and information systems), especially ATSC because of the benefits of advanced traffic management systems.

Question 5: ETC deployment has a huge, political barrier, if it requires taking away an existing lane. Converting existing toll facilities to ETC should not be a problem. ATMS has coordination barriers, but ISTEA has alleviated these to some degree by giving municipalities more control. There is a cost barrier for in-vehicle systems, as well as some standards issues.

Question 6: The benefits of ATSC will mainly be for commercial users because they are frequently using the transportation facilities, but the public also will benefit. The government will not tend to encourage ETC, particularly. For information systems, private involvement will help to spur development, and the public and the companies, providing these services could benefit. Public agencies could share costs and gather data in the process, and this could benefit research efforts.

Question 7: It is expensive to install and maintain in-road systems, so there probably will be a predominance of other systems. Transponders and overhead sensors could be used instead. By the year 2005, the growing use of other systems might almost equal the current use of loop detectors.

Question 8: We should see more wireless communications, along the current trend; and communication links will be very important. The government will not be very proactive, but government agents will try to leverage communications for public-sector purposes when existing “rights-of-way” are used to lay optical fibers. States tend to own the “rights-of-way,” so they can allow access to those that help the government.

Question 9: CVO is a promising group of technologies. Collision avoidance and “smart,” cruise-control systems are promising, but they are probably 20 years away from deployment. Transit technologies would help to improve reliability and access to information, and these technologies could help to make transit more viable by the year 2005.

Question 11: Transit technology deployment might increase with NEXTEA funding, since road-building is becoming less feasible. Also, the aging population might demand more collision avoidance systems and elderly transit services. The government wants to promote high-tech industry, especially with a focus on user-friendliness. In fact, there is an intelligent vehicle initiative (IVI), focusing on human factors.

Question 12: With respect to deployment barriers, safety is potentially a concern for new types of collision avoidance systems and new driver interfaces, in general. Liability concerns also could be a barrier.

Question 13: Expenditures on transit systems would benefit transit users, and new users might be added. This could free up some capacity on highways and benefit road users, as well. Safety technologies could benefit all drivers.

Comments: There is a study on the Oklahoma turnpike that showed emission reductions for the use of ETC. This is documented in a US DOT report.

Interview Subject(s): Brian Gardner

Subject Affiliation: FHWA, US DOT

Interview Date: Friday, July 25, 1997

Interview Location: Washington, DC

Scenario: "Government World"

Interviewer(s): Susan A. Shaheen
Timothy E. Lipman

Question 1:

a) ETC: Perhaps 30 to 50 percent of lanes in a busy corridor could be ETC in the 2000-2005 year timeframe.

OEM: It is not likely that there will be OEM, ETC functionality by the year 2000. By the year 2005, only about 10 percent of on-road vehicles may have transponders because there is no current standard.

b) ATSC: For a freeway corridor, nearly 100 percent coordination could be expected by the year 2000, and 100 percent coordination could be expected by the year 2005. For arterials, there could be nearly 100 percent coordination by the year 2000, and 100 percent by the year 2005, as well.

c) En-Route Traffic Information: By the year 2000, all major freeways should have CMS, and usage will be high if the information is accurate. HAR systems should exist, but they will not be used very much. Perhaps 10 to 20 percent of people would be getting information through the cellular phone system.

Business fleets will be early adopters for information guidance systems, but there probably will not be real-time systems until at least the year 2005; en-route traffic information probably will not be widespread by then.

d) En-Route Guidance: The penetration rate will vary by market segment. Trucking and service employees will have en-route guidance systems. Overall, perhaps five to fifteen percent of people would have these systems in the year 2005 and of those, 80 to 100 percent would use them.

Question 2: The bundling question is complex--for modeling, modelers need to know where the information is received and how people respond to it, unless researchers are running a user acceptance model.

Question 3: A number of initiatives could influence ITS deployment. These include congestion management initiatives, which are now optional; regional management and operation systems initiatives; and ISTEA programs. Providing more funds for centralized traffic information systems would help to alleviate staffing limitations. The NAAQS could make planning for ITS more complicated, and if conformity compliance is required, this could be a barrier to ITS deployment.

Question 4: There is a trend toward greater use of technology, with prices falling and capabilities increasing. With respect to economic trends, there will be a growing service industry and alliance with technology. In the social realm, there is a sense of NIMBY with regard to road-building projects. With growth in corridors like the "smart" corridor, something has to give--there either has to be greater use of transit or an increase in capacity.

Question 5: The lack of operational funding could be a barrier, as well as the lack of standards for various devices. There also are institutional barriers, including a lack of coordination and difficulty in maintaining public-private partnerships. Data delivery for these types of systems requires a lot of coordination, and the private sector may back out of this area if profits do not materialize.

Question 6: The general public and service industries would benefit from ETC deployment. Fleet and service vehicles would benefit from route information and guidance systems, as well as the private-sector companies providing these services.

Question 7: There are other ways to collect data then with loop detectors, which require a lot of maintenance. Radar, microwave, and sound-based systems are all possible, as well as cable TV systems. Loops will have a place, but they will only be used in certain areas, and they will be surface-mounted (piezo-electric) rather than embedded in the road. Probes could be used where there are toll facilities, especially for transit vehicles, taxis, delivery vehicles, and so on, but the data would not be publicly available.

Question 8: The changes in the Telecommunications Act may result in more providers and choices, but at present these providers seem to be consolidating. Cable and utility companies might become players in the industry. There is a push toward wireless communication, but existing networks will be expensive to change. In ten years, there should be more cellular companies. The government dose get some general revenue from this type of activity.

Question 9: AVL systems for transit vehicles should become more widely used.

Question 10: Transit technologies that provide more information could help mode shifts to transit. There might be less price elasticity for transit services, if people are more satisfied with the systems. This would probably require increased system frequency, as well. Also, better paratransit services could be provided through TV; telephone services could provide information on congestion; and systems could provide information on parking. All of these types of systems could increase ITS usage. SMART cards could catch on because people do not like change, and there could be links to other uses that would create synergies.

Question 11: There are market forces for better paratransit services. Providers are getting squeezed and are under pressure to cut costs. Better information would help to make systems more efficient and attractive. The government could provide some funding and require transponders in transit vehicles. By the year 2000, there should be a movement in this direction, with kernel systems being developed over the next five years. Nevertheless, the major priority is to keep the systems running at present. By the year 2005, most systems will begin to become “smart,” but this change will be slow.

Question 12: Barriers include the lack of available technologies and the fact that turn-key systems are not available. System costs require documented benefits to justify them, and some of this information is not yet available. The government can be a barrier to ITS deployment, in general, or an enabling force through its ability to set standards and develop an infrastructure. AVL is a core system that is needed for information systems. Finally, there is a need for strong public-sector involvement.

Comments: How will the INTEGRATION model be calibrated and validated? Will 1995 data be used to validate the model? If possible, researchers should use a modal emissions model. It is important to break individual links into operational characteristics (e.g., running, queue, transition, etc.). Since only a corridor is being addressed in this study, the benefits might be overstated. How will changes into and out of the corridor be addressed? At the very least, researchers should document other potential impacts.

Interview Subject(s): Philip Patterson

Subject Affiliation: Office of Transportation Technologies, US Department of Energy

Interview Date: Friday, July 25, 1997

Interview Location: Washington, DC

Scenario: General Vehicle Characteristics

Interviewer(s): Susan A. Shaheen
Timothy E. Lipman

Comments:

By the year 2005, there will not be very significant changes in the vehicle stock. Better diesel engines might be put into passenger vehicles by the year 2005, and these could offer a 40 to 50 percent fuel economy gain.

There is not enough political will right now to change the CAFE standards for all vehicles.

Electrically-heated catalysts are promising technologies, but unless these systems are needed to meet the NAAQS they probably will not be deployed by the year 2005 or 2010. For particulates from heavy-duty diesel engines, lower sulfur fuels and particulate traps will begin to be used in the 2000 to 2005 year timeframe.

In California, hybrid vehicles might be used by the year 2005, perhaps hybrids may be used to meet the ZEV mandate requirements. These vehicles would tend to have fairly long "ZEV" ranges and potentially low emissions for commuting trips.

The use of ITS technologies would tend to increase capacity and result in more travel. The Energy Information Administration is currently predicting 1.4 percent VMT growth, but VMT growth is three percent at present, and VMT growth may remain high as more capacity is drawn out of the system.

Interview Subject(s): Richard Schoenberg

Subject Affiliation: FHWA, US DOT

Interview Date: Friday, July 25, 1997

Interview Location: Washington, DC

Scenario: "Government World"

Interviewer(s): Susan A. Shaheen
Timothy E. Lipman

Question 1:

a) ETC: From an operational standpoint, it probably would be necessary to take two lanes to implement ETC. These lanes could also be set up for people traveling on a pay-per-trip basis. This situation would not change much between the years 2000 and 2005.

OEM: OEM, ETC functionality should occur by the year 2005. With energy policy as a driving force, a taxation or pricing scheme could necessitate some type of in-vehicle device. Perhaps at first, only the top 40 percent of vehicles (in terms of price) would have them.

b) ATSC: By the year 2000, 100 percent of freeways will be coordinated. By the year 2005, close parallel routes will be coordinated as well. By the year 2010, perhaps all routes in a one-half mile radius of freeways in major areas will be coordinated.

c) En-Route Traffic Information: Cell-phone based systems are available now. The next step is towards in-vehicle information systems. By the year 2005, perhaps 25 percent of the population will have some type of device. By the year 2010, this will be closer to 50 percent. Individuals with cell phones will tend to consult traffic information, if a HAT system is available, depending on the price. CMS systems should be on 100 percent of the freeways by the year 2000. By the year 2005, perhaps 30 percent of main parallel routes will have CMS.

d) En-Route Guidance: These systems are mainly for the rental-car market. By the year 2000, perhaps five percent of drivers will be using them, and by the year 2005, market penetration could be as high as ten percent, if successful.

Question 2: ETC and ATSC could be bundled, and in-vehicle information and guidance systems could be linked.

Question 3: NEXTEA could be a factor. Only 25 percent of funding is for new capacity, and this figure will drop in the future. The new NAAQS probably will not affect these technologies much because there is no political will to reduce VMT through ITS measures. Furthermore, measures that could be used to reduce VMT are not featured in this study. ATSC and ETC are the technologies that are the most ready to deploy, so they will be the first released. Perhaps ETC will be deployed with some form of pricing scheme..

Question 4: Energy prices would be the most likely to impact travel, along with potential taxation schemes between the years 2000 and 2005. Urban goods movement is getting more expensive, and this could be a driving force because the business sector is impaired by reduced traffic efficiency. Since there is a capacity constraint, technological solutions are indicated. A good economy will tend to aid ITS deployment, and a recession would hinder it. Continued sprawl is likely, and this could affect the deployment of some systems.

Question 5: Cost is one barrier. Public trust can be a barrier, and systems will need to be proven before they are widely adopted. Routes for redirecting vehicles need to be rational, and route guidance is somewhat unreliable at present.

Question 6: ATSC systems benefit everyone. ETC mainly would benefit business travelers because of the reduction in travel-time uncertainty. Information systems have wide benefits. Guidance systems would benefit tourists and those visiting new areas.

Question 7: Speed and volume data are collected today. By the year 2005, full-vehicle detection is likely. Remote sensing can be used for emissions, but this is only for research, not enforcement. Transponders will be used to collect travel data, but they will only be used to augment existing methods because there are many privacy issues associated with personal data collection.

Question 8: The Telecommunications Act should stimulate innovation and lower costs; this should be a boost for ITS.

Question 9: Full coordination and integration of signals is likely to occur. Incident management systems will be deployed. Real-time flow and speed-detection systems will aid air quality assessments. People want the government to perform these functions, so more will be done by the year 2005.

Question 10: A bundle of ATSC and speed/flow systems is likely to emerge to support the integrated system mentioned above.

Question 11: Economic development will be the main driver for full-coordinated systems, including transit and real-time flow and speed detection systems. If energy costs remain low, ITS systems will tend to be deployed faster. In contrast, if costs rise, then deployment might slow.

There was a CARB study that showed that an aggressive pricing scheme could reduce VMT by 15 percent.

Question 12: The greatest barrier to ITS deployment is competition for resources, especially between highways and transit.

Question 13: ITS system benefits will accrue to everyone eventually.

Interview Subject(s): Erin Bard
Keith Jasper

Subject Affiliation: Booz-Allen & Hamilton

Interview Date: Monday, July 28, 1997

Interview Location: Washington, DC

Scenario: "Industry World"

Interviewer(s): Susan A. Shaheen
Timothy E. Lipman

Question 1:

a) ETC: This will not happen on I-10 realistically by the year 2005 because of political barriers, unless the effort is environmentally motivated. ETC hot lanes would be possible where there is new infrastructure, such as on SR-91. There is no precedent for public sector takeaways for private-sector profit.

OEM: It would be controversial to have a tag in every car. The government would like to have it, but privacy issues present a barrier. Anecdotal account: attempts to use tags over and above ETC use to obtain travel-time data have raised the complaint of reduced transponder life because of an increase in battery use.

There are a lot of technology barriers to OEM ETC functionality as well. For example, there is a lack of standardization, although California is trying to establish standards. The franchise model might be a good one because standards could be made part of a contract.

b) ATSC: Control sensor management could be privatized. Incident detection is considered to be part of ATSC; however, incident management could not be a privatized service.

Two levels of ATSC: first, there is ramp metering, and second, meters can be connected to the arterial signals in an automated fashion.

I-10 is currently metered and has a lot of detection, but it probably is not fully coordinated yet.

Nationwide, it would be reasonable to expect only ten percent of freeway ramps to be metered by the year 2000, and 15 percent to be metered by the year 2005. For arterials in a typical corridor, about one-third of routes would be coordinated by the years 2000 and 2005, but it would take longer to coordinate the arterials with the freeway ramp meters.

For I-10, this would be one of the first areas in which coordination will occur, so this region would be fully coordinated by the year 2000.

c) En-Route Traffic Information: A market penetration rate of ten percent could be expected by the year 2000, and a 20 percent market penetration rate could be expected by the year 2005. Usage rates would be 100 percent (as much as possible). Route-change percentages tend to be about 30 percent.

CMS will be everywhere by the year 2000.

In Washington, DC, and Virginia, there is some private-sector involvement, in particular, some detection systems are being installed due to private interests. Companies can sell advertising, but there needs to be a market for traffic information.

There is probably a large market for bundled traffic information, using cell phones and pagers.

In Orange County, residents can access information through independent service providers, i.e., TRAVELTIP. This service will probably be much bigger than TransCAL or TravInfo; it was just kicked off.

d) En-Route Guidance: There is now a market for route guidance, especially in California where mapping is more developed. Auto manufacturers will tend to determine this, based on when they add these systems to their vehicle lines. People will not tend to retrofit vehicles, given the high cost.

The Apogee report projects a market penetration rate of five percent for personal route guidance systems in urban areas by the year 2005. The source of these estimates is based on "The National Architecture: Evaluation Results," June 1996, which was prepared for US DOT and FHWA by the Joint Architecture Team. These estimates will remain at a low percentage over the next 10 years, barring a technological breakthrough. Real-time information will be much more useful and adopted faster than static information.

Question 2: ETC will be a stand alone technology for the next ten years. En-route traffic information might be bundled with ATSC. En-route guidance systems can stand alone, if they are static. Dynamic re-routing with en-route guidance systems will not happen within the next ten years; there are too many barriers. Traffic information and guidance systems will be bundled in the future.

Question 3: There could be a quantum-leap in technology when satellites are used to collect traffic data, this would greatly accelerate activity in the market sector. Satellite data collection can actually be done today, down to 30 feet. This technology will continue to get even better. It is imminent that this technology will be around by the year 2000. By the year 2005, there could be privatization of information services, using satellite technology to collect traffic data.

Question 4: We are entering into a fairly stable period; the rate of movement across the country for jobs has slowed. Increasingly, we will see the educated, upper class moving out of the cities; pagers, cell phones, and modems will enable individuals to do this. This trend will accelerate. In addition, there is now a movement toward much stronger public-private partnerships. These partnerships will become stronger and facilitate the privatization of services.

Question 5: Dollars and, to some extent, technology will serve as barriers to ITS deployment over the next ten years. If we could make detection less intrusive and loop detectors less expensive, then information services and systems would take off.

Question 6: With ETC, everyone would benefit, except people who do not drive. Business travelers would benefit more so, if they are trying to make appointments. There really will not be a big winner with ETC. Traffic information and route guidance definitely would benefit individuals in upper income brackets and fleet operators as well.

Question 7: A comprehensive detectorization plan is needed. No one is going to have a comprehensive plan. At present, metropolitan areas are employing an incremental approach to road detection. We might see the use of satellites to collect traffic data within ten years. Over the next ten years, we might even see ten percent of vehicles being used as probes. Not many vehicles are needed to get good travel information.

Question 8: Over the next ten years, the Telecommunications Act will improve the communication backbone to connect different systems to a central server. We will know in the next year or two, the extent to which private companies will be allowed to do this. Most metropolitan areas, that are willing to privatize are likely to have a good communication backbone on freeways and some arterials. Hence, the Telecommunications Act could help to promote information technologies and services, e.g., en-route vehicle information.

Question 9: All freeways will take an automated approach to incident management. Crash avoidance systems, developed by private auto manufacturers, and accident management systems (e.g., automated highway technologies) will be deployed over the next ten years.

Question 10: There is not likely to be bundling of these two types of technologies, i.e., incident management and crash avoidance systems.

Question 11: Over the next ten years, industry's desire to move into the area safety will have the greatest impact on their development and deployment. Safety systems are highly marketable in cars and technology and are likely to be developed.

Question 12: Major barriers to ITS deployment include limited government funding and interest in safety systems and public acceptance (e.g., automated highways). Further, a major war could drive attention away from ITS safety and incident management systems.

If the U.S. became involved in another war, defense contractors would divert their attention away from ITS, and the government would temporarily back away from ITS.

Question 13: If safety and incident management systems are deployed over the next ten years, everyone who uses the roads will benefit.

Comments:

There are different ways to deploy ramp metering systems; zoned-ramp metering is one way that it is being deployed. UC Davis researchers might want to talk to Caltrans about different schemes, particularly with respect to the I-10 Corridor.

In general, the private sector is constrained by the public sector. There may only be a market for ITS systems and services, if the two partner. Government policies influence how the market develops. For example, in Seattle, the government has set a policy that information is free, so there is no market for information services.

Incident management is a somewhat separate issue; it does not require a lot of infrastructure. ETC offers the possibility for partnerships, but ATSC has little private-sector appeal. There is a possibility to establish an overlay district and hire a private party to set up this system. Nevertheless, incident management would not be privatized in California because the California Highway Patrol would not give this up.

Motorola pulled out of ADVANCE because they did not think that they could recoup their investment. The ADVANCE program focuses on the development and evaluation of various dynamic-route guidance concepts in the northwest suburbs of Chicago, Illinois.

Additional Comments from Keith Jasper:

Caltrans has established a franchise for ETC. There is no precedent for handing over an existing facility to a private interest. This is only happens in the case of a new facilities.

TRAVELTIP wants to encourage private-sector involvement, but the program developers are aware that this might not happen. The jury is still out on how this system will evolve. Therefore, Orange County may not even provide an accurate representation of Southern California.

The private sector might have to install its own infrastructure for information collection, because the public infrastructure may not be reliable. For instance, in California’s District 10, CMS-loop detector data sometimes do not appear to match video observations from the same monitored corridor.

Interview Subject(s): Karl Wunderlich

Subject Affiliation: Mitretek

Interview Date: Monday, July 28, 1997

Interview Location: Washington, DC

Scenario: "Market-World"

Interviewer(s): Susan A. Shaheen
Timothy E. Lipman

Comments:

Mitretek has been working on the Seattle ITS study for more than a year (i.e., approximately 30 staff months). Mitretek received this data in December, 1996, and are still working on it, which includes a lot of validation.

Mitretek is just getting started on Detroit; they plan to have a validated network by May, 1998 (i.e., approximately 18 staff months are needed).

Adolf May has done some simulations for Los Angeles on ITS using INTEGRATION, but he had trouble with assignment.

Jim Bunch at Mitretek knows a lot about planning models and applications, e.g., EMME/2. He is working on how to adapt steady-State models to obtain ITS results.

During the ITS architecture effort, the Rockwell team was tasked with assessing market penetration, perhaps they even conducted similar expert interviews.

There are Japanese assessments of market penetration for static route guidance systems. In Japan, between three to five percent of new vehicles were being equipped with static navigation systems in 1994, and researchers are presumably tracking the current market. Due to the complexity of streets, static navigation systems are very popular there. Systems are improved with the use of GPS (more accurate), and this has enhanced the popularity of these systems.

METSIM and DYNASMART are other model choices, but INTEGRATION is probably the best. Mitretek has converter programs for converting from INTEGRATION 1.5 to 2.0.

There may be some problems with INTEGRATION locking up at intersections. This problem may have been addressed in the latest version, but researchers should be sure that closely spaced ramp and signalized interchanges function properly.

Interview Subject(s):	Sergio Ostria Gary Erenrich Matthew Hardison
Subject Affiliation:	Apogee, Inc.
Interview Date:	Monday, July 28, 1997
Interview Location:	Washington, DC
Scenario:	"Industry World"
Interviewer(s):	Susan A. Shaheen Timothy E. Lipman

Question 1:

a) ETC: For typical corridors, most existing facilities would be ETC by the year 2005. Out of a four-lane highway, one to two lanes could have ETC. For the I-10 corridor, there could be HOV buy-in, since it is such a busy highway and due to the success of SR-91. But, there would only be 10 to 11 miles of travel-time savings, and this might not be big enough to justify doing this on the I-10 Corridor.

OEM: All that is really needed for ETC is a barcode. Transponders will be driven by the needs for travel across international and national boundaries, and they should be in place in new cars by the year 2010. There will not be enough fleet turnover to have many transponder-equipped vehicles in place by the year 2005. By the year 2010, most large, urban areas should have some form of tolling in place, so OEM, ETC functionality is likely

b) ATSC: The degree to which ATSC is distributed will depend on the deployment of the fiber optic network. By the year 2005, the ten largest regions may have fully-automated, real-time systems, not just partially adapted ones. However, some municipalities may not choose to maximize throughput, some municipalities might slow traffic.

Jurisdictional issues are important because of the different stakeholders involved. The I-10 corridor is well integrated, however. This is due, at least in part, to the experience the community has had with inter-jurisdictional cooperation on many issues.

c) En-Route Traffic Information: There will not be much use of en-route traffic information by the year 2000, because of the low willingness to pay and the general lack of alternative routes for work trips. Most market penetration will be in the form of CVO, but CB radios already work quite well, so growth in that segment may not be dramatic.

CMS systems will be on every major freeway by the year 2005. The key to their effectiveness is where they are placed. They probably will not be used on arterials because they are too expensive. Zoning issues may not allow them, and they might add to too much clutter on the roadway.

d) En-Route Guidance: By the year 2005, CVO, rental cars, and luxury vehicles should be employing some vehicle guidance technologies, although rental fleets are probably the main market. An interesting question to investigate is what proportion of rental car users are employing these systems today. There probably will not be much of a retrofit market, and there also is not much use for these systems for daily work trips. In many ways, there is nothing like daily experience for determining route choice.

Due to computers and telemarketing, there are fewer traveling salespeople today. In general, pre-trip information will have a bigger impact than en-route systems. Prices are too high right now, but a bundled vehicle “May-Day” navigation and vehicle performance system might be more marketable.

A truly dynamic information and guidance system is at least five years away.

The main environmental benefits from a system might be from its ability to maintain a smooth flow of speeds at approximately 45 mph.

Route diversion systems might be difficult to support politically because many areas along the arterial diversion routes might object.

Question 2: Vehicle information and guidance systems would be bundled in some corridors. ETC and advanced traffic signal systems could be bundled, but they would not need to be linked. Most public investments would be for ATSC and not ETC. Most private investment is in the area route-guidance systems.

Question 3: A key type of initiative is the public-private partnership. Innovative techniques for different types of projects, including ITS, are needed. Privatization may be the best way to proceed with ETC, with concessions being awarded to toll roads, either immediately or after a while.

Question 4: Technology is not the biggest issue, except for information and guidance systems. Political issues may be paramount, especially for ETC on new facilities. An important issue could be greater divergence between the “haves” and “have-nots.”

For existing toll facilities, better controls and less corruption would be attractive. For ATSC systems, there are some political issues pertinent to inter-jurisdictional system coordination. For information and guidance systems, the data could be used to divert funds from other methods of data collection (e.g., loop detectors). In order to link ATIS and ATMS, there is a need for centralized computer systems and public-private coordination.

Question 5: If ITS programs are mainstreamed into the TIP planning process, then they will to compete with other systems. The conformity process would be required for SIP credits to be awarded. At present, we do not have the tools to prove system impacts, so systems with demonstrable impacts may be preferred.

There are institutional and political barriers to ETC. Joint agreements can be hard to negotiate, this has been true in the Washington, DC region.

There are tort liability issues. For example, who would be liable if a pedestrian were to get hit while someone was looking at an on-board navigation system.

Sometimes municipalities have been overlooked, with efforts being focused mainly at regional levels. However, local groups could be important ITS players, especially with their emergency and other fleet vehicles. Typically, municipalities are skeptical of the economic benefit claims of ITS, and they do not have big dollars. Nevertheless, municipalities should be integrated into ITS planning processes.

There are issues associated with standards of which there are few today. Finally, ITS technology costs are an important deployment barrier.

Question 6: Fleet vehicles, including rental fleets, would benefit the most. "High-end" motoring might be allowed, in which case the wealthy could benefit and equity issues would likely emerge. Transportation services that would need to be purchased, such as with ETC and hot lanes, would create winners and potentially some losers (e.g., lower income groups).

Question 7: By the year 2010, most major streets would be instrumented, but in the year 2005 only major cities would be instrumented. Systems could be TV-, and internet-based but probably not in the near-term. There are privacy issues associated with collecting data directly from the public, and agencies would need to pay for these data. In the future, government vehicles could also serve as probes.

Question 8: The Telecommunications Act and the Internet have affected some of these technologies. There have been partnerships to deploy telecommunication systems for both private and public uses. In Missouri, fiber optic cables were given to the State for traffic management uses in exchange for access to the right-of-way.

Question 9: Transit vehicles could benefit greatly from ITS technologies. The brunt of the ATIS program is for this type of technology, which often emerge in the form of information kiosks and other types of pre-trip information. There will not be many ATIS transit services by the year 2000, but soon thereafter there will be. To date, FTA has not provided much leadership for these systems.

Better pre-trip information services will be a focus of development.

For example, fleet management systems with signal preemption for emergency and transit vehicles will be adopted because they will make these services more reliable and efficient in the future.

Collision avoidance systems also will be deployed by most manufacturers in the next five years. A sense of the market penetration for collision avoidance systems can be estimated by looking at other technologies. Luxury vehicles, which have a low-price elasticity, should be treated separately.

Collision avoidance systems will be deployed soon. The 2000 to 2005 year timeframe will only represent the first generation of this technology. Fully adaptive cruise control is far off, but radar breaking could soon be in place to reduce many types of incidents.

Question 11: NEXTEA funds will make some difference, but most ITS funds are from the federal aid highway program.

Some trends are relevant to these technologies. The fact that more jobs are in the suburbs is changing travel patterns. There is an increasingly aging population, with special needs. The immigrant population wants to become more mobile, and mobility issues tied with equity concerns are gaining increasing importance. Of the four technologies highlighted in this study, equity concerns are mainly relevant to ETC.

The Internet is having an effect, and more systems will be Internet-based instead of dial-up. The cell-phone system will likely be the most widely used system in the near term.

There is a growing gulf between the "haves" and "have-nots," and this could have an effect on ITS. Poorer areas may only have funds to maintain capital, and they also may be more ignorant of ITS options to make improvements.

Comments:

A public-private partnership scenario would be driven by proven technologies, such as ETC and ATSC. As vehicle emission technologies improve, the effects of ITS on environmental concerns will decrease. Close-coupled catalyst technologies and methods for reducing cold starts will improve vehicle emission-control performance. It is hard to change behavior, it is often easier to improve technology.

There is a lot of literature on what happened in Los Angeles with diversions after the earthquake. These data may be relevant to the modeling effort in this study. There were discussions about travel-time issues, delays, and the public response.

Travel time is really the critical issue, and people will pay to save time. The portion of a typical commute which includes travel within the I-10 corridor represents only a small part of an entire trip, so travel-time savings on that segment may not make much of a difference to an overall trip. If non-work trips could also be modeled, a different dynamic result and travel time impact could result.

Interview Subject(s): Cecilia Ho

Subject Affiliation: FHWA, US DOT

Interview Date: Tuesday, July 29, 1997

Interview Location: Washington, DC

Scenario: "Government World"

Interviewer(s): Susan A. Shaheen
Timothy E. Lipman

Question 1:

a) ETC: Some ETC systems have been deployed in Florida and New York. Usually two lanes are converted to ETC. By the year 2000, about 50 percent of facilities could be ETC on dedicated lanes, as long as there is not a back-up on the other lanes during certain time periods.

OEM: It might not be that practical for major automakers to install these systems, but they could be installed by a dealer. In the year 2005, perhaps 10 to 20 percent of vehicles will have such systems.

b) ATSC: Sometimes ramp meters do not need to be coordinated with the arterial signals. By the year 2000, all arterials should be coordinated in major urban areas, but full coordination is hard to predict. Incident management systems are usually lumped in with freeway-signalization systems.

With CMAQ funding under ISTEA, there are a lot of efforts directed toward ATSC, perhaps one-third of CMAQ funds are used this way. The coordination of adjacent areas is a concern, and sometimes it is hard to reconcile the disparate plans of different municipalities.

c) En-Route Traffic Information: If services are free, people would try them. If they have to pay, then usage rates will be lower. About one-third of drivers are using the Smart Traveler system in Boston. The reliability of the information will be key to usage rates because people tend to be skeptical and wondering about reliability.

There will be a much higher percentage of CMS on highways than on arterials, but municipalities are testing these systems on arterials in Phoenix. Perhaps only about five percent of arterials will have CMS in the years 2000 and 2005, but most freeways will have these systems.

d) En-Route Guidance: Price is the big issue with these systems, since they are market driven. Perhaps 10 to 15 percent of drivers will have them in the year 2000, and perhaps more in the year 2005, depending on the costs. Usage will tend to be high because those who buy these systems are individuals who like to try new things.

Question 2: ETC and ATSC could be bundled into an integrated system. In fact, all four of the technologies in this study could be bundled. An information service will require a traffic operations center, and this would facilitate the deployment of conducting other technologies and services.

Question 3: With NEXTEA, there is a focus on deploying systems and not just doing operational tests. There will be perhaps $100 million for deploying systems. Information systems will experience the largest gains, along with ATSC, because these technologies are under the purview of the federal government.

Question 4: Environmental groups consider these measures capacity increasing, and they tend to oppose them. Environmental interests might lead to land-use changes, although this would not be obvious or immediate. Thus far, environmental groups have not been very involved in ITS planning, but their involvement will increase and be more significant in the 2000-2005 year timeframe.

The conformity process has not be engaged much yet, but if this occurs, this could be a factor. The new NAAQS could have an impact, but the models to assess ITS and air quality impacts are lacking.

The ITS architecture could be functioning by the year 2000; however, this is optimistic because of the number of standards that are needed. The development of the architecture will be a big factor in ITS deployment.

The private-sector profit motive may be another driving factor, especially for ETC and vehicle information and guidance systems.

Question 5: Cost is a big barrier. At present, many of these systems are market driven and require public-private partnerships to support development. The high costs of information and navigation systems are particular barriers. For ATSC systems there are no out-of-pocket costs for consumers, so expense is less of an issue.

Standards should not be a big barrier, but more effort is required over the next several years.

Question 6: Technology providers would benefit from a government-driven world, as well as any agency that have access to travel and incident information.

Question 7: Technologies are currently available to instrument vehicles, but it is unclear how rapidly this deployment will occur. The government has control the information; this control could be used to leverage deals with the private sector. Some recruitment for equipped car transponders is occurring now.

Question 8: There still is not much telecommunication competition, despite the Telecommunications Act. However, there have been a few deals between governments and the private sector to deploy fiber optic networks.

Question 9: CVO technologies are promising, but it is unclear how many of these technologies will be developed. There is a big emphasis on information systems, with a greater emphasis on pre-trip information on a regional scope.

Question 11: Economic factors will be important to deployment, particularly for CVO and APTS systems. The equity question is important because people without access to information will benefit less (e.g., those without cell phones). APTS is getting more attention, as well as AVL systems and SMART cards, because they have broad benefits. Kiosk systems are popular, but there is a lack of funds to maintain them.

NEXTEA funds for transit systems might increase slightly.

Question 12: Barriers to CVO and APTS include high costs during the deployment phase. Institutional issues also are important, such as whether systems will be public or private, and who will maintain them. There are some critical coordination issues, especially with respect to system maintenance.

Question 13: All users would benefit from CVO and APTS technologies, and the benefits could be broadly distributed with a standardized system. Clearly, there is a great need for standardization. The digital cell phone is a good analogy for the importance of standards. For example, the limited coverage area for the digital technology has hampered its popularity.

Interview Subject(s): Joe Peters
Toni Wilbur

Subject Affiliation: JPO, US DOT

Interview Date: Tuesday, July 29, 1997

Interview Location: Washington, DC

Scenario: "Government World"

Interviewer(s): Susan A. Shaheen
Timothy E. Lipman

Question 1:

a) ETC: By the year 2000, all "hot lane" toll facilities will have ETC since there is no reason to make them manual. As for the number of lanes that will be "hot," this is speculative.

OEM: No comment.

b) ATSC: The Apogee report projects a market penetration rate for various ATSC equipment packages in urban areas by the year 2005; the numbers in the table below reflect the high market penetration estimate for these technologies. The source of these estimates is based on "The National Architecture: Evaluation Results," June 1996, which was prepared for US DOT and FHWA by the Joint Architecture Team.

Technology	*Equipment Package*	*Parameter*	*Market Penetration Estimate*
Traffic Signal Coordination	Roadway Signal Controls	Intersections	50%
	Collect Traffic Surveillance	TMCs	100%
	TMC Basic Signal Control	TMCs	40%
	Roadway Basic Surveillance	Loops etc.	100%
	TMC Regional Traffic Control	TMCs	67%
	Traffic Maintenance	TMCs	100%
	Incident Management	EMCs	50%

c) En-Route Traffic Information: The Apogee report projects a market penetration rate of one percent for personal basic information reception in urban areas by the year 2005, and a three-percent market penetration rate for personal interactive information reception. The source of these estimates is based on “The National Architecture: Evaluation Results,” June 1996, which was prepared for US DOT and FHWA by the Joint Architecture Team.

The Apogee report projects a market penetration rate of zero percent for automated road signing in urban areas by the year 2005. The source of these estimates is based on “The National Architecture: Evaluation Results,” June 1996, which was prepared for US DOT and FHWA by the Joint Architecture Team.

d) En-Route Vehicle Guidance: The Apogee report projects a market penetration rate of five percent for personal route guidance systems in urban areas by the year 2005. The source of these estimates is based on “The National Architecture: Evaluation Results,” June 1996, which was prepared for US DOT and FHWA by the Joint Architecture Team.

Question 2: ETC and signalization are a natural bundle. Also, incident management can be coupled with traveler information systems. (See the diagram in the Metropolitan ITS Components Report (p. 4) for a description of the hierarchical, interactive system.) The ITS program plan explains roles for public and private funding. There is no mandate for Federal involvement other than to give guidance and possibly to set standards. The allocation of funding is up to the States.

Question 3: Standards for the ITS architecture would influence deployment far more than anything else. The only standard in place today is one for signal coordination.

Question 4: The baby boomers are aging, and they might demand more in-vehicle navigation systems as they grow older. Economic factors will influence deployment, as will the costs and availability of information systems. The environmental impacts are uncertain at this point.

Question 5: The institutional barriers outweigh the technical ones. The lack of jurisdictional coordination is an important issue, as is the transition from the "design and build" mentality to an "operate and maintain" one.

Question 6: There are no clear winners if the government takes the lead in ITS deployment, although fleet owners and frequent travelers should benefit from mobility information.

Question 7: It would be too expensive to instrument all of the roads with sensors, but already these systems have been deployed in most urban areas. There probably will be greater attention to arterials in the future, through data collection effort and the use of transponders as probes.

Question 8: You might want to contact Bill Jones in the JPO office about the Telecommunications Act. His number is (202) 366-2128.

Question 9: The most cost-effective systems will be deployed in the greatest numbers. Incident management systems will be highly cost effective, since coordination is the main system requirement, not capital expense. Traveler information systems, particularly those that are regional and multi-modal, that will be deployed will be useful. In-vehicle safety devices, such as “May-Day” and other security systems, will experience increased demand as well.

Question 10: The ITS program plan identifies packages and bundles of ITS technologies.

Question 11: Demand for roads will increasingly exceed supply. The public sector will try to get the "biggest bang for the buck," and it will employ the most cost-effective solutions first. Alternative ways to provide lane miles will be explored. There are ways to incorporate ITS technologies into lane paving to make investments more effective.

Question 12: There are institutional and technical barriers. There are two reports to Congress on legal and contracting issues and standards. There is nothing that is unresolvable, but people need to work together to determine how to do things differently to meet the new challenges of ITS deployment.

Question 13: Benefits should not be estimated in a simplistic fashion. The program plan identified eight major categories of benefits, reflecting back to its goals (e.g., mobility, efficiency, safety, energy and the environment, customer satisfaction, etc.). Each area has different measures, for instance, number of accidents as a safety measure, throughput effectiveness relative to goods and people for effectiveness, and cost savings for productivity. One could define a matrix of users and benefit categories. The benefits of different technologies will vary. For example, CVO will save money for fleets and improve throughput.

Comments:

Only pre-trip information could be expected to cause a mode shift to transit, since people will not shift modes en-route.

SRI has done a market analysis of ITS technologies.

Interview Subject(s): Michael Replogle

Subject Affiliation: Environmental Defense Fund

Interview Date: Tuesday, July 29, 1997

Interview Location: Washington, DC

Scenario: "Public-Private Partnership World"

Interviewer(s): Susan A. Shaheen
Timothy E. Lipman

Question 1:

a) ETC: This would depend on operating policies. There is merit to an SR-91 type system where a congestion-free ride is guaranteed for paid lanes, but in order to have the system work smoothly the prices might have to be changed periodically, and perhaps the off-peak times should be discounted. Two priced lanes and a shoulder would probably be needed to maintain a smooth ETC operation, then three of the lanes could be left free. ETC might be introduced as only one lane, until ETC becomes popular and a second lane can be added. It would be more rational to make everyone pay for the toll lanes, but politically, HOV-3 vehicles might need to be let through without a charge. Toll revenues must be recycled to make them politically feasible, and ideally the funds would be used to support more transportation options and demand-reduction projects.

By the year 2005, perhaps 30 percent of facilities will be ETC. Not many will be by the year 2000, but by the year 2010, perhaps 80 or even 100 percent could be, depending on some of the operational issues.

There is a good article on toll roads regarding the E-407 corridor in Toronto in the "Toll Roads" newsletter. In this corridor, new technologies are being tested. For instance, license plate video imaging is being used to determine the length of each trip, and EZ-Pass users are offered a discount.

OEM: This would not be likely to occur by the year 2005, but possibly by the year 2010. Perhaps a multi-function system could be developed, which communicates with roadway beacons and acts as a speed governor to smooth traffic flow. This would never be acceptable, if it were mandated; however, people might choose to use it, if insurance companies offered a discount.

b) ATSC: These systems are easy to implement, so penetration would reach 100 percent very quickly. Even fully coordinated systems are a "quick fix," so many areas should have this by the year 2000. More sophisticated systems could result in a lot of small improvements to the performance of existing facilities.

The benefits of ATSC might be overstated, if it is not successful in smoothing traffic flow.

c) En-Route Traffic Information: By the year 2000, only about five to ten percent of drivers will have these systems, but by the year 2005, the percentage could reach 20 to 25 percent. The usage rate will depend on the meaningfulness of the information and the cost of the system. There probably will be a cost, if the information were up-to-date and accurate, so perhaps one percent (or 10 to 20 percent of system owners) of the population would use these systems in the year 2000, and ten percent (or 40 to 50 percent of system owners) of the population would use these systems in the year 2005.

CMS systems are too expensive for arterials, but freeways will have them. CMS systems do not provide specific enough information for drivers on arterials.

HAR systems are not very useful unless they are tailored, real-time systems.

d) En-Route Guidance: Since these systems are so expensive, only about one percent of drivers will have them by the year 2000, and ten percent will have them by the year 2005. People will use the systems regularly, only if they get meaningful information on congestion or if they regularly travel unfamiliar routes.

If about 25 percent of users have guidance systems, then this will tend to speed-up traffic flow, but if approximately 50 percent of drivers have them, then too many travelers may divert. A smart system is needed, but this will raise the question of who will benefit from system optimization.

Question 2: ETC and en-route vehicle information and guidance systems could be bundled, along with information on transit and smart buses, with signal preemption. The other technology that should be bundled in this system is real-time paratransit. The revenues from ETC could enable bundling of innovative options.

Question 3: A series of big cyclones and hurricanes that result in big insurance losses could cause the financial service industries to get worried about climate change. This could put an emphasis on growth management strategies. An oil crisis could also have a similar effect, but it would be short lived.

Question 4: Other issues with potential impacts include the growing congestion problem and fiscal issues associated with transportation financing. ETC, with congestion pricing and hot lanes, could have the biggest impact on these technologies.

Question 5: Barriers include the income disparity and income segregation that occurs in this country (i.e., equity concerns). In some ways, however, income disparity creates a market for products for wealthier segments, such as AHS.

Question 6: The winners would tend to be the more affluent, who could afford to buy-in to these systems and services. However, if ETC money were funneled into transit services, then transit riders also could benefit. Business travelers, fleets, and other high-value uses/users would benefit, and others could benefit indirectly (through reduced taxes, for example).

Question 7: Transponders used as probes are very cost effective, so this will probably be done more in the future.

Question 8: Big issues probably will emerge from the language in the Telecommunications Act, but it is hard to say what will happen at this point.

Question 9: In addition to the others mentioned, promising technologies include CVO systems such as electronic manifesting. These are market-driven systems, not environmental.

Comments:

The most important question is for what values is ITS held accountable? Without environmental concerns, only mobility is valued; with environmental concerns, environmental costs are considered and recognized. Mobility can then be seen as a balance between supply and demand in a way that takes account of environmental quality and quality of life. Thus, just having supply increases is not sufficient. With the use of ITS, technologies could help us to get at some of the deeper issues.

People should be given more choices, and institutional restructuring should be allowed to provide more of a consumer orientation, similar to the restructuring of the electricity and telephone industries.

With respect to vehicle technology, the greenhouse gas emissions issue could be a driver for new technologies, especially if there are catastrophic events. Then, perhaps we could have carbon taxes or a binding emission limitation agreement. Possibly, we may even aggressively develop hybrid vehicles to improve efficiency.

Due to increases in congestion, there should be more telecommuting in the future. The barriers to telecommuting are mainly management related. People might telecommute for a few hours in the morning to avoid the AM peak, particularly if there is congestion pricing.

A VMT-based fee on efficiency could cause shifts to more efficient vehicles. At present, there are a lot of vehicle choices on the high end, but few on the low end. A feebate scheme could lead to more differentiation of the low end of the market and more choices for consumers. Just as there is now an ethic around recycling, perhaps a similar ethic could develop transportation. A social marketing strategy could help to support shifts to more efficient vehicles, along with emissions caps and trading schemes.

Incentive structures could be created for private interests to make corridors more efficient. The franchise model might be a good one, with agreements for meeting performance criteria (and exceeding them to increase profits). For example, pavement quality and minimization of traffic delays could be some of the criteria used, and different incentive policies could also be adopted.

Los Angeles expert interview summaries

The following individuals were interviewed about specific ITS market penetration forecasts in California, as well as more general forecasts about the conditions that will most influence future ITS deployment:

Tim Carmichael, Coalition for Clean Air
Michael Fitts, National Resources Defense Council
Hector Obeso, Caltrans
Verej Janoyan, LADOT
John Cox, Southern California Economic Partnership
Gary Edson, Metro Dynamics
Erik Alm, Metro Dynamics
Michael Krueger, Transcore

Because some of those interviewed requested anonymity, the overview of the California interview results does not include references to specific individuals.

Responses to the specific market penetration forecast questions (Question 1) are presented in a summary Table 16 on page 103 of the main report. With respect to the more general questions, interviewees generally chose not to answer each question. Instead, most focused their responses on questions relevant to their particular expertise. Responses to interview questions are placed in *italics*. Table 16 on page 103 of the main report provides an additional summary of some of the issues discussed in the interviews.

All Los Angeles interviews were conducted by Daniel Jordan of CGS.

Interview 1: Market Representative

<u>Question:</u> It is likely that some ITS technologies will be deployed in "bundles" (i.e., deployed simultaneously and/or coupled to work together). Among the four ITS technologies listed above, which would most likely to be deployed in bundles in the years 2000 and 2005? If possible, construct a bundle by percentage for: 1) expenditure/investment for all four technologies, and 2) adoption/use for ETC, en-route traffic information, and en-route vehicle guidance systems for the years 2000 and 2005.

-*Bundling: ETC will not be bundled most likely, at least in the near term; neither is ATSC a bundling item.*

-*Traffic information and route guidance is a natural bundle, but it goes beyond this to include emergency notification/collision avoidance.*

-*Within five years, likely to have at least $1.5 billion invested in ITS infrastructure, and this is purely on the public sector side.*

<u>Question:</u> Which, if any, market-led initiative(s) would have the most influence on the degree of ITS deployment in the years 2000 and 2005?

-*Must distinguish public and private involvement: public involvement always likely to be public works projects such as traffic signals: unlikely to be privatized (always publicly owned and operated/TMCs/electronic highway system--what will be increasingly prevalent is the private sector being contracted to do certain tasks related to the public works project.*

-*Critical to the future deployment picture is in-vehicle emergency notification devices (i.e., incident detection/collision avoidance) is "major in terms of impact."*

-*Southern California Economic Partnership is a major market-led initiative: the intent is to advocate greater use of the ITS products/services, both by government and private sector. It does take some coordinated effort between the private and public sides because each side needs to know what the other side is doing, and Partnership is one means of sharing information (e.g., Panasonic has "all the devices you could ever want, but they don't do you much good if you cannot get any information from them"). Increasingly, information partnerships will begin to pick up steam by the year 2000, but there will not be significant market penetration even by the year 2005. The reason for this is that fleets are being replaced at about 10 percent per year, so turnover takes a long time.*

<u>Question:</u> Still operating under the "market-world" scenario, what factors (i.e., economic, social, technological, political, environmental, etc.) are likely to exert the most influence on ITS deployment in the years 2000 and 2005? What impacts would these factors have on the four ITS technologies listed above in the years 2000 and 2005?

-*Economics and technology are the main drivers, especially the technology.*

<u>Question:</u> What would be the major barriers facing ITS deployment of the four technologies listed above in the years 2000 and 2005? In other words, what ITS-related marketing activities would the private sector find particularly difficult to accomplish without significant assistance from the government and support from the environmental community for the four ITS technologies in the years 2000 and 2005?

-Ten million cars are in the LA basin: penetration must be significant before you begin to see any kind of impact.

-*We need the ability to collect information: some parts of the region and State have fairly good infrastructure to do this (e.g., Santa Ana, Irvine; most State freeways in Southern California "are pretty good." LA county has about 60 percent coverage and is going to be highly upgraded over the net few years. Orange County has about 90 percent coverage; Inland empire has virtually no coverage today.*

-*Market acceptance is critical (i.e. microwave oven analogy: roughly 50 microwaves sold the first year they were sold, and they were marketed as a way to cook your Thanksgiving turkey).*

-*What is the biggest problem in getting ITS to market: much of it is perception: a wheat-field makes a good analogy to ITS. The Problem in the farming industry long ago was how to make a wheat field into a box of Wheaties (i.e., into a consumer product that people would understand and buy). Raw traffic information is largely like a wheat-field: there is a consumer market for this information, but how do you turn the information side (e.g., loop detectors, signals, and TMCs) in to a box of the equivalent of a box of Wheaties?*

<u>Question:</u> Considering the whole universe of ITS technologies, what technologies (and to what degree) will be deployed in a typical urban corridor in the years 2000 and 2005?

-*Toll facilities: all new toll facilities will have it; the question is to what extent can you convert the older ones, although there will probably always be some non-ETC lanes.*

-*The car is becoming much more of a "service-oriented vehicle." Travel information data are likely to be a standard part of future automobiles, but a "10 percent market penetration by the year 2005 is a stretch in many cases."*

Interview 2: Market Representative

Question: It is likely that some ITS technologies will be deployed in "bundles" (i.e., deployed simultaneously and/or coupled to work together). Among the four ITS technologies listed above, which would most likely to be deployed in bundles in the years 2000 and 2005? If possible, construct a bundle by percentage for: 1) expenditure/investment for all four technologies, and 2) adoption/use for ETC, en-route traffic information, and en-route vehicle guidance systems for the years 2000 and 2005.

-The most likely bundle is traffic information and vehicle guidance, although incident detection may ultimately prove more popular than any other ITS technology.

Question: What would be the major barriers facing ITS deployment of the four technologies listed above in the years 2000 and 2005? In other words, what ITS-related marketing activities would the private sector find particularly difficult to accomplish without significant assistance from the government and support from the environmental community for the four ITS technologies in the years 2000 and 2005?

-Legacy problems and issues in market place

- *Market is fragmented/agency structure fragmented;*
- *Piecemeal implementation: big money, but not integrated;*
- *Political structure fragmented; and*
- *What is needed is a "United Nations" of Highways: not SCAG (people pay attention to SCAG purely because they have money).*

-Technology is leading policy

- *National Architecture, for example, gave requirements; never asked what the requirements are; and*
- *Need a systems engineering process: define need, requirements, and a benefits and costs expected, define system that meets needs.*

-Need better detection: loops are okay, but better traffic information detection could be made available (e.g., surveillance equipment on cars) and better feedback mechanisms: vehicle as data gathering mechanism.

Question: Considering the whole universe of ITS technologies, what technologies (and to what degree) will be deployed in a typical urban corridor in the years 2000 and 2005?

-SMART Corridor is the future (i.e., using technology to fully integrate freeways and arterials).

-Twenty potential SMART Corridors identified in the LA and Orange County areas.

Interview 3: Group Interview with Market Representatives

Question: What would be the major barriers facing ITS deployment of the four technologies listed above in the years 2000 and 2005? In other words, what ITS-related marketing activities would the private sector find particularly difficult to accomplish without significant assistance from the government and support from the environmental community for the four ITS technologies in the years 2000 and 2005?

-CAAA: standards have to be met. This could lead to high number of alternative fuel vehicles for upcoming fleets.

-Government: taxes and corporate welfare. Will ITS funding get slashed as part of corporate welfare crackdown?

- *The government must build essential infrastructure, but if they keep giving it away they discourage the very market activity they are trying to encourage.*

-Privacy Barriers: may prove to be more of an issue than the environment.

Question: Which group(s) of transportation system users and technologies (e.g., public agencies and private users) would benefit most from the private sector taking the lead in ITS deployment in the years 2000 and 2005, for the four ITS technologies listed above?

-ITS could magnify already existing social inequities: Lexus owners have it, the poor do not.

Question: Considering the whole universe of ITS technologies, what technologies (and to what degree) will be deployed in a typical urban corridor in the years 2000 and 2005?

-*There is no "typical" corridor; degree of deployment will differ radically across regions (and even within regions).*

Interview 4: Environmental Professional

<u>Question:</u> It is likely that some ITS technologies will be deployed in "bundles" (i.e., deployed simultaneously and/or coupled to work together). Among the four ITS technologies listed above, which would most likely to be deployed in bundles in the years 2000 and 2005? If possible, construct a bundle by percentage for: 1) expenditure/investment for all four technologies, and 2) adoption/use for ETC, en-route traffic information, and en-route vehicle guidance systems for the years 2000 and 2005.

-*An obvious bundle is traffic information and vehicle navigation; advanced signalization and ETC can stand alone.*

<u>Question:</u> Which, if any, environmental initiative(s) would have the most influence on the degree of ITS deployment in the years 2000 and 2005? What possible environmental or energy-related "event" (e.g., oil crisis, new data on global warming, etc.) might significantly influence ITS deployment for the four technologies listed above in the years 2000 and 2005?

-*It depends on what ITS is perceived to be do. It could make all kinds of travel more pleasant and result in greater demand.*

<u>Question:</u> Still operating under the "enviro-world" scenario, what factors (i.e., economic, social, technological, political, environmental, etc.) are likely to exert the most influence on ITS deployment in the years 2000 and 2005? What impacts would these factors have on the four ITS technologies listed above in the years 2000 and 2005?

-*Air quality standards (e.g., new PM standards).*

-*CO2 standards.*

<u>Question:</u> What would be the major barriers facing ITS deployment of the four technologies listed above in the years 2000 and 2005? In other words, which of the four ITS technologies would be promoted if environmental quality was made a high priority in the years 2000 and 2005?

-*Advanced signalization will be the deployed under any circumstance; all of the other technologies will depend on budgetary constraints.*

<u>Questions:</u> Which group(s) of transportation system users and technologies (e.g., public agencies and private users) would benefit most from the environment being a leading ITS deployment priority in the years 2000 and 2005, for the four ITS technologies listed above?

-*With ITS, drivers and truckers will benefit most under almost any scenario.*

Interview 5: Environmental Professional

Question: It is likely that some ITS technologies will be deployed in "bundles" (i.e., deployed simultaneously and/or coupled to work together). Among the four ITS technologies listed above, which would most likely to be deployed in bundles in the years 2000 and 2005? If possible, construct a bundle by percentage for: 1) expenditure/investment for all four technologies, and 2) adoption/use for ETC, en-route traffic information, and en-route vehicle guidance systems for the years 2000 and 2005.

-En-route traffic and vehicle guidance systems will be bundled extensively by the year 2005.

Question: Which, if any, environmental initiative(s) would have the most influence on the degree of ITS deployment in the years 2000 and 2005? What possible environmental or energy-related "event" (e.g., oil crisis, new data on global warming, etc.) might significantly influence ITS deployment for the four technologies listed above in the years 2000 and 2005?

-It is unlikely that any environmental "initiative" will profoundly effect ITS deployments over the next ten years.

-New data on global warming and criteria pollutants could, however, increase the pressure for environmentally beneficial ITS technologies.

Question: Still operating under the "enviro-world" scenario, what factors (i.e., economic, social, technological, political, environmental, etc.) are likely to exert the most influence on ITS deployment in the years 2000 and 2005? What impacts would these factors have on the four ITS technologies listed above in the years 2000 and 2005?

-Environment:

- *CAAA: meeting those requirements (e.g., SCAG now admits that latest Plan does not achieve SIP emission budget, leaving federal funds at risk); and*
- *By the year 2005, consumption of oil will be increasingly important issue.*

-In the LA area, goods movement is perhaps the biggest issue:

- *SCAG projects a 300 percent increase in truck traffic from airport expansion; and*
- *SCAG projects a 400 percent increase in truck traffic from port expansion.*

Question: Which group(s) of transportation system users and technologies (e.g., public agencies and private users) would benefit most from the environment being a leading ITS deployment priority in the years 2000 and 2005, for the four ITS technologies listed above?

-*The benefits of ITS deployment likely to be broad (i.e., most segments of the population receive at least some benefit), but commercial operators will likely benefit the most.*

Question: Considering the whole universe of ITS technologies, what technologies (and to what degree) will be deployed in a typical urban corridor in the years 2000 and 2005?

-An important future driver for ITS (and is an especially promising technology from an environmental point of view) are SMART Shuttles;

-Advanced signal coordination;

-remote sensing: still being tested, but so far it is fairly effective in detecting gross emitters; and

-on-board diagnostics.

Interview 6: Government Professional

Question: Which, if any, government-led initiative(s) would have the most influence on the degree of ITS deployment in the years 2000 and 2005?

-There is a great deal of focus on "systems integration" (e.g., NEXTEA has provision for $100 million to do system integration). There is an emphasis on TMC-to-TMC communications, information sharing between agencies, etc.

Question: Still operating under the "gov-world" scenario, what factors (i.e., economic, social, technological, political, environmental, etc.) are likely to exert the most influence on ITS deployment in the years 2000 and 2005? What impacts would these factors have on the four ITS technologies listed above in the years 2000 and 2005?

-*Budgetary capabilities/priorities (among governments) are likely to exert the most influence over ITS deployment through the year 2005.*

Question: What would be the major barriers facing ITS deployment for the four technologies listed above in the years 2000 and 2005? In other words, what ITS-related activities would the government find particularly difficult to accomplish without significant assistance from the private sector and support from the environmental community for the four ITS technologies in the years 2000 and 2005?

-*Gaining a commitment from agencies to install, maintain, and operate infrastructure is a significant barrier to ITS deployment.*

-Having an adequate communication system in place is a huge barrier. The SMART Corridor has fiber optic cables deployed, for example, while many areas do not. This restrict the amount of information that can be processed.

Question: Considering the whole universe of ITS technologies, what technologies (and to what degree) will be deployed in a typical urban corridor in the years 2000 and 2005?

-*There is a big push is for ATMS, ATIS, and CVO. There is no "typical" corridor; most urban areas will have all these technologies deployed to some degree. The question is to what extent and how well their systems be integrated?*

-There are big gains (environmental/time-savings) related to incident detection and management.

-In the year 2000, all traffic signals (i.e., roughly 550 signalized intersections) within the SMART Corridor will be connected to the ATSAC system (as well as all traffic signals in city of LA, roughly 4,000 signalized intersections).

Interview 7: Government Professional

Question: It is likely that some ITS technologies will be deployed in "bundles" (i.e., deployed simultaneously and/or coupled to work together). Among the four ITS technologies listed above, which would most likely to be deployed in bundles in the years 2000 and 2005? If possible, construct a bundle by percentage for: 1) expenditure/investment for all four technologies, and 2) adoption/use for ETC, en-route traffic information, and en-route vehicle guidance systems for the years 2000 and 2005.

-ETC and advanced traffic signals are not likely to be bundled; traffic information and route guidance are an increasingly typical bundle.

Question: Which, if any, government-led initiative(s) would have the most influence on the degree of ITS deployment in the years 2000 and 2005?

-In California, the push for more "SMART Corridors" will have a major influence, especially in Orange County.

Question: Still operating under the "gov-world" scenario, what factors (i.e., economic, social, technological, political, environmental, etc.) are likely to exert the most influence on ITS deployment in the years 2000 and 2005? What impacts would these factors have on the four ITS technologies listed above in the years 2000 and 2005?

-Agency owners must see problem to be addressed to deploy ITS systems and services (i.e., a big push to deploy ITS technologies must come from implementing agencies themselves).

-ITS funding from federal and State governments to maintain the current level of congestion.

-SCAG Steering Committee: forums, reports and broad studies could move deployment along, although deployment up to now has been on the slow side

Question: What would be the major barriers facing ITS deployment for the four technologies listed above in the years 2000 and 2005? In other words, what ITS-related activities would the government find particularly difficult to accomplish without significant assistance from the private sector and support from the environmental community for the four ITS technologies in the years 2000 and 2005?

-A major barrier to ITS deployment is a lack of communication between agencies. This has improved greatly over the past ten years, but it still needs improvement.

Question: Considering the whole universe of ITS technologies, what technologies (and to what degree) will be deployed in a typical urban corridor in the years 2000 and 2005?

-Systems Integration: Automated and integrated systems that "think" are the next wave of ITS; this will push transportation agencies to share information (e.g., fiber on the freeways, all fiber hook-ups on Santa Monica Freeway by the year 2005).

Expert Scenario Workshops

This section presents all the introductory materials and summaries of the Washington, DC and California (Davis) expert scenario workshops. The introductory materials were provided to participants prior to the event; the DC and Davis materials differ slightly in the seven scenario steps listed. The first workshop (DC) did not include the task of creating the matrix of market penetration estimates, and the second workshop (Davis, CA) did not include a session for implications of the scenarios created. The initial scenario descriptions (Table D-1) and market penetration estimates (Table D-2), provided to the Washington, DC participants are based on the expert interviews. The scenario descriptions provided to the Davis, CA expert workshop participants were the revised scenarios developed by the DC workshop participants. These descriptions were modified in the California workshop. The market penetration estimates developed by the Davis participants for the final set of scenarios are presented in Table 21.

Washington, DC: Introductory Material for Scenario Workshop on the Future Development of ITS Technologies on Monday, September 15, 1997

The future of ITS technologies

Over the past few months, Institute of Transportation Studies-Davis (ITS-Davis) researchers have interviewed a group of ITS experts in Washington, DC, and Los Angeles to discuss the *Future of ITS Technologies*. These expert interviews have been used to create four future scenarios. The scenario methodology allows participants to create multiple stories, or alternative visions of the future and to identify key political, institutional, economic and technical indicators that differentiate those alternatives. ITS-Davis has prepared outlines of initial scenarios based on the expert interviews. In the workshop, participants will review, modify and elaborate those scenarios, generate a list of "early warning signals" for each of the scenario futures, and develop a strategy to plan for each of the futures.

Strategic planning and scenarios

In recent years the discipline of strategic planning has undergone a shift from the use of single point forecasts toward the use of multi-point forecasting. After World War II, the United States grew in a reliable and orderly fashion up until about 1970. Plans that merely extrapolated past events into future results were effective and generally reliable. Since 1970, the business environment has become less predictable. Who would have imagined the oil shocks and stagflation of the 1970s, the advent of the personal computer in the 1980s, and the widespread use of the Internet in the 1990s? As technology advances and the economy globalizes, new tools are necessary to gauge the future. Scenario planning is a flexible tool for a changing world. Scenarios offer planners the ability to focus on the future, without locking in on one forecast—a forecast that would probably be inaccurate.

What are scenarios

Scenarios are alternative environments in which today's decisions may be played out. They are neither predictions nor strategies. Instead, they are descriptions of different futures or alternative realities that are designed to highlight the risks and opportunities involved in specific strategic issues. Thus, they can provide a *base* for strategic planning and analysis. Scenarios can help planners and policy makers manage uncertainty in the future. The point is not to gather evidence for some induction about a most probable future. Rather, the point is to entertain a number of different possibilities to make better reasoned choices among them. One of the goals of this workshop is to bring together experts in the ITS field to uncover trends that will shape the future of ITS over the next ten years.

The future of ITS technologies scenario workshop

In preparation for the upcoming workshop, ITS-Davis researchers developed outlines of the initial scenarios. The steps in this initial process were:

- Define a focal issue around which the exercise is based;
- Develop a list of driving forces that impact the future of ITS; and
- Create a group of four scenarios.

The scenarios created by ITS-Davis researchers will serve as "models" to which workshop participants respond. The workshop will bring together a group of experts to improve and extend the initial scenarios. In a one-day workshop, experts will retrace all steps in development of scenarios, in order to examine the validity of model scenarios and to expand upon each of the *scenario worlds.* Following a list of the steps in the scenario process and a snapshot of each of the four *worlds.*

Steps in the scenario process

There are seven steps in this scenario process[10]. As mentioned above, we will retrace these steps during the workshop to refine and expand upon the original scenarios.

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[10] The scenario methodology, adapted in this workshop, and the scenario steps are described in Peter Schwartz's *The Art of the Long View: Planning for the Future in an Uncertain World* (New York: Double Day Currency, 1991).

Step One: Identify Focal Issue

In this step, participants identify the focal issue for the scenarios. ITS-Davis researchers have developed the following focal issue for this workshop: "What is the market for specific ITS technologies and systems over the next ten years?" (The list of ITS technologies is the same as that used in the expert interviews.) This focal issue will serve as the initial "model" for the workshop. Participants can discuss modifying the focal issue with input from the workshop facilitator and organizers. It is important that participants do *not* change the focal issue too much, so that it crafted to respond to the goals of the Partnership for Advanced Transit and Highways "ITS and Environment" project. In these worlds, it is critical that researchers estimate market penetration for the ITS technologies in each of these scenarios.

Step Two: Key Forces in the Local Environment

Participants identify critical facts that decision makers will want to know when making key choices. For instance, what key issues will decision makers want to know about customers, suppliers, competition, government support, etc.? Below we list some of these key questions (the answers to which would be the "key issues") that emerged from our expert interviews in Washington, DC.

Some Key Issues from DC Expert Interviews:

What is/are the…?

- Impact of the Telecommunications Act on data quality and costs;
- Response of public to pricing policies;
- Impact of global warming and air quality on the ITS market;
- Impact of baby boomers (e.g., concern for safety);
- Impact on economy;
- Potential for behavioral change (e.g., mode shift);
- Potential for lower data collection costs;
- Role for Internet, smart cards, cell phones in the ITS market;
- Impact of NEXTEA;
- VMT projections;
- Land-use trends (e.g., continued sprawl and urban renewal);
- Impact of information technologies on commercial markets;
- Impact of ITS on transit systems;
- Need for operation funds (e.g., impact if funds are not available);
- Impact of consumer acceptance;
- Role of public/private partnerships; and
- Impact of standards on architecture and ITS deployment

Step Three: Driving Forces

In this step, participants identify driving forces behind the key issues identified in Step 2. Not surprisingly, some forces are very structured, such as demographics, and others are highly uncertain, e.g., public acceptance. Driving forces generally include social, economic, political, technological, and environmental factors.

Driving forces identified in the DC expert *interviews* are listed in the description of each of the scenario worlds below. The four scenarios include:

1) status-quo world,
2) industry world,
3) government world, and
4) public/private partnership world.

Step Four: Rank by Importance and Uncertainty

Next, participants will rank key factors and driving forces based on two criteria:

1. Degree of importance for the success of the focal issue or decision identified in Step One.

2. Degree of uncertainty surrounding those factors and trends.

Participants should identify two or three factors or trends for each scenario that are *most important* or *uncertain.*

Step Five: Scenario Logic

Organizing scenarios according to some logic is crucial to creating each world or story. First, participants will decide upon crucial uncertainties. Next, the group will decide whether or not to present each scenario relative to these particular uncertainties (e.g., economy, customer acceptance) along one axis, a matrix (i.e., two axes), or in a volume (i.e., three axes). These axes can help participants to identify and elaborate upon different scenarios. To summarize, these logical structures should help characterize significant scenario drivers.

Step Six: Expanding the Scenarios

While the most important forces will determine logic of each scenario, other lesser forces and trends can be used to flesh out each scenario.

- How would the world get from here to there?
- What events might be necessary to make the end point of each scenario possible?

Step Seven: Implications

After participants develop scenarios in some detail, then the experts will return to the focal issue (Step One) to explore the implied future.

- How does the future look in each scenario?
- What vulnerabilities have been revealed?
- Which technologies and customers predominate the market in each of the scenarios?

Step Eight: Selection of Leading Indicators and Responses

After each of the scenarios have been elaborated and implications for the focal issue have been determined, then participants will identify a few key indicators that can be used in monitoring the future. Further, participants will identify a few alternative responses that government agencies and private companies might take, if signposts for each scenario begin to emerge. Finally, participants will review a set of ITS market penetration estimates for each scenario, which reflect opinions gathered from the DC expert interviews.

Table D-1: Draft Scenarios Based on Interviews on the Future Development of ITS Technologies

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Status-Quo World	• ITS deployment continues along a steady and incremental trajectory. • There are no major changes in the economy, social acceptance, and rates of increase in ITS-technology usage. • There are no technology breakthroughs, and information quality and collection methods do not change. • Standard-setting and protocols receive some attention from government.	• NEXTEA passes with support for ITS programs. • Market acceptance of ITS technologies is limited. • Private-sector investment continues at a slow rate. • Public-sector investment continues at a moderate rate.	• Market acceptance (low). • Willingness-to-pay (low). • Private-sector investment (low, increasing to moderate). • Public-sector investment (moderate and stable). • Information availability (low). • Information quality (low, focused on broadcast of information to a general public market).

Table D-1: Draft Scenarios Based on Interviews on the Future Development of ITS Technologies (cont.)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Industry World	• ITS deployment, especially information-based technologies, explodes. • The market for information-based technologies soars. Consequently, the public sector benefits from high, quality information gathered by industry. • Technology breakthroughs allow for inexpensive and high-quality information collection and dissemination. • Entrepreneurial efforts by industry outpace government efforts at ITS management (i.e., standard setting and deployment). • Short to medium-term market chaos; often incompatibility between competing products.	• Technology breakthroughs. • Industry and government standards promote information acquisition and exchange. • Market acceptance of Internet, Web TV, PDAs, and cell phones aid in willingness-to-pay and market demand for new information technologies. • Private-sector investment high.	• Market acceptance (high). • Willingness-to-pay (high). • Private-sector investment (high). • Public-sector investment (low to moderate). • Information availability (high, largely directed to specialized, paying market). • Information quality (high, focused on a specialized, paying market).

Table D-1: Draft Scenarios Based on Interviews on the Future Development of ITS Technologies (cont.)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Government World	• ITS deployment, in terms of information collection, dissemination, and traffic signal coordination, high. • Information is gathered and distributed to meet the needs of the general public, e.g., traffic information available through highway advisory telephone and CMS. • Market for specialized information technology is low. • Technology continues to evolve largely through government investment. Government investment in ITS outpaces private-sector investment. • Government actively engaged in development of private market for ITS.	• Architecture standards promote government information acquisition and dissemination. • Market acceptance of "free" information services is high. • Private-sector investment drops and is diverted to other high-tech applications. • Public-sector investment continues due to increasing VMT and congestion, and concomitant energy and air quality impacts. • Environmental and social concerns (e.g., equity) play a key role.	• Market acceptance (moderate, yet increasing). • Willingness-to-pay (low). • Private-sector investment (declining). • Public-sector investment (high). • Information availability (moderate to high, but limited to public market). • Information quality (moderate to high, focused on general public market).

Table D-1: Draft Scenarios Based on Interviews on the Future Development of ITS Technologies (cont.)

Scenario	Brief Description	Driving Forces	Possible Logic Axes
Public-Private Partnership World	• ITS deployment is high in both traveler information and traffic management arenas. • Information is used to meet both the needs of the general public and specialized users. • Market for specialized information technology is high. • Public and private sectors work together to create seamless transportation network and services. • Technology development slow. • Government actively working with industry to develop markets for ITS.	• Market acceptance of new technologies and information services is high. • Public acceptance of new pricing policies is high, which facilitates ETC. • Private-sector investment in ITS is moderate; it is increasingly directed at other high-tech applications (e.g., emission control technologies). • Public-sector investment increases. • Barriers to ITS deployment drop. Cooperative efforts increase. • Environment plays a large role.	• Market acceptance is increasing for traveler information and traffic management technologies, including ETC (moderate and increasing). • Willingness-to-pay (high). • Private-sector investment (moderate). • Public-sector investment (moderate). • Information availability (high, focused on both public and specialized markets, shared between public and private sectors). • Information quality (high, focused on general public and specialized markets).

Table D-2: Summary of Scenario Market Penetration Estimates (Developed from Interviews) [11]

Scenario Worlds	Electronic Toll Collection			Advanced Traffic Signal Coordination			Vehicle Information Systems			Vehicle Navigation Systems		
Status-Quo World	**System**	**2000**	**2005**	**System**	**2000**	**2005**	**Syste m**	**2000**	**2005**	**System**	**2000**	**2005**
Smart Corridor	**ETC** **OEM**	0 No	0 No	**Freeway** **Arterials**	100% 50%	100% 75%	**Have** **Use** **CMS**	10% 75% 100%	25% 75% 100%	**Have** **Use**	1% 100%	5% 100%
Typical Urban Corridor	**ETC** **OEM**	10-15% No	25-30% No	**Freeway** **Arterials**	10% 33%	15% 33%	**Have** **Use** **CMS**	5% 75% 25%	20% 75% 50%	**Have** **Use**	1% 100%	5% 100%
	System	**2000**	**2005**	**System**	**2000**	**2005**	**Syste m**	**2000**	**2005**	**System**	**2000**	**2005**
Industry World	**ETC** **OEM**	20-25% 5%	40-45% 20%	**Freeway** **Arterials**	10% 33%	15% 33%	**Have** **Use** **CMS**	20-25% 100% 50%	50% 100% 50%	**Have** **Use**	10-15% 75%	25-30% 75%
Government World	**ETC** **OEM**	30% 0	50% 10%	**Freeway** **Arterials**	50% 50%	100% 75%	**Have** **Use** **CMS**	25% 75% 100%	50% 75% 100%	**Have** **Use**	1% 1%	2% 2%
Public-Private Partnership World	**ETC** **OEM**	50% 10%	75% 30%	**Freeway** **Arterials**	100% 100%	100% 100%	**Have** **Use** **CMS**	30-35% 80% 100%	50-55% 85% 100%	**Have** **Use**	5% 75%	10% 75%

[11] The market penetration estimates for each of three scenario worlds reflects projections for a typical urban corridor.

Scenario Workshop on the Future Development of ITS Technologies: Summary of Workshop Held in Washington, DC, September 15, 1997

Goals of Workshop

The goals of this workshop, included:

- Exploring models to evaluate environmental and energy impacts of ITS;
- Creating contexts/worlds to estimate market penetration rates for ITS; and
- Developing possible future worlds upon which the group could agree.

- Scenarios:
  --Useful for strategic planning;
  --Facilitates outside-the-box creative thinking;
  --Brings together people who normally don't work together; builds alliances;
  --Provides divergent perspectives (better not to agree); and
  --Narratives, not data summaries.

Participant Introductions

The following invited experts were active participants in the Washington, DC workshop. Contact details for these participants and for the workshop facilitators and notetakers are presented in Table D-5 at the end of this presentation of the workshop (prior to the presentation of the Davis, CA workshop.

1. Bob Noland, U.S. Environmental Protection Agency
   - Working with FHWA to perform ITS system emission evaluations
   - Has found minimal benefits, if at all, working on ITS.

2. Lane Swauger, Parsons
   - An engineer who works on planning issues with Departments of Transportation.

3. Johnathan Slevin, WALCOFF
   - Involved with marketing and communications, the PR components of ITS
   - Says that "benefits" is a "fluffy" public relations word
   - Also writes column for ITS World.

4. George Beronio, U.S. Departmentof Transportation, ITS-JPO

- Says it is unclear whether there are environmental benefits of ITS, and that it is difficult to substantiate those claims.

5. Bill Cowart, U.S. Environmental Protection Agency
    - A Transport Economist whose focus is determining more efficient pricing of transport, and economic efficiency.

6. Erin Bard, U.S. Departmentof Transportation
    - A Civil Engineer whose work on ITS technologies has evolved from construction, to design, and finally planning and policy.
    - She therefore understands both the public and private perspectives on ITS.

7. Ben Fuller, DaimlerBenz
    - Previously trained in the Global Business Network.
    - Specialty is scenario building.
    - Problems with extrapolation--cannot predict by extrapolation of the past, unanticipated events will arise.
    - Create scenarios by conducting expert interviews, and providing the results to managers for aid in decision making.

Step One: Focal Issue

As described in the general description of how scenario analysis was implemented for this study, the initial focal issue presented and accepted by the first workshop in Washington, DC was:

"What is the market for various [specific] ITS technologies and systems over the next ten years?"

The specific ITS technologies and systems to be considered were these four:

- electronic toll collection (ETC);

- advanced traffic signal coordination (ATSC) for arterial networks and freeways, and either including or not including incident detection;

- vehicle information systems supplying dynamic, real-time information; and

- vehicle navigation, or route guidance, systems.

<u>Summary of discussion of the focal issue</u>

List of the different points raised during discussion of the focal issue:

- Market driving forces
  - --Social, economic, market acceptance, institutional issues;
  - --Privacy/satellite tracking;
  - --Technology;
  - --Computer chips;
  - --Wireless telecommunications; and
  - --Family Structures.

- How widespread will ITS become? On the margins or broad?
  - --Congestion pricing; universal?
  - --ETC
  - --Diffusion issues.

- Who will pay for ITS?
  - --Public versus private investments.

- What is ITS? Different things to different people?
  - --Capital questions: How much capital from emerging companies will depend on early successes.

- Political forces/Enabling legislation
  - --perception is key (example: pricing policies).

- Economy of use; exclusivity/elitist; more emphasis on traffic than public transportation.

- Demographics changes
  - --land use patterns, impacts on system planning;
  - --new communities; and
  - --the elderly.

- ITS: Technology driven?
  - --Implementing technology for technology's sake. Looking for a problem to solve, example: Highway Automation.
  - --Congestion, safety, environmental issues. . .are these really problems?
  - --Big picture planning needed.

- Land use/Development
  - --urban/rural; land use pattern shift; how do we develop?

- Are ITS objectives incompatible with land use strategies? If ITS focuses on flow, it doesn't improve land use patterns.

- Data Collection
  --serving multiple needs, and
  --connect the planning process with information collection and dissemination.

- What is the market for various ITS technologies over the next five to ten years?

- Why should there be a market for ITS technologies:
  --consumer demand,
  --telecommunications impacts,
  --freight applications/ goods,
  --multimodal/ intermodal,
  --pricing,
  --land use, and
  --environmental impacts.

- Increase accessibility with increasing mobility.

- Public versus private "goods" in ITS. Example: Can a highway be a private good? Right now it is non-exclusive.

- Exclusivity of Use.

- Is large-scale privatization a possibility in ten years?
  --Who ever thought we'd have private electric utilities?
  --What would be the implications?
  --Congestion pricing impacts.
  --History of private turnpikes.
  --Cultural change would be enormous?
  --Global trends moving towards privatization.

- What is the market for ITS technology and to what degree will government be involved?

- *Comment:* (Erin) There are unseen driving forces in the market, and changes in US transportation systems. There are important social factors including social acceptance, institutional issues, privacy issues, and technology concerns.

- *Comment:* (Bill Cowart) Will there be marginal penetration or universal applications? How widespread will be the use of these technologies, including ETC? What will be the diffusion of ITS?

- *Comment:* (George) Who will pay for ITS? There exists a public versus private debate.

- *Comment:* (Johnathan) How much capital will be infused into industry for ITS technology development. What is ITS? What about quality of life and mobility issues?

- *Comment:* (Lane) What about political forces. . . "Who drives the bus?" Will there be a public/ private partnership? There is a lack of good legislation. What will be the long-term benefits? What about "economy of use"? The elitist look to ITS. What are the economics for public transit? Will the general population benefit? We should discuss demographics and land use, as well as societal changes. What about planned communities and assistance for the elderly? These factors should influence planning and operations.

- *Comment:* (Ben) Perception is key. "Economy of use"--more emphasis on traffic than public transportation. Early adopters will be the rich, but will these technologies later benefit us all?

- *Comment:* (Bob Noland) The ITS community is technology-driven. They are wanting to promote the technologies without really understanding the impacts they will have. They are looking for a problem to solve. They will focus on the:

  -- Congestion problem,
  -- Safety problem, and
  -- Environmental problem.

The paradigm is sprawled development. There are land use issues of urban and rural development. Are the ITS objectives incompatible with land use strategies?

- *Comment:* (George) Data Collection is valuable for planning, but what about privacy issues, and the fear of "Big Brother".

- *Comment:* (Lane) Need a good historical database from which to plan. Currently we have a lack of data.

- *Comment:* (Susan) Over the next ten years, what is the market for various ITS technologies?

- *Comment:* (Bob) Why should there be a market for these technologies? Consider pricing; with congestion pricing, there will be less need for other services. Consider land use, environmental impacts, and environmental benefits.

- *Comment:* (Erin) What are the environmental benefits? Examine visible urbanization. For example, compare the four lane highway with a two lane highway for pollution. Sometimes air quality is invisible. What is the public perception of the market? Most people don't know about environmental issues.

- *Comment:* (Bill) Increase accessibility with increasing mobility.

- *Comment:* (Johnathan) There are freight implications of ITS: consider railroads, trucking, and multi-modal versus intermodal.

- *Comment:* (Bob) What about consumer demand for teleshopping and telecommunications?

- *Comment:* (Erin) What are the public goods/ externalities of ITS? What are the private goods?

- *Comment:* (Bob) As an example, consider the deregulation of utilities, such as electricity. Can we imagine the privatization of freeway systems? The distribution of public and private funding could change. The freeways may be taken over by industry. "Exclusivity of use."

- *Comment:* (Erin) ITS may be taking shape as a private good. What about social equity factors? Will there be privatization in ten years? Consider congestion pricing and political barriers.

- *Comment:* (Lane) What is the role of a public agency? There will be a radical cultural change in expectations of public goods.

- *Comment:* (Bob) The first roads in the U.S. were private. To deregulate and privatize them now would increase their efficiency.

- *Comment:* (Bill) Two-thirds of the roads in Sweden are private.

- *Comment:* (Bob) The global trend is a move towards privatization, but there are political barriers to this.

<u>Conclusions:</u>

What is the market for ITS?
What could the government role be in ITS development?
In freight and services, ITS are being used without government involvement.

Steps Two, Three and Four: Identifying and Prioritizing Driving Forces and Environmental Factors

Following the discussion of the *focal issue*, a list was created of *driving forces* and *environmental factors* that will determine the future of information management systems and their impact on transportation systems. These environmental factors can be social, economic, political, or technological. They are intended to be underlying root causes of the driving forces, and in terms of uncertainty, can be characterized as the "unknown unknowns."

Once a list of driving forces and environmental factors was generated, the group voted on which factors they felt were both the most important and the most uncertain. Voting took place through a bidding process—each participant had a maximum total number of votes they could cast (25) across all driving forces, and could cast no more than five votes for any one driving force. Once votes had been placed and tallied, the group debated whether some of the driving forces and environmental factors logically formed coherent groups, possibly *meta-driving forces* and *meta-environmental factors*.

The list of single driving forces and environmental factors, and the votes they received, are shown in the two tables below. Note that driving forces and environmental factors are listed in the order in which they were Stated by the group, not by their voting rank.

Table D-3: Votes for Driving Forces by Creation Order (Washington, DC)

Creation Order	Driving Force	Votes
1.	Traffic signal coordination (ATSC): --Get rid of "artists": smarter, new software replaces engineers. --Algorithm as artists. *--(Erin: Develop smarter software to automate traffic signal coordination.).*	0
2.	Pricing for environment *(Bob):* --ETC. --Congestion pricing. --On-board diagnostics for emissions. --Transponders in the car.	0
3.	Regulation (*Lane: Privacy and governmental policy).*	0
4.	Data collection strategies/ organizing the planning community (*Since information is needed for planning, pay individuals to carry transponders in their car for a week to obtain travel information as well as network information.)*	8
5.	Interoperability of architecture/ standards.	10
6.	We may "lock-in" to particular ITS technologies as a possible by-product of national architecture *(Erin)*.	0
7.	Cities timing lights poorly as planning strategy (*Bill's example: Cambridge, MA did this intentionally to discourage drivers from taking the city as a commuter path.)*	0
8.	Open versus closed systems *(George)*.	0
9.	Political influences/ intrusions on standards *(Johnathan's example: Joint Program Office)*.	0
10.	Telecommunications/deregulation *(Bob: See benefits in private competition; innovation and profits.)*	0
11.	Private versus public, e.g., competition for spectrum.	0
12.	Deregulating telecommunications versus regulating transportation.	0
13.	The Big Players: AT&T, Intel, Microsoft, and Departmentof Defense *(Johnathan: the Departmentof Defense is the largest mover of goods, transporting the most freight.)*	11
14.	Fare collection standards *(Lane: banks, Chase Manhattan, etc.):* --debit cards. --ETC. --payment services will bring in financial institutions.	0

Table D-3: Votes for Driving Forces by Creation Order (Washington, DC) (cont.)

Creation Order	Driving Force	Votes
15.	Environmental perceptions *(Bill: misperceptions):* --ITS will have benefits by "moving" traffic? *(Belief that as long as congestion is reduced, environment will benefit).* --ITS to "smooth" the flow and stop hard accelerations *(Bob: but what about ramp metering. . . increasing hard . +-accelerations will increase emissions)).* --(*Vehicle miles traveled may go up, and with that, emissions?).*	0
16.	ITS as part of the overall technology market *(George: Integration with other markets).*	9
17.	What if cars didn't pollute? *(Bob: for example, fuel cells; then there won't be a need for ITS environmentally. Then the focus must shift to other aspects such as congestion and safety.)*	9
18.	Induced demand / from where is demand coming?	0
19.	Plague or sickness caused by air pollution *(Public perceptions may change in response to a health crisis due to air quality.)*	0
20.	Climate changes/ hurricanes in California.	0
21.	Second hand smoke analogy. . .Health Alert.	0
22.	Can ITS reduce U.S. sedentary lifestyles?	0
23.	Fatalistic acceptance of commuting. *(In the United States, the average daily commute is one-half hour, and in the world it is ninety minutes a day. Humans seem to be predisposed to this daily travel time, as evidenced by the fact that when the work commute is longer, people tend to reduce non-work related travel, to reach a ninety minute equilibrium.*)	0
24.	Congestion: --ITS driven by congestion. --Symptom or problem? --Congestion as economic activity, growth.	8
25.	Safety: --Road information. --Prioritize it to make people safe. --Safety at any cost.	0

Table D-3: Votes for Driving Forces by Creation Order (Washington, DC) (cont.)

Creation Order	Driving Force	Votes
26.	Major war conflict *(Erin)*: --Guns or butter/ how is government money allocated? (From ITS to other technologies?) --Defense companies find more lucrative markets for weapons; --Industry pulls dollars away from ITS; firms focus their resources on war; --Timing of market development, when they bail out? --New useful technologies come out; and --Time lag to bring the peace dividend.	0
27.	ITS funding priorities.	5
28.	Rate of ITS development: Slow or Fast.	11
29.	Lack of available public funds for infrastructure *(Johnathan: Privatization)*. --new ways to finance public infrastructure with private money. --philosophy.	14
30.	Private sector driving different aspects of ITS *(Bill)*.	3
31.	Road Rage: --What causes road rage. --Cultural artifact. --Perception: could push towards privatization. --Safer vehicles/ survival more likely: contributes to erratic driving behavior. *(Erin: less stress with ITS? Know congestion lies ahead and can avoid it.)*	0
32.	Car-to-car communications: --Internet.	0
33.	Community ITS needs: --Traffic calming. --More, larger, faster vehicles.	7
34.	Recession: changes travel patterns *(Erin)*.	8
35.	Plague causes people to stop traveling - half of the population is wiped out. *(Erin)*.	0

Table D-4: Votes for Environmental Factors by Creation Order (Washington, DC)

Creation Order	Environmental Factors	Votes
36.	End of Communism.	0
37.	Political warfare replaced by economic warfare.	0
38.	Information overload - data processing. (*The car is isolated; the only place you can't get information - so bring it into the car)*.	0
39.	Globalization - shrinking world.	0
40.	"Turn it off!": Social revolution *(Anti-technology backlash; too much information; blending of work and leisure, no freedom from work at home nor in the car, no downtime; issues of safety, privacy, and cost; going crazy; turn it off!)*.	10
41.	Safety in the car.	0
42.	How will culture of work evolve? Technologies for the "elite" *(Are the technologies affordable and universal, or will there only be a small group of users?)*.	7
43.	Smart roads…………………Smart vehicle --Cuts the human being out of the decision-making process. --End point: The Automated Vehicle/ Automated Highway.	0
44.	Congestion pricing: people want more information *(Erin)*.	0
45.	Roads with "Network Equilibrium" *("Partners-In-Motion" free cellular calls for general traffic information; there was a 50% decline in use of all carriers when Bell Atlantic dropped out of free service. Now three primary carriers dropping free service.*	0
46.	Business models for ITS services. Related services: --wireless providers --mainstreaming --subscription --advertising --transaction.	0
47.	Will information actually be better than what we already have?	0
48.	Masses cutting off roads to take the same shortcut *(Just moving congestion to the arterials, not really eliminating it.)*	0
49.	Operational improvement before information improvements *(Legislation, political persuasion, influence)*.	0
50.	Travel information before traffic management to increase visibility and help obtain funding *(Infrastructure was not yet in place)*.	0
51.	Holistic approach needed *(Erin: There exists a disconnect between local and federal planning)*.	0
52.	Taxes/ Lobbying reform.	0
53.	Social acceptance/ Demand.	11
54.	Car as an "Island."	0

55.	The Internet as a tool: --like the microwave.	0

Creating "meta-driving forces" and "meta-environmental factors"

Similarities between many of the driving forces and environmental factors caused some difficulty in voting. People saw several natural groupings of forces and factors; in many cases different people identified similar concepts in different forces and factors, and thus while voting for different items, they were in fact voting for the same concepts. In order to reduce the number of forces and factors the group would have to consider and to resolve differences and similarities in meanings, the next step was to debate the creation of groups of forces and factors. Note that the distinction between driving forces and environmental factors was allowed to collapse at this stage. As a first step, all forces and factors receiving fewer than five votes were eliminated from further consideration.

The final list of *meta-driving forces and environmental factors* is shown below. We note here, allowing for the specific method of creating these aggregate categories, that the participants developed this "top" thirteen prioritized list of meta-driving forces and environmental factors that will determine the impact of information management systems on transportation systems:

1) Public infrastructure funding/ITS funding priorities: 19
2) The Big Players/Private sector influence on ITS: 14
3) Rate of ITS development: 11
4) Social Acceptance/Demand: 11
5) "Turn it off!" Social revolution: 10
6) Interoperability of Architecture: 10
7) ITS as part of the overall technology market: 9
8) What if cars didn't pollute?: 9
9) Recession: 8
10) Data Collection: 8
11) Congestion: 8
12) Community ITS needs (e.g., traffic calming): 7
13) How will culture of work evolve?: 7

We note that an issue that is often assumed to be the driving force behind ITS, i.e., congestion, was ranked only eleventh. Public infrastructure funding priorities for ITS was ranked ahead of any other driving forces and environmental factors. The second and third ranked forces were the influence of the private sector on ITS and the rate of ITS development. Taken together, we interpret this to mean that the overall investment by the public sector and the influence of the private sector on ITS development are far more important to the formation of an ITS market than traditionally conceived forces, such as congestion.

Step Five: Scenario Logic Structures

Absent development of such a specific logic structure, the workshop proceeded to the next step, refining the scenario world descriptions. Ideally, no more than a few sets of driving forces and environmental factors would be identified in the previous steps. However, this workshop group had developed a set of seven. Given the large number of driving forces that remained after the aggregation process and the time constraints faced by the workshop, the group decided not to take any more time to try to reduce the list further. The purpose of further refinement would have been to develop one, two, or three axes along which the scenario worlds could be placed. That is, if one driving force was thought to distinguish all the scenario worlds, then they could have been placed in relation to each other along that single axis. Similarly, two-axes would have defined a plane in which the scenario worlds could be shown relative to each other.

Step Six: Scenario World Descriptions

Participants were provide with initial, scenario world descriptions that were developed drawing from the expert interviews conducted in Washington, DC, and Los Angeles, CA. Notable changes made by this workshop to these initial scenarios are indicated below. The complete summary descriptions of the scenario worlds from the expert interviews and the DC workshop are shown in the accompanying table. Note that the status quo world was not reviewed by the workshop participants.

<u>Government World</u>

Beginning of 1997-1998

- More focus on what is on the street than in the cars.
- World Peace develops:
    --Korea is united;
    --Middle East peace;
    --Communism ends in China;
    --Defense funding declines;
    --Transfer from public to private sector jobs.
- Commitment to do nothing about climate change: no research.
- U.S. backs out of climate change commitments they have already made (Kyoto).
- Economy is good and stable.
- Department of Defense firms realize there is no money in ITS.
- NEXTEA passes with $32 billion
    --25 to 30 percent increase in infrastructure expenditures.
- Economy is good and stable.
- Willingness to pay declines.

Middle of 1999-2001

- Satellite imaging allows full detection, complete information.
- Ubiquitous communications networks.
- Streets are less safe:
  --Welfare reform fails.
- Violence erupts from excess refugee population:
  --Environmental disaster in Mexico caused by the United States.
- Growing underclass - inequality, crime.
- Gore elected in 2000:
  --Moderate Republican or Democrat.
- Cheaper information and communications technology
  --Miniaturization, packaging.
- Lockheed Martin signs $2 billion contract to help fund and build infrastructure:
  --Fee-for-service; and
  --One of the many government contracts of 2000 for the $20 billion per year investments.
- Government mandates embedded systems from Detroit and subsidizes the Big Three with $20 billion because of United Autoworkers strike.
- Protectionism; high import duties.

End of 2002-2005

- Big recession, stagflation:
  --Caused by too much government spending. and
  --Interest rates go up.
- Gore is assassinated, and Gephardt becomes president and "Buy American" program begins (Protectionism).
- U.S. industry less competitive.
- Vatican dumps GM stock and buys Fiat.
- Transportation services are cut back.
  --Government starts cutting "personal" services and contracts.
- War in Turkey created Departmentof Defense jobs.
- Militia movements in the West:
  --shut down traffic control; and
  --peoples' cars are controlled over the Internet.

<u>Industry World</u>

Beginning of 1997-1998

- Outsourced services.
- Private, multi-technology world.
- Invisible technology.

- UPS strike encourages more companies to develop fleet management technologies for the consumer market.
- Satellite technology unveils new detection methods: Industry becomes "Big Brother."
- NEXTEA gets only one year authorization and parts of infrastructure are sold off.
- General Motors orders 400,000 embedded vehicle navigation units.
- Government funds basic research and gets involved in limited partnerships.
- GM gets big bucks for research.

Middle of 1999-2001

- Major competition worldwide in multiple sectors: ITS technologies become more important.
- Bigger market for ITS.
- Globalization creates wider dispersion of manufacturing.
- Three major MPOs in ITS spurs major herd mentality and investment in ITS.
- Congestion pricing based on VMT (flat fees for Road Pricing is the first step).
- Federal government plays diminished role in infrastructure funding
- Steve Forbes becomes president.

End of 2002-2005

- Resurgent public transport.
- Change in government policies.
- Environmental movement: anti-sprawl:
  --People have to pay to live "spread-out."
- Land values in inner city go up.
- Renaissance of "Great America."
- Re-urbanization.
- Adoption of European land use patterns/ new urbanism.

<u>Public-Private Partnership World</u>

Beginning of 1997-1998

- Public and private sectors work together to create intermodal transportation network and services.
- DOTs barter there right-of-way for telecommunications infrastructure as mandated by NEXTEA (no federal highway funding without it).
- General telecommunications deregulation enables public/ private partnership:
  --e.g., FM Rebroadcast.
- Satellite detection; regulated by government.
- Rich data:
  --Broad data comes out of public infrastructure and is reprocessed.
- Data is readily traded from public to private in exchange for contracting opportunities.

- Financial institutions offer electronic payment systems to public agencies:
  --e.g., use your Visa card to pay on buses.
- Movement to a paper-less society.
- Private sector handles transactions for bus systems (RFPs) - becomes standard feature and lowers their operating costs.

Middle of 1999-2001

- Traveler information infestation:
  --Metro, ETAK.
- Federal mandates allow companies to make money by reselling traveler information.
- Ascendance of MPOs.
- Established standards create ability to exchange data (from market forces and government guidance).
- Congestion pricing on limited scale for new capacity through HOT lanes and peak-hour pricing.

End of 2002-2005

- Possible pitfalls:
  --legal battle to challenge monopolies,
  --public outrage against congestion pricing, and
  --corporate welfare.
- More services are available to meet new needs.
- Less reliance on government funding as result of broader market.
- Public agencies will have a new face: operations management, become less capital intensive.
- Rise of mobility company conglomerates serving public needs.
- CVO air links.
- Airports are privatized.
- Freight delivered by rocket.
- Positive interpretation of status-quo. (Laws are changed to facilitate this.)
- Financing becomes available where only limited financing was previously available.

Step Seven: Implications

After the workshop participants reviewed and revised the scenarios, the experts returned to the focal issue to explore the implied future:

- How does the future look in each scenario?

- What vulnerabilities have been revealed?

- Which technologies and customers predominate the market in each of the scenarios?

The experts developed implications and options for the three scenarios. These descriptions for each world are listed below.

Government World

- Create tight coalition of regional people to agree on needs and priorities.
- Create "legal protections" against government intrusion (State and MPO level).
- Do as much as possible to divert cash flow.
- Go the public/ private route; foster relationships.
- Invest in urban areas, not just ITS technologies.
- Go into resource management.
- Fight for MPO direct funding, (State constitutions)
- When NEXTEA expires, fight for new funding.
- Direct federal money to MPOs.
- MPOs must be elected as a requirement of tax money.
- Shift of power from local to regional.

Industry World

- Are MPOs needed?
- Less a transportation agency and more like an operating agency --Could look like a utility company that manages communication infrastructure.
- Aggressively form private sector partnerships.
- Set up ways to implement bidding for infrastructure.
- Assert itself (MPOs) in land use areas and perhaps less on the transportation side.
- MPOs still in the same role - no free reign for private industry.
- Could allude to better suited industries in various industries.

Public/ Private World

- Bulk up legal staff to think about "policy issues."
- Stronger emphasis on regional and local economic development.
- Public/ private partnerships for joint development:
    --e.g. railroad stations, and
    --e.g. anti-sprawl.
- Regulation is generally softer.
- Risk-sharing.
- You can control your destiny, but detailed planning is required:
    --legal and institutional mechanisms support MPO.

- Compete with other governmental levels to be the partner of private sector.

Table D-5: Washington, DC Scenario Workshop Participants

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Davis, CA: Introductory Material for Scenario Workshop on the Future Development of ITS Technologies on Tuesday, October 21, 1997

Steps in the scenario process

There are seven steps in this scenario process. We will retrace these steps during the workshop to refine and expand upon the original scenarios.

Step One: Identify the Focal Issue

In this step, participants identify the focal issue for the scenarios. ITS-Davis researchers have developed the following focal issue for this workshop: "What is the market for specific ITS technologies and systems over the next ten years?" (The list of ITS technologies is the same as that used in the expert interviews.) This focal issue will serve as the initial "model" for the workshop. Participants can discuss modifying the focal issue with input from the workshop facilitator and organizers. It is important that participants do *not* change the focal issue too much, to ensure that it is crafted to respond to the goals of the Partnership for Advanced Transit and Highways "ITS and Environment" project. It is critical that researchers estimate market penetration for the ITS technologies for each of the scenarios.

Step Two: Key Forces in the Local Environment

Participants identify critical facts that decision makers will want to know when making key choices. For instance, what key issues will decision makers want to know about customers, suppliers, competition, government support, etc.? Below we list some of these key questions (the answers to which would be the "key issues") that emerged from our expert scenario workshop in Washington, DC.

Some Key Issues from DC Expert Scenario Workshop:

What is/are the…?

- Impact of the Telecommunications Act on data quality and costs;
- Response of public to pricing policies;
- Impact of global warming and air quality on the ITS market;
- Impact of baby boomers (e.g., concern for safety);
- Impact on economy;
- Potential for behavioral change (e.g., mode shift);
- Potential for lower data collection costs;
- Role for Internet, smart cards, cell phones in the ITS market;

- Impact of NEXTEA;
- VMT projections;
- Land-use trends (e.g., continued sprawl and urban renewal);
- Impact of information technologies on commercial markets;
- Impact of ITS on transit systems;
- Need for operation funds (e.g., impact if funds are not available);
- Impact of consumer acceptance;
- Role of public/private partnerships; and
- Impact of standards on architecture and ITS deployment.

Step Three: Driving Forces

In this step, participants identify driving forces behind the key issues identified in Step 2. Not surprisingly, some forces are very structured, such as demographics, and others are highly uncertain, e.g., public acceptance. Driving forces generally include social, economic, political, technological, and environmental factors. Driving forces identified in the DC expert scenario workshop are listed in the description of each of the scenario worlds below. The four scenarios include:

1) status-quo world,
2) industry world,
3) government world, and
4) public/private partnership world.

Step Four: Rank by Importance and Uncertainty

Next, participants will rank key factors and driving forces based on two criteria:

1. Degree of importance for the success of the focal issue identified in Step One.

2. Degree of uncertainty surrounding those factors and trends.

Participants should identify two or three factors or trends for each scenario that are *most important* or *uncertain.*

Step Five: Scenario Logic

Organizing scenarios according to some logic is crucial to creating each world or story. First, participants will decide upon crucial uncertainties. Next, the group will decide whether or not to present each scenario relative to these particular uncertainties (e.g., economy, customer acceptance) along one axis, a matrix (i.e., two axes), or in a volume (i.e., three axes). These axes can help participants to identify and elaborate upon different scenarios. To summarize, these logical structures should help characterize significant scenario drivers.

Step Six: Expanding the Scenarios

While the most important forces will determine logic of each scenario, other lesser forces and trends can be used to flesh out each scenario.

- How would the world get from here to there?
- What events might be necessary to make the end point of each scenario possible?

Step Seven: Developing Scenario Matrix

After participants develop scenarios in some detail, then the experts will generate a set of market penetration estimates for the years 2000 and 2005 for each scenario, specifically for the four technologies listed below:

- Electronic Toll Collection,
- Advanced Traffic Signal Coordination,
- Vehicle Information Systems, and
- Vehicle Navigation (Route Guidance) Systems.

Scenario Workshop on the Future Development of ITS Technologies: Summary Davis, CA, October 21, 1997

Step One: Focal Issue

As described in the general description of how scenario analysis was implemented for this study, the initial focus issue presented to this second workshop was an output of the first scenario workshop in Washington, DC. This *focal issue* was…

"What is the market for various [specific] ITS technologies and systems over the next ten years?"

The specific ITS technologies and systems to be considered were these four:

- Electronic toll collection (ETC) (including congestion pricing);
- Advanced traffic signal coordination (ATSC) for arterial networks and freeways, and either including or not including incident detection;
- Vehicle information systems supplying dynamic, real-time information; and
- Vehicle navigation, or route guidance, systems.

After considerable discussion, the *focal issue* was rephrased as…

"What is the likely impact of information management systems on the transportation system likely to be over the next then years?"

It was suggested that the notion of environmental, energy, and congestion impacts of ITS technologies and systems were subsumed in this phrasing of the *focal issue*. It also was Stated that "impact" implied market penetration.

<u>Summary of discussion of the focal issue</u>

Participants struggled with several aspects of the initial *focal issue*. Concerns ranged from details of the question itself to the overall context which the initial *focal issue* appears to assume.

Detailed concerns addressed the timeline and the specific technologies. It was suggested that ten years was not a long enough time period for us to consider any significant level of market development because it was not a long enough time period to consider real world deployment (as opposed to demonstration projects). The realities of the speed (or lack thereof) with which State and local transportation and environmental agencies can affect change and decisions by State and local governments, was the primary concern here.

A distinction between "collective" and 'individualistic" technologies also was discussed. In the former case, a system administrator can apply the technology to the entire traffic stream along a specific route (e.g., congestion pricing). In the latter case, the service might only be available via subscription by individual travelers (e.g., route guidance). Participants struggled a bit with whether these different types of technologies could be conceptualized within a single system, that is, would the deployment of one type of technology have any impact on the deployment on the other type?

Two concerns were raised that addressed whether the *focal issue* as phrased above was framed within the appropriate context. One perspective was offered in which all the separate technologies would be superseded by an entirely different system. Such a system might incorporate an open architecture that would allow multiple, and customized, information functionalities. Under such a system, there would be no independent deployment of four distinct technological systems as implied by the list of ITS technologies. Rather, it was suggested that we should be discussing a telecommunications and computer-based information management system.

A second perspective questioned whether we had presumed an answer to the logically prior question, "*should* we deploy ITS technologies?" This question was raised within the context of whether ITS technologies and systems had been adequately assessed for their environmental, congestion, and safety impacts. [Note that an environmental assessment of the four technologies is the ultimate goal of this research project.] A distinction was offered between a "government" world in which costs and benefits, including environmental impacts, would have to be assessed first and a "market" world in which traveler information services would be sold regardless of social impacts or external costs.

List of the different points raised during discussion of the focal issue:

- Collective vs. individual services, benefits.

- Technology bundling:
    1. How would the four specific technologies be bundled?
    2. Would a larger open architecture be deployed in which the four technologies would no longer be distinct?

- Internet compatibility of information systems.

- Will telecommunications company strategies supersede ITS technologies, e.g., will ITS services simply be a strategy to sell palm top computers?

- Long term vs. short term change (and how long are "long" term and "short" term).

- Delayed ITS technology rollout.

- Time required for State and local authorities to act.

- Public/private partnership hurdle—partnerships are likely to be necessary and to take time

- Information management (e.g., remote central or local dispersed computational resources).

- Questions regarding environmental impacts of ITS, including air quality, energy conservation, habitat protection, and urban sprawl.

- Mix of public/private issues and regulatory effects.

Steps Two, Three and Four: Identifying and Prioritizing Driving Forces and Environmental Factors

Following the rephrasing of the *focal issue*, a list of *driving forces* and *environmental factors* that will determine the future of information management systems and their impact on transportation systems. These environmental factors can be social, economic, political, or technological. They are intended to be underlying root causes of the driving forces, and in terms of uncertainty, can be characterized as the "unknown unknowns."

Once a list of driving forces and environmental factors was generated, the group voted on which factors they felt were both the most important and the most uncertain. Voting took place through a bidding process—each participant had a maximum total number of votes they could cast (25) across all driving forces, and could cast no more than five votes for any one driving force. Once votes had been placed and tallied, the group debated whether some of the driving forces and environmental factors logically formed coherent groups, possibly *meta-driving forces* and *meta-environmental factors*.

The list of single driving forces and environmental factors, and the votes they received, are shown in the

Table D-6 and Table D-7 below. Note that driving forces and environmental factors are listed in the order in which they were Stated by the group, not by their voting rank.

Table D-6: Votes for Driving Forces by Creation Order (Davis, CA)

Creation Order	Driving Force	Votes
1.	Price of oil, availability of oil: • Energy crisis, rising gasoline prices; and • Affect on quantity of travel and transportation alternatives.	8
2.	Future roadway congestion: • Need for information management systems will depend on it.	24
3.	Lifestyle simplification: • People want tools to simplify their lives, and • People want tools to save time.	7
4.	Changing work environment: • Telecommuting, and • Flex-time.	19
5.	Aerospace/defense industry is no longer world's technology drivers; consumers electronics is the technology driver: • Ninety-nine percent of aerospace companies will be out of business; • speed at which government influences technology slows technology evolution, e.g., $30 billion expenditure on ITS is very small compared to overall market of $10 trillion; and • Technology will be driven by private sector.	15
6.	Alternative Fuels technologies: • LEVs (low emission vehicles), ZEVs (zero emission vehicles); • Fuel cells; and • Shift from environmental (air quality) to congestion concerns and urban planning.	7
7.	Perception of travel time: • Complimented by in-car infotainment; and • Internet, mobile office.	15
8.	Car as an escape (as an alternative to 7 above): • Information overload, car is a place to get away.	0
9.	Feeling of being safer in your car vs. in an airplane: • Personal control issues.	0
10.	ITS technologies help safety: • Specifically, automated highways technology allow you to work in car, but (see 9 above) then you are not in control.	5
11.	Negative effects of technology enabling us to spend more time alone: • Anti-social; • Business, work, activity everywhere—car, home; and • Negative social/work effects of telecommuting.	5
12.	Technophobia, cultural backlash, Luddism.	2

Table D-6: Votes for Driving Forces by Creation Order (Davis, CA) (cont.)

Creation Order	Driving Force	Votes
13.	Income inequality rising: • Dispersion, inequity; • Use of computers dramatically affected by income level, but not by education; and • Information inequity— cant redistribute "information wealth" if people can't interpret information or use it.	6
14.	Increased globalization of economic activity.	9
15.	Increased cultural diversity: • Demographic shifts, e.g., increasing proportion of Hispanic population in the U.S. West and Southwest; • More immigration; and • Interaction with inequity and inequality.	8
16	Industrialization of the Developing World: • Differences in the industrialization of developing countries compared to path of the currently developed countries—"Chinese want computers more than they want cars;" and • Leapfrog of technologies—Developing world more likely to copy "smart car" infrastructure" than the current transportation infrastructure that the developed world is working to modify, e.g., Singapore leads the world in traffic management.	14
17.	Privacy.	17
18.	Mistrust of government around the world.	1
19.	Government Devolution: • Decentralization of decisions, programs, spending down from federal level to local governments, agencies.	2
20.	Information directly to individuals to facilitate personal decision making: • Information access leading to "personal accountability."	0
21.	Mistrust of the media: • Inaccuracies, sensationalism, perspectives driven by concerns for sales (readership), not facts.	0
22.	Economic Factors: • Tax revenues, • Personal income, and • Corporate profits.	26
23.	Mistrust of technology companies: • Prioritization of search results in web search engines can be purchased, U.S. Federal Justice Department investigation of Microsoft Explorer.	1

Table D-6: Votes for Driving Forces by Creation Order (Davis, CA) (cont.)

Creation Order	Driving Force	Votes
24.	Environmental, as well as other broader, government policy: • Clean Air Act, • ZEV Mandate, • NEXTEA, and • Affect on policy of scientific uncertainty regarding the importance in the future of various pollutants.	21
25.	• Status imparted by having the latest new thing—Boomers. • Elderly—not wanting to be isolated, left behind. [Leads to 26.]	0
26.	Market segments, target groups: • End of the "mass market," must market to elderly, young, "boomers," "genX," etc.	3
27.	Effect of technology on urban form: • New buildings • Concentration of land use vs. urban sprawl • Loss of habitat	4
28.	Changing business model, end of monopolies: • Complex, adaptive, "biological" system of competition; • The network is the computer; • Multiple nodes; and • New types of planning, linear planning obsolete, not "top-down," centralized planning in transportation will be complicated.	15
29.	Market acceptance by public: • Willingness to pay for private toll roads, navigation systems in cars, etc. seems low; • If willingness to pay is high, industry will provide services; if willingness to pay is low, government will have to subsidize; and • What will people pay for information?	36 [1]
30.	Other information services and service costs vs. ITS: • Cable television, internet access, etc.; • Other types of internet access; and • Radio traffic reports—are people already satisfied?	13
31.	Shifting household expenditure patterns: • Consumer electronics, and • Relative value of time and money.	0

1. Market acceptance by public was later removed entirely from the list, and all the votes given to it were reallocated to other driving forces. The vote totals in this table, for all other driving forces and environmental factors, reflect the "reallocated" votes. See text below the "meta-driving forces and environmental factors" table for further explanation.

Table D-7: Votes for Environmental Factors by Creation Order (Davis, CA)

Creation Order	Environmental Factors	Votes
32.	Market development strategy, market segmentation: • Early markets might by "progressive" boomers and gen-Xers, and • Top down or bottom up roll-out—put technology in a few luxury cars at first, or in a wider variety of cars that are not intended solely for the luxury market.	0
33.	Global warming.	9
34.	Economic development in the developed countries.	0
35.	Internet could obviate other information technologies.	25
36.	Data collection.	7
37.	Telecommunications Act.	2
38.	Giveaway models of doing business, also taken from Internet.	6
39.	Restructuring business: • May not be able to own information, then how does an information business make money?	0
40.	Personal security: • Aging of America may indicate a market for travel information and navigation services.	10
41.	Public sector forced to distribute information for free if citizens feel they have already paid for it as taxpayers.	2

Creating "meta-driving forces" and "meta-environmental factors"

Similarities between many of the driving forces and environmental factors caused some difficulty in voting. People saw several natural groupings of forces and factors; in many cases different people identified similar concepts in different forces and factors, and thus while voting for different items, they were in fact voting for the same concepts. In order to reduce the number of forces and factors the group would have to consider and to resolve differences and similarities in meanings, the next step was to debate the creation of groups of forces and factors. Note that the distinction between driving forces and environmental factors was allowed to collapse at this stage. As a first step, all forces and factors receiving fewer than five votes were eliminated from further consideration.

The final list of *meta-driving forces and environmental factors* is shown below. Important details from the discussion leading to this table are summarized after the table. We note here, allowing for the specific method of creating these aggregate categories, that the participants developed this top seven prioritized list of meta-driving forces and environmental factors that will determine the impact of information management systems on transportation systems:

1) Development of the internet as a service provider and business model;
2) Evolving lifestyle issues related to time, new technology and security;
3) State and federal environmental and transportation policy;
4) Evolving traffic congestion;
5) Domestic U.S. economic factors;
6) Globalization of economic activity; and
7) Privacy issues.

We note that the issue that is often assumed to be the driving force behind ITS, i.e., congestion, was ranked only fourth. The impact of the internet, both as an information architecture and a business model was ranked far ahead of any other driving forces and environmental factors. The second and third ranked forces and factors were personal lifestyle related to time, technology and security, and broad environmental and transportation policies. Taken together, we interpret this to mean that the overall context in which information management services will be implemented with respect to transportation systems is far more important than the specific technologies or information services themselves.

We discuss the last two entries in the table of meta-driving forces and environmental factors first. The group spent time trying to decide whether driving force 28—a new business model developing around a complex and adaptive system of competition—was related primarily to the "internet" or the "globalization" meta-driving forces. This issue was never resolved. We note that even if this driving force had been added to the globalization meta-driving force, globalization would not have supplanted the role of the internet as the number one driving force—and globalization would have moved only from sixth to fifth on the list. Finally, even though it was the single most heavily weighted of the individual driving forces, the "market acceptance of ITS by the public" was recognized to actually be the focal issue, and therefore could not logically be both the question and part of the answer. It was removed from the final list of driving forces, and those who had voted for it were allowed to reallocate their votes.

The privacy meta-driving force generated some discussion. Several group members agreed that privacy and trust (mistrust) issues should be grouped as one meta-driving force. Two arguments against this were that trust and privacy were inherently different issues and that trust-related driving-forces (18, 21, and 23) received almost no support from the group.

<u>Other groupings of driving forces and environmental factors</u>

Other groupings of driving forces and environmental factors were recorded by workshop participants. As an example, we show one such grouping next. We offer this set of meta-driving forces and environmental factors not as an alternative to the one derived by the whole group above, but as insight into the nature of the process that must turn several personal perspectives into one group perspective.

Table D-8: Final List of Meta-Driving Forces and Environmental Factors (Davis, CA)

Meta-driving forces and environmental factors	**Component forces and factors**	**Total votes**
Internet	30. Other Services 35. Internet 36. Collection of data 38. Giveaway model	51
Lifestyle	3. Lifestyle simplification 4. Changing work Environment 12. Technophobia, cultural backlash, Luddism 15. Increased cultural diversity 40. Personal security	43
Environmental Policy	6. Alternative fuels, California's LEV policy 24. Environmental, and other broad, policy 27. Urban form 33. Global warming	41
Congestion	2. Future roadway congestion 7. Perception of travel time	39
Domestic economic factors	22. Economic factors	26
Globalization	14. Increased globalization of economic activity 16. Industrialization of the Developing World	23
Privacy	17. Privacy	17
Complex, adaptive system of competition	28. Complex, adaptive system of competition	15
Market acceptance of ITS by public[1]	29. Market acceptance of ITS by public	36

1. Market acceptance of ITS by public was removed from the final list of meta-driving forces. See text below.

Table D-9: Example of Alternative Grouping of Driving Forces and Environmental Factors (Davis, CA)

Meta-grouping of Driving Forces and Environmental Factors Created by One Participant	Component Driving Forces and Environmental Factors
Economic	1. Price of oil, availability of oil 13. Income distribution 22. Domestic economic factors 34. Economic development in the developed countries
Work Environment	4. Changing work environment 5. Aerospace industry no longer world's technology driver 19. Government devolution
Technology	6. Alternative fuels and electric vehicle technology 30. Other information services and service costs vs. ITS 35. Internet obviating other technologies 36. Data collection
Attitudes and perceptions	7. Perceptions of travel time 12. Technophobia 18. Mistrust of government 21. Mistrust of media 23. Mistrust of technology companies 25. Status of having latest technology 26. Target market segments 31. Shifting household expenditure patterns 32. Market development strategy, market segmentation
Personal	3. Lifestyle simplification 8. Car as an escape from information overload 9. Safety issues around personal control 10. ITS technologies help safety 11. Negative social impacts of technology enabling us to isolate 15. Demographic shifts 17. Privacy 20. Increased flow of information directly to individuals 40. Personal security
Global	14. Increased globalization of the economy 15. Demographic shifts 16. Industrialization of the developing world

Table D-10: Example of Alternative Grouping of Driving Forces and Environmental Factors (Davis, CA)

Meta-grouping of Driving Forces and Environmental Factors Created by One Participant	Component Driving Forces and Environmental Factors
Business Practices	38. Giveaway model 39. Structuring business around product, information, that is difficult to "own" 41. Public sector forced to give away information
Environment	27. Urban form 28. Complex, adaptive, "biological" model of business 33. Global warming
Lifestyle	3. Lifestyle simplification 4. Changing work environment 15. Demographic shifts 40. Personal security

Steps Five: Scenario Logic Structures

Absent development of such a specific logic structure, the workshop proceeded to the next step, refining the scenario world descriptions. Ideally, no more than a few sets of driving forces and environmental factors would be identified in the previous steps. However, this workshop group had developed a set of seven. Given the large number of driving forces that remained after the aggregation process and the time constraints faced by the workshop, the group decided not to take any more time to try to reduce the list further. The purpose of further refinement would have been to develop one, two, or three axes along which the scenario worlds could be placed. That is, if one driving force was thought to distinguish all the scenario worlds, then they could have been placed in relation to each other along that single axis. Similarly, two-axes would have defined a plane in which the scenario worlds could be shown relative to each other.

Step Six: Scenario World Descriptions

Participants were provided with initial, scenario world descriptions that were developed at the Washington, DC workshop. Notable changes made by this workshop to these initial scenarios are indicated below. The complete summary descriptions of the scenario worlds from this workshop are shown in Table 20.

Industry World

Description

- FHWA (and the U.S. Congress) will authorize the conversion of the Federal InterState system to toll facilities.
- In the year 1999, an open architecture information management system will start to be installed in automobiles. This system will encompass in-vehicle information and navigation functions—to the exclusion of single service technologies that are incompatible with the architecture.
- Multiple, new start-up companies will provide information services.
- Satellites provide ample bandwidth for multiple in-car services by the year 2000.
- Since proprietary, single function information technologies are not favored in this world, the existing example of General Motors ordering 400,000 embedded in-vehicle navigation units is stricken from the scenario description.
- Noted that the "Big Players" listed in the sixth driving force are not, as of now, big players in ITS.

Driving Forces

- ITS is a "splash" market for the information industry—a market that can be captured at little additional cost because the necessary technology and systems are already being developed for other applications.
- Invisible "push" technologies will drive ITS. Push technologies are those that take information about users, create customized information packages, and narrow-cast, or push, that customized information back to users.
- Information management systems will produce and provide high quality, personal data.
- Information management systems will be built to communication and computer industry standards, not automotive industry standards.

Possible Logic Axes

- No significant changes.

Government World

Description

- Government becomes more competitive.

Driving Forces

- Eliminate the driving force stating that their will be lock-in to specific technologies based on the development of a national architecture.
- Political adoption of open standards. Purpose of National Architecture is to eliminate closed architectures.
- Leveraging open standards to produce

--efficient information management, and
--and dual use—public and private.

- Government focuses on simplifying and improving operations, a by product of which is information beneficial to end users

Possible Logic Axes

- Change last two logic axes related to information availability and quality. Information not limited to public markets, but rather to benefit of end users.

Public/Private Partnership World

A question that was not entirely resolved by the participants was who would be generating the high quality data in this world. If the private sector generates the data, would it be of higher quality than the data generated by public actors? Would data be more or less trustworthy? Will consumers have more or less recourse if data is poor or false?

Description

- It would not be government mandates (for example, from NEXTEA) driving placement of telecommunications infrastructure right-of-way, but rather negotiations between public and private partners.

Driving Forces

- Rich, broad data comes out of public/private partnerships.

Logic Axes

- Willingness-to-pay is low to moderate.

Step Seven: Market Penetration Estimates

Finally, to address the need for market penetration estimates for the modeling phase of this research, small groups were formed to assess each scenario world and generate market penetration estimates for each of the four ITS technologies selected as the focus of this research (see following section).

Table 21 presents the market penetration estimates generated for each of these technologies by the participants of the Davis, CA workshop. These market penetration estimates will be used as a basis for the modeling effort described in the following section to capture the ITS environmental impacts in each of the future scenarios that were developed. The modeling effort is described in the following section.

Table D-11: Davis, CA Scenario Workshop Participants

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