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AUTOMATED HIGHWAY SYSTEM FIELD OPERATIONAL TESTS FOR THE STATE OF CALIFORNIA: POTENTIAL SITES, CONFIGURATIONS AND CHARACTERISTICS

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ABSTRACT

In 2002, the National Automated Highway System Consortium (NAHSC) is scheduled to complete its work on development of an automated highway system prototype. Upon completion of its mission, NAHSC is likely to be followed by one or more "Field Operational Tests" (FOT) in which ordinary drivers will use automated vehicles on a real roadway, under test conditions. The purpose of this document is to describe possible objectives for such a test, identify potential test sites in California, and evaluate the merits of these sites for conducting different types of tests. The evaluation is based on interviews with local officials, visits to 14 sites around the state and collection of detailed data on these highways. We conclude that there exist many potential FOT sites in California, provided that the federal government pays for a large portion of infrastructure costs, and that the new infrastructure is turned over to local agencies upon completion of the test. The most attractive sites are in suburban locations, where either an existing roadway has substantial surplus capacity or where there is already a desire to construct high-occupancy-vehicle lanes. Alternatives include interurban roadways, of which there are many, and specialized facilities focused on transit or trucking.

Keywords: **Automated Highway Systems (AHS)**
Deployment
Field Operational Tests
Institutional Issues
Site Analysis

EXECUTIVE SUMMARY

In 2002, the National Automated Highway System Consortium (NAHSC) is scheduled to complete its work on development of an automated highway system prototype. Upon completion of its mission, NAHSC is likely to be followed by one or more "Field Operational Tests" (FOT) in which ordinary drivers will use automated vehicles on a real roadway, under test conditions. The purpose of this document is to describe possible objectives for such a test, identify potential test sites in California, and evaluate the merits of these sites for conducting different types of tests.

The report covers a range of topics related to concept development, FOT design, FOT planning and site selection. In Section 2, we review system and market concepts that have been created by NAHSC, with a focus on their relationship to FOTs. We also examine prior research on AHS deployment, the state of electronic technologies in vehicles and prior AHS case study research. Section 3 defines objectives and attributes for an AHS FOT. We assume that an FOT must satisfy at least five criteria from the outset:

- High degree of safety and reliability, to protect both AHS users and conventional traffic.
- Local cooperation and participation
- Cost-effectiveness, minimizing the need for new construction, investment in vehicle equipment and investment in roadside electronics, while achieving test objectives.
- Ability to serve real, instead of purely experimental, trips.
- Ability to conduct desired tests.

The tests themselves are divided into five categories: (1) technology, (2) user/non-user, (3) institutional, (4) system, and (5) cost/benefit, with description for each. Test sites are divided into eight categories: (1) urban commuter, (2) suburban commuter, (3) urban shuttle, (4) urban transit, (5) urban truck, (6) interurban, (7) mountainous, and (8) unbuilt, and the general characteristics of these sites are described. Section 4 introduces 14 candidate FOT sites in the State of California. These were selected to provide a representative sample of locations around the state, spanning the eight site categories.

Section 5 discusses AHS FOTs within the context of the transportation planning process and within the context of institutional issues. Summary results are provided from interviews with transportation officials within Caltrans and MPOs around California, and general guidance is provided as to how to successfully implement an FOT.

Section 6 provides the assessment of the 14 candidate sites. We conclude that there exist many potential FOT sites in California, provided that the federal government pays for a large portion of infrastructure costs, and that the new infrastructure is turned over to local agencies upon completion of the test. The most attractive sites are in suburban locations, where either an existing roadway has substantial surplus capacity or where there is already a desire to construct high-occupancy-vehicle lanes. Alternatives include interurban roadways, of which there are many, and specialized facilities focused on transit or trucking.

General report conclusions are offered in Section 7. We recommend that future FOT sites be selected through a competitive bid process, so as to minimize the federal project cost and to ensure local commitment to the project. We believe that with adequate federal funding for infrastructure construction, many local agencies within California would respond to such a solicitation. California could prepare for a future federal solicitation through a solicitation of its own, perhaps offering state matching funding to the most promising local sites.

The report's appendix contains detailed comments from interviews with local transportation officials, data on candidate sites and a review of electronics technologies in vehicles.

1. INTRODUCTION

Highway automation entails the use of electronic sensing, communication and computation technologies to control the movement of vehicles along limited access highways. In complete automation, the vehicle's braking, steering and throttle are all computer controlled while traveling on a highway, with the driver providing, at most, guidance in selecting the path from origin to destination and input to emergency systems.

In 1995, the United States Department of Transportation funded the creation of the National Automated Highway System Consortium (NAHSC). NAHSC's mission is to

> specify, develop and demonstrate a prototype Automated Highway System (AHS) by the year 2002. The prototype AHS will provide fully automatic vehicle operation in dedicated lanes to make travel safer and more efficient, improve the mobility of people and goods, increase the productivity of surface transportation and contribute to a better quality of life.

Upon completion of its mission, NAHSC is likely to be followed by one or more "Field Operational Tests" (FOT) in which ordinary drivers will use automated vehicles on a real roadway, under test conditions. The purpose of this document is to describe possible objectives for such a test, identify potential test sites in California, and evaluate the merits of these sites for conducting different types of tests.

Because AHS are still in concept development, it is impossible to identify the exact conditions under which an FOT will take place. However, it is possible to identify some of the inherent advantages and limitations of an AHS FOT on a site specific basis so as to create a realistic FOT test plan in the future. This is our aim.

1.1 Background on AHS

In concept, automated highways are not a new idea. Chayne wrote in 1960 of research at General Motors (GM) in which a "car's front wheels are automatically positioned by responding to signals picked up by tuned coils mounted on the front of the car. The coils sense a magnetic field produced by a current carrying wire in the road." Later, in 1972, Wanttaja describes a "Metro Guideway" transportation system that uses a "common automated roadway and an integrated multimode system of automatically controlled vehicle for public transportation, personal private transportation, and goods movement." Again in 1982, a major study on AHS was completed at General Motors under contract to the US Department of Transportation (Bender et al, 1982). In fact, research on highway automation has taken place on-and-off over the last 40 - 50 years at such places as General Motors, Ohio State University, Carnegie Mellon and RCA.

The current effort toward automation has its roots in the automated highways program at Partners for Advanced Transit and Highways (PATH), supported by the California Department of Transportation (Caltrans). Research began there in the late 1980s on a concept in which vehicles would travel within closely spaced platoons, with vastly higher traffic volumes than the present. Vehicle mounted sensors would measure the distance from each vehicle to its immediate predecessor, along with detect vehicles in adjacent lanes and potential hazards. Vehicles would communicate to each other within platoons, and communicate to the roadside for traffic management purposes (Hedrick et al, 1994; Varaiya and Shladover, 1991). PATH developed a steering control system that is reminiscent of the GM's system, with the exception that roadway mounted magnets replace current carrying wire. PATH also developed a longitudinal control system that utilizes a forward-looking radar to sense vehicle separation that is combined with vehicle-to-vehicle communication as input.

Based in part on the success of PATH, and in part on the general impetus of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 to develop transportation technology, the Federal Highway Administration has funded two successive AHS development efforts. The first, called the Precursor Systems Analysis (PSA) program, contained numerous studies on AHS related issues, such as control, deployment and infrastructure (FHWA, 1995). The PSA program concluded in 1994, but it was immediately followed by the launch of NAHSC. By congressional directive, NAHSC was charged to demonstrate an AHS by the year 1997 and to develop a prototype AHS by the year 2002. NAHSC's core members are Bechtel, Caltrans, Carnegie Mellon University, Delco, General Motors, Hughes, Lockheed Martin, Parsons Brinckerhoff and PATH.

NAHSC (1995) has created a set of targets for an end-state AHS to guide its development efforts. These targets follow from program principals outlined in FHWA's original solicitation to form an automated highways consortium. The following is a partial list of targets from NAHSC (1995):

〈 An AHS will safely operate properly equipped vehicles under automated control on properly equipped lanes.

〈 Human errors and inefficiencies will be virtually eliminated when all vehicles in the lane are fully automated.

〈 The fully automated AHS will be developed through a planned progression from today's vehicle-highway system.

〈 An AHS uses modern electronics to safely and efficiently move AHS equipped vehicles along instrumented, dedicated lanes under fully automated vehicle control with no driver involvement required.

〈 Manually driver vehicles will be denied access to the AHS lanes.

〈 On conventional lanes the driver may choose to use partial automated vehicle control capabilities...

〈 AHS will be able to accommodate private, commercial and transit vehicles. The extent of support for each type of vehicle is likely to be a local implementation decision.

NAHSC has the goal to develop a system that "offers the potential for dramatic changes in the driving experience, such that safety would be vastly increased and drivers would be free from the stress of driving in heavy, congested traffic." (NAHSC, 1995) That system is intended to produce benefits in many areas, including benefits to users, benefits to society, benefits to state and regional transportation agencies, benefits to communities and benefits to U.S. industry.

To accomplish its mission, NAHSC must complete four principal tasks: (1) Develop and select a system configuration, (2) Conduct a feasibility demonstration in 1997, and (3) Design, develop and test an AHS prototype. In support of these tasks, NAHSC is also charged with establishing performance objectives and specifications, assessing and developing enabling technologies, and addressing critical institutional and societal issues. The end product of NAHSC will be a tested AHS prototype that is ready to move into the next stage of development: product testing through a field operational test.

In addition to NAHSC, Caltrans has its own research program in automated highways through the Vehicle Safety Systems area of its New Technology and Research Program (Caltrans, 1996). Caltrans projects that AHS will enter an operational evaluation phase sometime after 2002, which will continue through the year 2010. "Threshold deployment" of AHS is projected to take place sometime around the year 2015.

1.2 Study Objective

The objective of this study is to describe possible objectives for an AHS FOT, identify potential test sites in California, and evaluate the merits of these sites for conducting different types of tests. The AHS FOT is viewed as a follow-up activity to NAHSC, to be funded at least in part by the US DOT. The goal of the FOT is to test safety-assured technologies with real users under test conditions, so that the AHS can be fine-tuned to produce the most favorable ratio of benefits to costs under full deployment.

The remainder of this report is divided into six sections. Section 2 describes system concepts and deployment concepts for AHS, with focus on their relationship to FOTs. Section 3 creates a set of attributes and objectives for AHS FOTs. In Section 4, potential sites for an AHS FOT in California are introduced and described. Section 5 describes how FOT planning would be accommodated within transportation planning processes and associated institutional issues. Section 6 evaluates the merits of these sites for conducting different types of FOTs. The report ends with Section 7, which provides conclusions and recommendations. An appendix provides detailed descriptions of potential FOT sites, transcripts from interviews and a review of in-vehicle electronics.

2. SYSTEM AND DEPLOYMENT CONCEPTS AND THEIR RELATIONSHIP TO FIELD OPERATIONAL TESTS

The scope and character of an AHS FOT will depend on three major factors: (1) The design and features of the NAHSC prototype, (2) The system configuration for the end-state, fully deployed, AHS, and (3) Plans for deploying AHS technologies between the time of the FOT and the fully automated "end-state". With these factors in mind, this section reviews AHS system configurations and deployment plans as they exist today. At this point, the specific features of the prototype have not been addressed; therefore, this issue will not be covered.

2.1 AHS System Configurations

Within the product development process, a "concept" is defined as an "approximate description of the technology, working principles, and form of the product. It is a concise description of how the product will satisfy customer needs" (Ulrich and Eppinger, 1995; Stevens, 1993, defines concepts within the context of AHS). In essence, a concept is a high level description of the functions performed by a product, its method of operation, and how it meets requirements. A concept is considered to be a precursor to developing the "product architecture," which both defines the functionality and defines the elements that constitute the product and how they interact (see Hall, 1995, for product architecture as it applies to transportation). The product architecture, in turn, is the precursor to more detailed levels of design and testing. As NAHSC defines it, a "system configuration" is analogous to a product architecture, with the addition that some of the technological choices are incorporated in the configuration.

NAHSC is investigating five concept families that are defined by distribution of intelligence between vehicle and infrastructure, as well as other attributes. Sometime in the future, these concepts will be narrowed to a single configuration. The concepts are as summarized as follows:

Independent Vehicle Concept: Vehicles will have a "high degree of autonomous operation", allowing them to operate with or without roadside systems. An objective is to develop vehicles that can operate automatically when mixed with manual traffic.

Cooperative: Vehicles have the capability to broadcast messages and to receive messages broadcast by other vehicles or the roadside, in addition to possessing sensing capabilities.
Operating rules are established to ensure vehicle coordination, but vehicles will have on-board sensors to view the surrounding area.

Infrastructure Supported: In this concept, the infrastructure plays an active role to enhance performance. Automated vehicles would travel on dedicated lanes, which use infrastructure intelligence to support decision-making at the vehicle level.

Infrastructure Supported: The infrastructure now provides additional support by way of two-way communication with vehicles to help coordinate vehicle maneuvers during entry, exit, merging and emergencies.

Maximally Adaptable Concept: This concept envisions a set of standards by which vehicles could operate under a variety of conditions, depending on local design decisions. Adaptability would allow a vehicle to operate under infrastructure supported mode in one location, and under independent mode elsewhere, to take an example.

Concept details can be found in the NAHSC task C2 final report (NAHSC, 1997a).

An AHS FOT may be designed to emulate an end-state AHS concept (such as any of the above), or may be designed to emulate some earlier stage of deployment. If designed to emulate an end-state concept, the FOT could be designed to represent operating conditions that are less demanding than the end-state, in terms of traffic volume, climatic conditions, road conditions or mixing of vehicle classes, types or states of repair.

2.2 AHS Deployment Plans

From the standpoint of product development, the NAHSC program is unusual in that the product being developed is likely to be the successor to various intermediate products, which have not yet been fully defined. These precursor concepts fall within a framework that is commonly called a "deployment plan." The deployment plan defines a sequence of deployment steps that lead to the desired fully automated end-state. Equally important, achieving the AHS end-state depends on a plan for developing the enabling technologies, as well as legislation and standards. Over the course of the next 20 years, these technologies will be in varying states of development and in varying states of deployment (as represented in market penetration and fleet penetration).

An FOT is one of the steps in the product development process, and should be viewed as a precursor to deployment. Just as deployment of enabling technologies is likely to be sequential, it is also possible that FOTs will sequentially test increasingly sophisticated technologies. Because it is unclear whether the first FOTs will be designed to test end-state technology, interim technology or some combination thereof, AHS deployment is an important consideration in planning for FOTs

2.2.1 Studies on AHS Deployment

For many years, AHS deployment planning has been an important challenge that seems to invite speculation more than analysis. Though many authors have proposed plans and planning objectives, there is little evidence to show that one plan is better than another, or that any level of planning could achieve a desired end-state in automation. Nevertheless, the issue is important to consider, and especially important to consider in the design of FOTs.

Deployment planning was proposed as early is 1989 in a paper by Johnston et al, but grew in prominence through the PSA program and the efforts of Ward (1993, 1997). Ward argued for an evolutionary deployment that "represents an essentially seamless and non-disruptive deployment. It postpones the need for major infrastructure modifications until there is a substantial population of instrumented vehicles capable of taking advantage of them." Ward's incremental approach envisioned an "autoplatooning process" in which capacity would be increased through the spontaneous formation of platoons among instrumented vehicles.

At about the same time as Ward's effort, Ioannou (1994) proposed five "evolutionary representative system configurations," beginning with collision warning systems and moving through a hierarchy of assistance and collision avoidance technologies to full automation. Other planned deployment sequences can be found in Blancett et al (1997), Hall (1997a), Stevens (1997) and Tsao (1995). Al-Ayat and Hall (1994) offer guidelines for comparing deployment plans. More recently, NAHSC (1997a) has defined deployment stages for each of its five concept families. These represent staged introduction of system features.

The market penetration aspects of AHS deployment were studied by Hall (1996), who examined sales trends for other new technologies, such as cruise control and air bags. If supporting AHS technologies follow similar trends as other technologies, it will optimistically take 3 to 10 years from introduction until a technology reaches 20% penetration of new car sales and 5 to 18 years from introduction until a technology reaches 20% of the vehicles on the road. The implication is that it will take a long time before a lane dedicated to AHS would have a large population of potential users. However, unlike most prior vehicular technologies, AHS technology may lose considerable functionality without the construction of new infrastructure. This may well extend the time until reaching higher market penetrations.

2.2.2 Deployment Concepts from NAHSC

NAHSC is in the process of developing a set of AHS related "market packages" and "automated vehicle control services" as a means for deployment planning. Candidate packages (those potentially appropriate for NAHSC development and prototyping) include side collision avoidance, lane departure avoidance, adaptive cruise control, fully automated on dedicated lanes, and fully automated in mixed traffic. The automated vehicle control services is a much longer list, which is divided into nine categories:

1. Situation warning in mixed traffic,
2. Temporary emergency control in mixed traffic,
3. Continuous partial control in mixed traffic,
4. Integrated emergency control and continuous partial control in mixed traffic
5. Fully automated control in mixed traffic,
6. Background warning and control in mixed traffic,
7. Continuous partially automated control on dedicated lanes,

8. Fully automated control and dedicated lanes, and
9. Miscellaneous services.

For each service, NAHSC (1997 b,c,e) identifies sensing and control requirements and performs an initial assessment with respect to technical feasibility and benefits.

2.3 The State of ITS Technology in Vehicles on the Market

Appendix II describes AHS related technologies that are currently for sale as optional or standard features in motor vehicles. In recent years, computer controlled vehicle systems have become increasingly common, including anti-lock braking systems (ABS), Electronically Assisted Power Steering (EAPS), cruise control systems and radar based collision warning systems. These systems, when designed to AHS specifications, represent a logical step toward a fully automated vehicle.

The 1997 AHS Demonstration includes a fleet of 10 specially equipped Buick LeSabres, each of which includes

〈 magnetometers for sensing lane position
〈 acceleration, yaw and pitch sensors
〈 vehicle-vehicle data transmission
〈 forward-looking radar to measure the distance to preceding vehicle
〈 computer controlled braking, throttle and steering

A fully automated vehicle would also require side-sensors to detect vehicles in adjacent lanes.

With rapid growth in vehicle electronics, by the time of the FOT it should be easier to install specialized AHS equipment within vehicles. However, electronics have not reached the point where an FOT could retrofit a diverse population of vehicles owned by participants. Instead, a limited production run of FOT vehicles would have to be manufactured to specification. An integral step will be identifying a manufacturer for these vehicles.

2.4 Deployment Analyses

Both NAHSC and the earlier PSA program included studies of potential sites for AHS deployment, either as a fully automated highway or as an early deployment project. Examples include:

〈 Hollywood Freeway, Los Angeles (US 101), PSA
〈 Katy Freeway, Houston, NAHSC
〈 Lincoln Tunnel, New Jersey/New York (I-495), PSA
〈 Long Island Expressway, New York (I-495), PSA

The Hollywood Freeway deployment (Yim et al, 1997; Miller et al, 1994) study was part of a larger project that surveyed highways throughout California to identify design features (such as overpasses and retaining wall restrictions) that could prove challenging for AHS. The Hollywood site was chosen for case study analysis because it contained the "greatest challenge to AHS deployment" among a set of more than 50 candidates. Conceptual designs were developed for the AHS roadway and its interchanges for the Hollywood Freeway, along with some less challenging rural sites. In addition to the Hollywood Freeway, case studies were included for a 10 mile stretch of I-5 in the Central Valley, a 13 mile mountainous portion of I-5 in the Tehachapi mountains, and a 19 mile section of SR 99 between Fresno and Sacramento.

Delco examined deployment of three different AHS configurations (infrastructure centered platoon control, vehicle centered platoon control and space-time slot control) on the I-17 in Arizona. Both an 8-mile urban section in Phoenix and a 44-mile rural section were studied. The authors concluded that shoulders are desirable to provide continuous operation of automated lanes when incidents occur, that AHS lanes can be narrower than the present, and that travel times would be more reliable than the present.

Battelle examined risks and issues related to deployment of AHS based on four types of sites: urban (I-10 in Phoenix), rural (I-10 between Phoenix and Tucson), fringe (I-394 at the urban fringe of Minneapolis) and small population center in a rural area (I-35 through New Braunfels, Texas). Spatial requirements (e.g., shoulders, barriers and frontage), infrastructure and construction were all studied. The study concluded that the costs to convert lanes to AHS would be $3.6 to $41 million per mile. Exclusive AHS lanes would be most easy to implement on freeways that have dedicated HOV lanes with separate entrance and exit facilities. The authors also concluded that it may be easier to construct elevated sections in some urban areas rather than attempt to acquire additional right-of-way. Finally, they felt that AHS roadway design should be tailored to the site and generalizations should be avoided.

The Calspan study also examined the impact of AHS implementation on different types of sites, including urban (I-93) in Boston, suburban (I-495, Long Island Expressway and Maryland I-495), and rural (New York State Thruway from Harriman to New Paltz). Calspan also evaluated commercial and transit AHS applications and found the Lincoln Tunnel - Exclusive Bus Lane (XBL) on I-495 to be a highly suitable application for AHS for the following reasons:

〈 The XBL moves more people than the other three lanes combined (about 30,000 per hour in peak hours versus 3,000 each in peak hours)
〈 Capacity addition through additional access lane and/or boring another tunnel would be prohibitive in terms of cost and capacity augmentation through AHS seems to be the most cost-effective solution.
〈 AHS would smooth out the flow of buses and improve travel time reliability.
〈 Short length (less than 5 miles)
〈 A smaller pool of buses using the XBL repeatedly (less than 1500).
〈 All buses are property of NJDOT.

The potential problem with this site is the bottleneck that would be created at the Manhattan side of the tunnel at the Port Authority Bus Terminal.

The Katy Freeway case study (NAHSC, 1997d) focused on a reversible HOV lanes in the median of the Katy Freeway, which would be automated to support both cars and buses. The ability of the highway to accommodate varying traffic levels was evaluated for each highway automation concept, on a location specific basis. Design features were also evaluated for entrance and exit from the highway. NAHSC has recently embarked on additional case studies in Southern California and in the Chicago area.

3. ATTRIBUTES AND OBJECTIVES OF FIELD OPERATIONAL TESTS

A field operational test (FOT) evaluates new technologies under conditions that approach or approximate fully deployed operation. As stated in Bolczak (1992), "Operational tests are, in general, joint public/private ventures, conducted in the real world under live transportation conditions. They serve as the transition between Research and Development (R&D) and the full scale deployment of IVHS technologies." FOTs have been used extensively within the Department of Transportation's (DOT) Intelligent Transportation System (ITS) Program. Typically, these tests are administered as a partnership between a state or local transportation agency, a private contractor, and a third party evaluator (usually a non-profit institution, such as a university). FOTs have been used to test technologies in a variety of areas, including traveler information systems, adaptive signal control systems and bus tracking and fleet management systems.

An FOT is intended to assess the benefits and problems with new technologies prior to their full-scale deployment. In this context, the FOT is intended to determine which technologies are most promising, and to help refine and enhance technologies that need improvement. The FOT evaluation is key to this effort on several levels:

- Technical evaluations, (e.g., system reliability and attainment of performance specifications)
- User and non-user evaluations (e.g., surveys of user perceptions and behavioral changes)
- Institutional evaluations (e.g., organizational effectiveness)
- System performance evaluations (e.g., effects on congestion, pollution or safety)
- Cost/benefit evaluation (i.e., whether the system benefits justify the costs)

As a whole, the evaluation assesses whether the technology is viable at a technical level and whether it will be beneficial, in light of the expenses.

It should be borne in mind that an FOT is not supposed to be the testing ground for highly experimental technology, unless that technology cannot be otherwise tested in a laboratory setting. Within the parlance of product development, an FOT is akin to a "beta" test, which is a secondary level of testing conducted with a limited set of real users. A beta test follows "alpha" testing, which focuses on proof of concept and verification of product specifications. A beta test is used to shake out product defects, develop marketing plans, and make final refinements. Beta tests are designed to discover problems (and improvements) that materialize in operation by real users in real operating environments.

As in all product development projects, an AHS beta test (i.e., FOT) is distinguished from prior alpha testing in its incorporation of real users. That is, an AHS FOT must utilize the driving public as direct participants. For this reason, it is essential for the underlying technology to be verified and tested prior to its application within an FOT to attain a very high level of safety assurance and reliability. Without a high level of confidence in the technology, the FOT would place the users at unjustifiable risk, and place the technology at an unacceptable risk of losing market, industry and government acceptance

In the case of AHS, an FOT should not be viewed as a single test but as a series of coordinated tests designed to experiment with and measure various aspects of the system. Tests may be conducted in different locations and at different times, both to compare the effectiveness under different operating concepts and to test the effect of location and time specific conditions (such as weather patterns and traffic flow conditions).

One aspect of the system that probably cannot be tested in an alpha setting, and will almost certainly require an FOT, will be operation with large numbers of vehicles. These tests will likely center on higher-level control issues (defined as the link layer or higher in Varaiya and Shladover, 1991), driver decision-making and user satisfaction and perception. However, at least initially, an FOT is unlikely to produce the very high traffic volumes envisioned for later stages of AHS (though high volumes might be approximated over short time intervals). At an institutional level, the test as a whole will be used to evaluate the potential obstacles and incentives for creating an AHS. However, lower level controls and enabling technologies must be fully tested with professional drivers prior to their deployment within an FOT setting to provide safety and reliability assurance.

3.1 Field Operational Test Objectives

We assume here that the purpose of the FOT is to test AHS technologies that either provide partial automation or complete automation of driver functions. Partial automation would provide, at a minimum, automated lateral control (i.e., steering) or automated speed control. Partial automation might also entail both speed and steering control while traveling in isolated lanes (i.e., no intermediate entrances and exits and no lane changes). We do not explicitly consider FOTs that do not entail significant infrastructure, such as some collision warning or avoidance systems. Though many of the objectives and features of such an FOT would be similar, significant differences in roadway mounted equipment (and whether the test is site specific) merit separate consideration.

To achieve success, an FOT must satisfy at least five criteria from the outset:

- High degree of safety and reliability, to protect both AHS users and conventional traffic.
- Local cooperation and participation
- Cost-effectiveness, minimizing the need for new construction, investment in vehicle equipment and investment in roadside electronics, while achieving test objectives.
- Ability to serve real, instead of purely experimental, trips.
- Ability to conduct desired tests, at technical, user and institutional levels.

It is desirable, but not essential, for the FOT to produce immediate benefits, such as congestion relief or safety, to participants or the community. However, as with all FOTs conducted to date, these benefits are secondary to testing, which serves the greater purpose of developing a deployable technology. On the other hand, it is just as important that the FOT not cause any harm to the community, as this would certainly detract from the objective of attracting their cooperation and participation.

Safety and Reliability is established through design and testing under conditions that approximate actual operation, but do not expose real users to any safety risk. Tests are conducted through use of models, component tests, and full-scale tests with professional drivers on isolated facilities.

Local Cooperation and Participation can be assessed through the willingness of local and state agencies to open up their facilities to the test, and to a degree their willingness to provide monetary or in-kind commitment to the project. Staff from local and state agencies will almost certainly be needed in planning and design phases for FOT related roadway construction. Local cooperation and participation can also be assessed from the willingness of fleets to join the project and by the attitudes of citizens and businesses toward testing in their vicinity.

Cost-effectiveness can be assessed through the infrastructure and fleet costs associated with a particular site or test. Due to the high cost of retrofitting vehicles for AHS, cost-effectiveness will likely demand that the test fleet come from a single vehicle model, or from a limited number of vehicle models. These vehicles will be manufactured exclusively for the test in a batch production run. The models may build off a commercial platform, but are likely to be unique in many ways, including the installation of sensor, communication and control systems. Economy will be a consideration in selecting the specific model, taking into account baseline control equipment, ability to install requisite hardware within an unmodified vehicle body, normal selling price, and financial participation.

Economy will also be a factor in evaluating a particular site, including the need to construct additional lanes to conduct the test, the ability to add lanes without having to retrofit bridges or acquire new right-of-way, and the existence of communication infrastructure and supporting electronic technology. On the back-end of the project, the ability to re-use the facility after completion of the test (perhaps as an HOV lane or as a fully deployed AHS or permanent test facility) is another factor in making the FOT cost-effective. On the front end, the ability to re-use a prototype test facility, such as the I-15 freeway, for an FOT would also lend itself to cost-effectiveness.

Ability to Conduct Tests will be a function of the facility design, topographic and climatic conditions, characteristics of vehicles using the facility (e.g., the number of trucks and cars), and characteristics of the facility users (e.g., trip patterns and demographics). This will be a direct product of the evaluation test plan. For example, if the objective of the FOT is to perform tests under less demanding conditions, it could be desirable to select a site with little rain, rare visibility problems, no challenging curves or inclines, excellent pavement conditions and low traffic volume. If the objective is to test the system under a range of conditions, then a site that has imperfect road conditions and experiences seasonal weather and heavier traffic loads might be preferred.

3.2 Types of Tests

As stated earlier, an FOT is not intended to demonstrate whether a technology works or does not work so much as to refine the technology based on real user experience under actual operating conditions. The following provides general classifications for tests that could be conducted during an FOT. Most of these classifications apply equally well to a test of partial automation as to a test of full automation. In either case, we assume that the technology has been proven from the standpoint of safety and reliability prior to the FOT.

3.2.1 Technology Tests

Entry/Exit Control: Assessment of alternative methods for controlling entry of vehicles into the system and exit back into the normal traffic stream.

Link Level Control: Assessment of alternative strategies for assigning vehicles to lanes, controlling vehicles speeds and controlling vehicle headways.

Obstacle Intrusion: Assessment of methods meant to prevent the intrusion of obstacles into the AHS, along with associated safety risks.

Vehicle Maintenance: Assessment of whether the required technical performance of vehicles and infrastructure can be maintained by real users and real transportation agencies.

3.2.2 User and Non-user

Behavior: Assessment of the conditions under which participants use the system, how they use the system, and how the system affects travel patterns.

Human Factors: Human factors based experiments testing how system functions are used, how easy they are to use, and the comparative ease-of-use for alternative interfaces and functions. In addition, experiments could be conducted to measure mental work load, attention and human errors.

Satisfaction/Perceptions: Surveys, focus groups and interviews to measure both user and non-user attitudes toward the system (e.g., likes and dislikes), suggestions for improvements, and willingness to pay.

3.2.3 Institutional

An institutional evaluation can be used to assess the obstacles to planning and executing future AHS deployments. This can include examination of human and financial resource issues, environmental issues, legal and liability issues, organizational commitment, public acceptance and competition with other projects. The institutional evaluation can include interviews, focus groups, direct observation of stakeholders and review of project documentation (such as minutes).

3.2.4 System

Safety: Compared to baseline conditions, the frequency (and existence) of collisions can be measured, along with the frequency in which the system enters hazardous states, to eliminate potential system faults.

Congestion: An FOT is unlikely to have significant effects on congestion due to its limited scale. However, measures of lane throughput might be used to estimate congestion effects under full deployment. Also, the degree to which AHS entrance and exit affect adjoining manual traffic could be assessed.

Energy Consumption: Through vehicle instrumentation, energy consumption per kilometer of travel could be measured, possibly to estimate benefits due to platooned operation or smoother travel.

Pollution: Through vehicle instrumentation, emissions per mile of travel could be measured, possibly to estimate benefits due to platooned operation or smoother travel.

3.2.5 Cost/Benefit

Cost benefit analysis would integrate the results from other evaluation elements to assess the potential user and system benefits under fully deployed operation, to determine whether and where AHS is most viable.

3.2.6 Data Collection/Experimental Design

To complete the evaluation, an FOT must provide extensive data collection capabilities, from participants, non-participants, vehicles and institutions. For instance, it will be desirable to equip each vehicle with data-logging equipment and a GPS receiver to track the state and location of the vehicle at frequent polling cycles, and to collect data over very frequent cycles prior to and following critical events. The interior of some vehicles would be equipped to track the alertness and attention of the driver (e.g., with eye tracking equipment). Roadway mounted sensors to collect data on traffic flows and traffic density would also be needed, possibly employing video-image-processing technology. It may also be necessary to instrument non-AHS vehicles for data collection to measure impacts of the AHS on the manual traffic stream.

Data collection requirements would be specified within an FOT evaluation plan. Other important factors that would be specified in this plan include:

Participant Selection Travel characteristics along with demographics are important both to provide cost-effectiveness (i.e., ensure that participants regularly travel through the test site) and diversity (e.g., different income and educational levels and English skills). Participants would be recruited to attain a desired stratification of participant groups. Participants may also be selected based on their ability to maintain vehicles or by the ability to control maintenance. It may be preferred to work with a single corporate fleet, for instance. Finally, participants could be selected on the basis of vehicle classification, for example, if the desire is to perform a test on a certain weight range of heavy-duty vehicles.

Experimental Grouping Participants can be grouped according to the nature of their AHS usage. In a naturalistic experiment, participants would use vehicles for an extended time period in their ordinary travel (6 months or more). This provides the most accurate representation of travel patterns, but limits the participants to a relatively small group and makes it more difficult to control vehicle maintenance. In a rental study, participants would borrow cars for a short time period (a day to a week or two). This has the disadvantage that it is difficult to train and control participants, and also provides them little time to adapt to the technology. A third variation would be a leased study, in which vehicles might be used for a period of a few months.

Experimental Control Over the course of the FOT, a series of experiments would be conducted to test alternative link level and entry/exit control rules. These must be timed to provide for comparable conditions and statistically significant comparison of results. Control rules could be varied by time of day, day of week, week or month. The timing must account for natural variations in traffic flow, temperature, precipitation and other climatic conditions. Control rules could also be varied by location. In addition, certain experiments may be location specific, for instance testing performance under difficult climatic conditions or under difficult geometric conditions (e.g., curves or grades).

3.3 Field Operational Test Classifications

An FOT is defined by a great many characteristics, pertaining to the roadway, surrounding land uses, climatic conditions and user characteristics. This section provides broad classifications for FOT sites, to be followed in Section 3.4 by some of the more specific factors that define a particular test. The broad classifications are as follows:

- Urban Commuter
- Suburban Commuter
- Urban Shuttle
- Urban Transit
- Urban Truck
- Interurban
- Mountainous
- Unbuilt site

In addition to these classifications, each test is defined by a technology or by a sequence of technologies that are evaluated. For example, a test site might initially be used to test some form of partial automation with respect to safety enhancement, and later transition into a test site for fully automated vehicles. Each section that follows is divided into two parts, first describing the facility and second describing the fleet of participating vehicles.

A test site will also be defined by the physical configuration of the AHS facility. Though we expect that the test will occur on dedicated lanes that are isolated from conventional traffic, the possibilities include:

〈 Completely isolated lanes with dedicated on and off ramps
〈 Isolated lanes, with access via conventional highway lanes (no dedicated ramps)
〈 Isolated lanes for the test, but allowing for a mixture of automated and manual vehicles on the test lanes
〈 Complete intermixing of test vehicles and manual traffic.

In the last case (and likely the third), we expect that the vehicles would not be fully automated, but instead be limited to safety assistance devices. These alternatives are ordered according to decreasing construction cost. However, the primary criteria in selecting a configuration will be safety and ability to conduct the desired tests. As will be seen in the analysis of Chapter 6, some sites are more conducive to isolated lanes than others, while virtually any site, from the standpoint of construction, could allow for mixed traffic.

Urban Commuter An urban commuter test is characterized by a high traffic volume roadway with densely developed surrounding land uses, and a large commuter population.
Due to high traffic volumes, the test roadway is isolated from manual traffic, except at entrance and exit. The facility could initially operate with a single lane and single entrance and exit and later on expand to additional entrances and exits.

Commuters who use the route regularly would be invited to participate in the test. Volunteers would receive an AHS equipped vehicle at a cost below that of competitively priced conventional vehicles. The difference between the price paid by volunteers and the cost of manufacturing the vehicles would be borne by the FOT. As a condition for participation, volunteers would be required to use the AHS facility during their normal commute. A second condition would be participation in user surveys, focus groups, trip diaries and possibly direct measurement of driver reactions in use.

Suburban Commuter A suburban commuter test is characterized by a site within a metropolitan region, with surrounding low-density land uses, and a substantial commuter population. Trips are likely to be long on average and traffic volume is likely to be below capacity during most of the day.

Participant recruitment and conditions would be similar to an urban-commuter site, with somewhat more emphasis on people who travel long distances.

Urban Shuttle An urban shuttle test is characterized by an urban site (high traffic volume and dense development) combined with a large population of regular non-commute users. The facility characteristics are similar to those of an urban commuter site. However, the location would be different, being a highway approaching a major airport or some other major destination frequented by vehicle fleets. An advantage of a fleet orientation is that vehicle maintenance could be more easily controlled.

Fleet owners would be invited to participate in the test on a volunteer basis. These may include airport vans, taxis, or perhaps service/maintenance vehicles. Fleet owners would receive AHS equipped vehicles at a cost below that of competitively priced conventional vehicles. The difference between the price paid by fleet owners and the cost of manufacturing the vehicles would be borne by the FOT. As a condition for participation, fleet drivers would be required to use the AHS facility whenever traversing the AHS equipped route. A second condition would be participation in user surveys, focus groups, trip diaries and possibly direct measurement of driver reactions.

Urban Transit/HOV An urban transit site is characterized by high-occupancy-vehicle lanes, with heavy transit usage in an urban environment. The test facility is isolated from single-occupant vehicles, except at entrance and exit, and possibly isolated from all manual traffic. The test facility is likely to be an existing HOV lane, but could also be a newly constructed facility.

A limited number (most likely just one or two) of transit agencies would be invited to participate in the test. The transit agency would receive AHS equipped buses at minimal or no cost, with subsidy coming from FTA and FHWA. Participating agencies would be required to assign the buses exclusively to routes serving the AHS equipped roadway. A condition for receiving the buses would be participation in patron/driver surveys and focus groups, completion of trip diaries and possibly direct measurement of driver reactions.

Urban Truck An urban truck site is characterized by large commercial truck volumes on a road located within an urban area. The test facility is isolated from manual traffic, except at entrance and exit. Initially the facility operates with a single lane with a single entrance and exit. In later stages of testing, entrances, exits and a second lane may be added. The test facility is possibly a roadway approaching a major port.

Fleet owners would be invited to participate in the test on a volunteer basis. These are likely companies that provide shuttle service between the port and an intermodal rail terminal or drayage facility. Fleet owners would receive AHS equipped trucks or tractors at a cost below that of competitively priced conventional vehicles. The difference between the price paid by fleet owners and the cost of manufacturing the vehicles will be borne by the FOT. As a condition for participation, fleet owners would be required to assign the equipment to the AHS route and use the AHS facility whenever traversing the route. A second condition would be participation in user surveys, focus groups, trip diaries and possibly direct measurement of driver reactions.

Interurban An interurban facility is a roadway that connects major metropolitan areas and passes through a sparsely developed region. The test could be designed to operate as an isolated facility, as a mixed-traffic facility, or possibly some combination. Due to lower construction cost, the facility could be quite long.

A variety of different types of users could be invited to participate in the test, including some combination of trucks, long-distance commuters, and business travelers. The AHS fleet may be somewhat heterogeneous in size and characteristics, though for any class of vehicles (e.g., car, truck, bus), all vehicles are likely to be of the same model. A condition for participation would be frequent use of the test roadway. However, weekly use may have to suffice due less frequent commute patterns. A second condition would be participation in user surveys, focus groups, trip diaries and possibly direct measurement of driver reactions. As an alternative, the AHS vehicles might be rented out to tourists using the roadway. Due to relatively low traffic levels, the test might be designed to evaluate effects of mixed traffic conditions, among AHS and non-AHS vehicles, and among heavy and light vehicles.

Mountainous A mountainous site is characterized by steep roadway gradients, small-radius curves, adverse weather conditions (ice, snow, fog and wind) and relatively low traffic volumes. A mountainous site might be designed to test AHS technologies that are specifically targeted at safety improvements under hazardous conditions, and be *a step short of full automation*.

The participant group is likely to be highly varied, and draw from people who work and reside in the vicinity of the highway. In addition, heavy-duty-vehicles could be a part of the test, including roadway maintenance, tour buses and commercial trucks. Participants would receive their vehicles at reduced cost under the condition of their participation in the evaluation. As with an inter-urban site, participants might be rental car users.

Unbuilt An unbuilt site could be a location where a freeway is currently planned or it could be an entirely new site. The AHS test could then be integrated with a new manual roadway, or alternatively used for the sole purpose of conducting the test. The site could be in an urban, suburban or rural location. However, an urban site is likely to be the most difficult due to lack of available land.

The participant group could be commuters, non-commuters, transit or commercial vehicles. However, unless the site is urban, it would be difficult to involve many buses. Incentives and participation requirements would be similar to other types of tests.

3.4 Attributes of AHS FOTs

At a more detailed level, each FOT is defined be a set of site and test characteristics. The site characteristics depict the roadway and surrounding environment as it would be without the test, whereas the test characteristics depict the elements that are introduced as a part of the test.

Site Characteristics: The site characteristics include descriptions of existing roadways, the site right-of-way, surrounding land-uses and surrounding communities, along with planned non-AHS roadway changes and climatic conditions. The site characteristics are crucial to defining the cost of conducting the FOT, the ability to attract participation, and the ability to conduct certain types of tests. For instance, if the existing roadway has surplus capacity, it might not be necessary to add lanes to conduct the test. On the other extreme, some roadways both operate at capacity and are difficult to expand due to narrow bridges or restricted right-of-way, making the FOT more expensive to conduct. In addition, it may be important to consider planned or desired roadway improvements, within which an AHS FOT might be incorporated. For instance, a newly constructed lane might originally be used as part of an FOT and later be transferred to a conventional use. Not only could this be cost-effective, but could also be an approach for gaining local participation.

Another important site characteristics is the availability of infrastructure to support testing. Test infrastructure would include roadway electronics and sensor for data collection, proximity to research facilities and proximity to maintenance facilities.

Test Characteristics: The test characteristics include descriptions of the participants, the fleet, the AHS infrastructure and the AHS technologies. These characteristics affect the types of tests that can be conducted from technical, user, system and cost/benefit perspectives, and to a degree from an institutional perspective. These tests would be defined in a testing plan, which is beyond the scope of this document (Casey and Collura, 1994 and Bolczak, 1992, provide general FOT evaluation guidelines, which are not specific to AHS.) Especially important considerations are the vehicle classifications (light-duty, truck, bus, etc.), number of vehicles and the AHS technologies.

Table 1 outlines specific attributes that define FOT test sites. (next page)

Table 1a. FOT Site Characteristics

Roadway Characteristics (Existing Roadway)

Physical Characteristics
Number of Lanes, Width of Existing Roadway
Number of Bridges on Mainline, Width, Condition
Number of Bridges Crossing Highway, Width
Number of tight radius curves (and their radius)
Cost/Feasibility of Adding Lane
Number of Entrance and Exit Ramps, Left/Right Positioning
Number of Signal Controlled Intersections (if any)
Length of roadway
Required/planned Expansion or Retrofit and Schedule
Connections to other highways
Grades (maximum ascent, descent)
Roadway surface conditions/Pavement materials

ITS Characteristics
Communication Infrastructure
Traffic/Environmental Sensors
Ramp Metering
Changeable Message Signs
Interconnect to TMC
Interconnect to Arterial Systems

Performance Characteristics
Vehicle hours of delay per day
Accidents/fatalities per 1,000,000 vehicle miles
Average daily traffic level
Average peak hour traffic level
Average daily HOV traffic level
Average daily truck volume

Characteristics of Proposed Right-of-Way

Width of ROW (min/max/variation)
Number/Value of Existing Structures
Property Value of ROW
Number of Streets Crossing ROW
Existing Permits
Required/planned Construction or Retrofit and Schedule
Distances from nearest parallel highways
Connections to existing highways

Table 1a (cont.). FOT Site Characteristics

Surrounding Land Uses

Population density in the immediate vicinity of the site
Property values in the immediate vicinity of the site
Distances from surrounding residences and affected land uses
Noise issues affecting surrounding properties

Surrounding Communities

Location of major trip generators from which participants could be drawn
Vehicle fleet composition for major trip generators
Support of affected municipalities and counties for highway projects
Success of Caltrans District in deployment of ITS related projects
Support of MPO for ITS projects
Compliance with federal/state air quality standards
Water quality issues related to roadway runoff
Noise levels in surrounding residential areas
Population in surrounding corridor
Employment in surrounding corridor
Retail square-footage in surrounding corridor

Climate

Extreme temperatures
Extreme wind conditions
Low visibility situation (fog or dust)
Icing conditions
Annual rainfall and snowfall

Test Facilities

Location of AHS relevant research laboratories in highway vicinity
Location of roadway and vehicle maintenance facilities in highway vicinity
Existing and planned roadway instrumentation for traffic conditions
Existing and planned instrumentation for climatic conditions

Table 1b. FOT Test Characteristics

Participant Characteristics

- Trip frequency for site
- Time of day travel pattern
- Demographic classifications (gender, income, occupation, etc.)
- Driving classifications (speed, accident experience, assertive behavior, etc.)
- Annual miles traveled
- Vehicle preference
- Vehicle size classification
- Duration for participation (e.g., one time, one week, one year, etc.)
- Remuneration or economic incentives

Fleet Characteristics

- Number of Vehicles
- Classification (auto, truck, bus, etc.)
- Size, weight, and performance
- Ownership
- Fuel
- Standard vehicle electronics/electronics available as option

AHS Infrastructure Characteristics

- Number of automated lanes
- Start and end of automated portion
- Location and number of entrances/exits
- Separation from conventional traffic
- Grade separation from traffic

AHS Technologies

- Vehicle sensors
- Roadway sensors
- Lateral control system
- Longitudinal control system (braking and throttle)
- Vehicle-vehicle communication
- Vehicle-roadside communication
- Roadside control system
- Entry/exit processes
- Lane-changing process
- Transition to/from automation

4. DESCRIPTION OF POTENTIAL FOT SITES IN CALIFORNIA

As part of this research, 14 sites were identified as potential locations for AHS FOTs, which span the FOT categories in Section 3. These sites were selected because they are conducive to performing AHS tests and because they are representative of their FOT categories. However, it should be borne in mind that all types of tests cannot be conducted on all types of roadways. It should also be borne in mind that the site list is not exhaustive. They are presented as a means for focusing discussion on the objectives that an FOT should accomplish and the type of site that is best suited to achieving those objectives.

4.1 Urban Commuter

Two urban commuter sites were identified, one in the vicinity of Downtown San Francisco and the other in the vicinity of Downtown Los Angeles. In addition to high traffic volumes and dense surrounding development, these sites were selected because there is a prospect for major roadway improvements in the next 15 years. We felt that in order for an urban commuter site to be viable economically, the FOT would have to be incorporated within a major infrastructure investment program.

<u>I-5 Santa Ana Freeway</u>

Los Angeles County, 91 to East LA Interchange, 18.8 miles

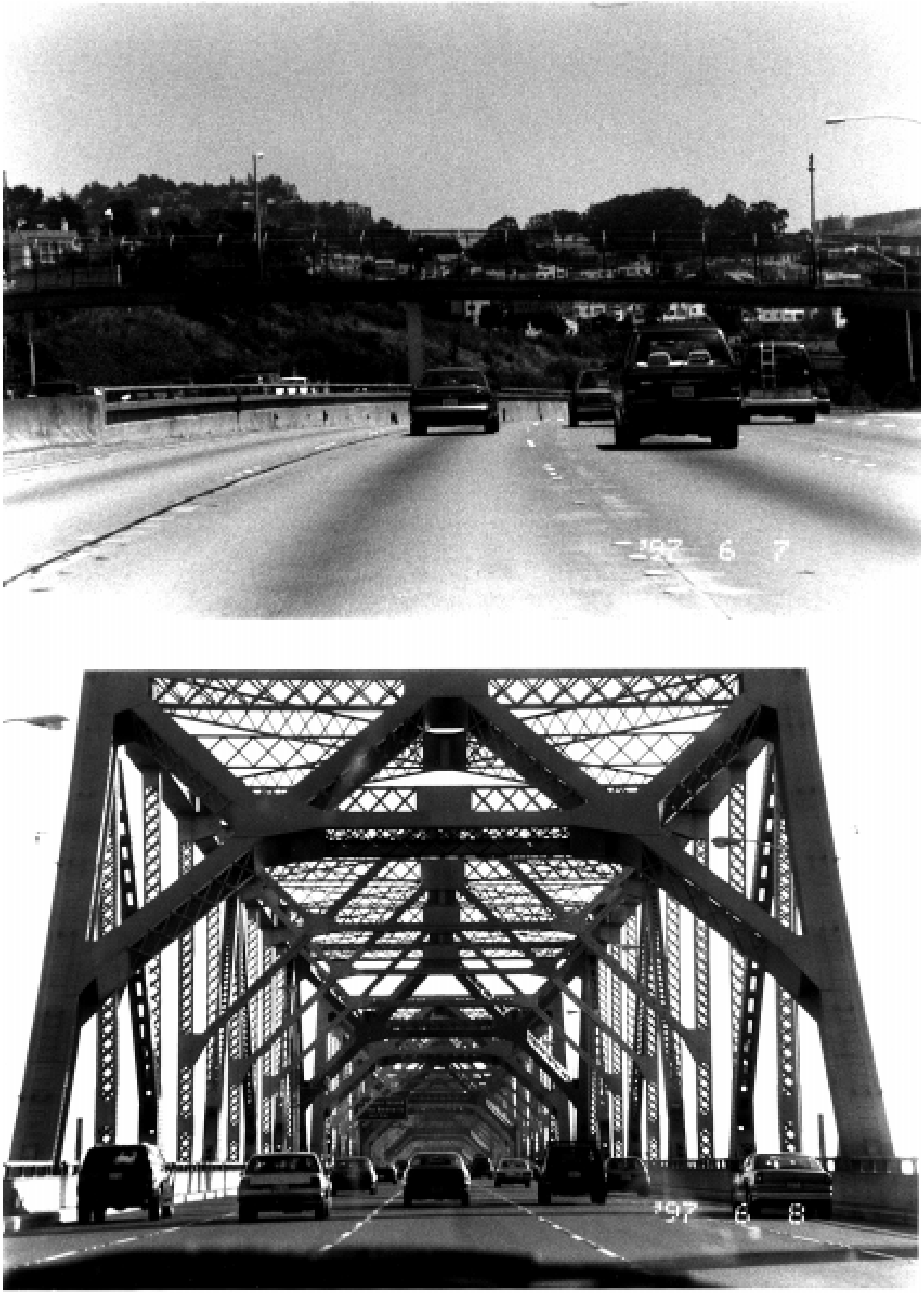
The Santa Ana Freeway is the primary roadway linking downtown Los Angeles (LA) with Orange County and San Diego (Figure 1a). It is one of the older freeways in the Los Angeles area. The corridor is heavily industrialized, especially in the area immediately to the south and east of downtown LA. The predominant traffic flow is from the residential areas in the south to the industrial and commercial areas in the north in the morning and the opposite in the afternoon. However, due to overall high traffic volumes and relatively poor infrastructure, congestion can occur at almost any time and direction. Congestion is especially bad in and around the "East LA Interchange" where I-5 intersects the 101 and I-10 freeways. Other major interchanges are located at 610, 710 and 91 freeways

<u>I-80 MacArthur Freeway/Eastshore Freeway/Bay Bridge</u>

Alameda/Contra Costa/San Francisco Counties, San Francisco to Pinole, 19 miles

The I-80 corridor from San Francisco to Richmond (Figure 1b) is arguably the most congested roadway in the Bay Area, if not the state. The Bay Bridge is the primary automobile connection between the East Bay cities and San Francisco. The Eastshore freeway serves the densely developed suburbs of Emeryville, Berkeley, El Cerrito and Richmond. Congestion in this corridor was exacerbated by the destruction of the Cypress freeway in Oakland. However, the freeway is being replaced, with initial segments opening in 1997. In addition, the Eastshore freeway is undergoing major improvements,

1a Urban Site: Santa Ana Freeway



1 b Urban Site: Eastshore Freeway, Bay Area

including HOV lanes between the Toll Plaza and Pinole. A major interchange is being constructed at the juncture of the 80, 580 and 880 freeways. The Bay Bridge itself is scheduled for major seismic upgrade and possible replacement of the eastern span with a new structure. The site has the advantage of being in direct proximity to PATH headquarters and the Richmond Field Station.

4.2 Suburban Commuter

All of the suburban sites are situated in areas with relatively low density land uses. They carry substantial traffic volumes, but tend to be congested only during short peak periods (if at all) and only in the predominant direction of travel. From the standpoint of infrastructure development, they face far fewer challenges than urban sites yet they still offer the potential for attracting a large pool of participating commuters. For the suburban commuter category, in particular, there are many alternative sites.

<u>I-15 Escondido Freeway</u>

San Diego County, 163 to Ted Williams Parkway, 6.2 miles

The I-15 site is the location for ongoing NAHSC and PATH experiments with automated vehicles (Figure 2a). The roadway is wide, relatively new, and contains two reversible HOV lanes in its median. Much of the surrounding area is undeveloped or sparsely developed, though construction continues to occur in its vicinity. The site is classified as suburban/commuter instead of transit/HOV because only limited bus service is offered. The site is especially attractive from the standpoint of investment cost, as there might be a smooth transition from prototype testing to FOT.

<u>I-80/US 50 Alan Hart Freeway</u>

Sacramento/Yolo Counties, SR113 to I-5, 18.7 miles

This portion of the I-80 freeway, coupled with its US 50 extension into Sacramento, serves both as a commuter route and an inter-urban route (Figure 2b). The primary commuter traffic is between Sacramento and Davis. Because much of the surrounding land remains in agricultural use, commute period congestion tends to be light. However, the route is heavily traveled on weekends by vacationers traveling to the Sierras and between Sacramento and San Francisco, and can be most congested on Friday afternoons (eastbound) and Sunday afternoon (westbound). A major obstacle is crossing a flood plain on the Yolo Causeway.

2a: Suburban Site: I-15 Freeway, San Diego

2b. Surburban Site: I-80 Freeway, Sacramento

I-280 Junipero Serra Freeway

San Mateo/Santa Clara Counties, SR 85 to I-380, 30.9 miles

I-280 is a wide and majestic freeway (Figure 2c), dubbed by some as the most beautiful in the world. The roadway travels through rolling hills paralleling the Santa Cruz Mountain range. Much of the surrounding land is publicly owned and prevented from development. The adjacent cities are somewhat rural in character, where houses are built on large properties in low density developments. However, the roadway also serves as one of two primary links between the "Silicon Valley" communities of Palo Alto, Cupertino and Sunnyvale and San Francisco and may be conducive to tests focused on technically sophisticated drivers.

SR 73 San Juaquin Hills Tollway

Orange County, Jamboree Road to I-5, 7.8 miles

This is the newest highway considered, having just opened in 1996 (Figure 2d). It is also unique among those considered in that it is a toll road. Traffic volumes are very low on this road and there is considerable excess capacity. The road passes through rolling hills and has few site specific challenges. The surrounding land uses are a mix of rural and suburban/residential. It is situated in an area of rapid growth.

4.3 Urban Shuttle

Two urban shuttle sites were identified, both of which provide links between major airports and a central business district. They offer the potential for participation from airport fleets, including taxis and vans. This is attractive from the standpoint of frequency of use and fairly large and homogeneous fleets. Both sites traverse urbanized areas, though the 105 site is somewhat less urbanized than others.

US 101/I-280 Bayshore Freeway

San Mateo/San Francisco Counties, SFO to Downtown SF, 12.3 miles

The Bayshore Freeway is one of the oldest and most heavily traveled in the Bay Area (Figure 3a). It is the most used route for persons traveling between the San Francisco peninsula and San Francisco, and is the primary route from San Francisco International Airport (SFO) to downtown San Francisco. SFO serves 35 million passengers per year, and is one of the 10 busiest airports in the world. The area around the route is primarily industrial and high-density residential, though one 2 mile portion follows a causeway across San Francisco Bay. Major interchanges exist at the intersections with the 380, 280 and 80 freeways.

2c. Surburban Site: Junipero Serra Freeway, Bay Area

3a. Urban Shuttle Site: Bayshore Freeway, Bay Area

I-105 Glenn Anderson (Century) Freeway

Los Angeles County, Sepulveda Blvd. to Harbor Freeway (110), 6.9 miles

The Century Freeway (officially the Glenn Anderson freeway) is one of the newest and most expensive roadways in the state (Figure 3b). It travels west/east, from Los Angeles International Airport (LAX) to the LA suburb of Norwalk. With over 50 million passengers per year, LAX is the busiest airport in California and one of the five busiest in the entire world. HOV lanes are provided for the entire length of the roadway, with direct HOV/HOV connections to the San Diego and Harbor freeways. In addition, the LA MTA green line (light rail) is situated in the highway median over most of the route. The roadway provides the primary access route to LAX from downtown LA and points east. Portions of the route are used for travel from LAX to the south or north.

4.4 Urban Transit

A variety of locations were surveyed as potential sites for a transit FOT (Table 2). One site, I-10, dominated the rest in two respects: (1) it has the highest daily volume of buses in the state, and (2) it already has barrier separated HOV lanes. Only one other site provides nearly the same bus volume as I-10. That site, I-80 in San Francisco, was classified as an urban commuter site due to the high cost of constructing an HOV only facility at that location. The I-110 Harbor Freeway is being constructed with a busway/HOV lanes in its median, but scheduled bus service is considerably less than I10.

I-10

Los Angeles County, Downtown Los Angeles to El Monte Bus Terminal, 11 miles

I-10 is one of two primary routes connecting Downtown LA with the suburbs to the east (Figure 4). It also serves as the initial leg for vehicles traveling east to Nevada and Arizona. Heading east from downtown, the area around the initial segment is primarily industrial, but gradually becomes residential within ethnically diverse suburbs. The LA County hospital and California State University at Los Angeles are immediately adjacent to the highway, and each has its own bus station along the HOV lane. In the beginning segment of the highway, the HOV lane is totally isolated from regular traffic. Toward the end, the HOV lanes are adjacent to regular traffic and are not physically separated. The lanes terminate at the El Monte bus station. The route is served by seven MTA lines (requiring 75 pieces of equipment) and 11 Foothill Transit lines (requiring 139 pieces of equipment), with about 400 buses per day traversing the route in each direction.

3b. Urban Shuttle Site: Century Freeway, Los Angeles

Table 2. Comparison of Bus Volumes on Selected Highways

Location	Peak Buses/Hour	Buses/Day	Agencies
Bay Bridge (I-80)	134 (West), 104 (East)	310/direction	AC Transit
Santa Monica Frwy (I-10)	25 (East), 26 (West)	97/direction	MTA,Snta Monica
Hollywood Frwy (US101)	24 (East), 26 (West)	210/direction	MTA
El Monte Bswy (I-10)	87 (East), 93 (West)	400/direction	MTA,Foothill
Harbor Frwy (I-110)	13 (South),14 (North)	80/direction	MTA
I-15, San Diego	18 (South),18 (North)	40/direction	SD MTS/NCTD

4. Urban Transit Site: I-10, Los Angeles

4.5 Urban Truck

We assume that the test site must have a large volume of trucks that repeatedly use the roadway and that there must be the possibility to economically construct isolated trucks only lanes for the tests. We found one site that matched these objectives well in the vicinity of the Port of Los Angeles. Though other sites have high truck volumes, they tend to be either heavily congested or non-urban roadways. Each of these cases is covered in another section.

A general challenge for a truck site is that if the AHS is constructed in the highway median, then access will be difficult. Trucks are not ordinarily allowed to travel in the left lane, and highways are not constructed to support the weight of trucks in the left lane.

SR 47 Terminal Island Freeway

Los Angeles County, 2.7 miles

The 103 is a unique freeway in that it is located in an urbanized region yet connects to no other highway (Figure 5). The roadway begins at the Port of Los Angeles, travels 2.7 miles north, then abruptly ends. As a consequence, it is characterized by a very low traffic volume, but one of the highest truck percentages in the state for a roadway within a metropolitan region (almost 20%). The road varies from 2 lanes per direction to 3 lanes per direction, and includes one major bridge -- the Heim drawbridge over Cerritos Channel. Portions of the freeway have a wide median and shoulders, though the 6-lane bridge portion has neither.

4.6 Interurban Freeway

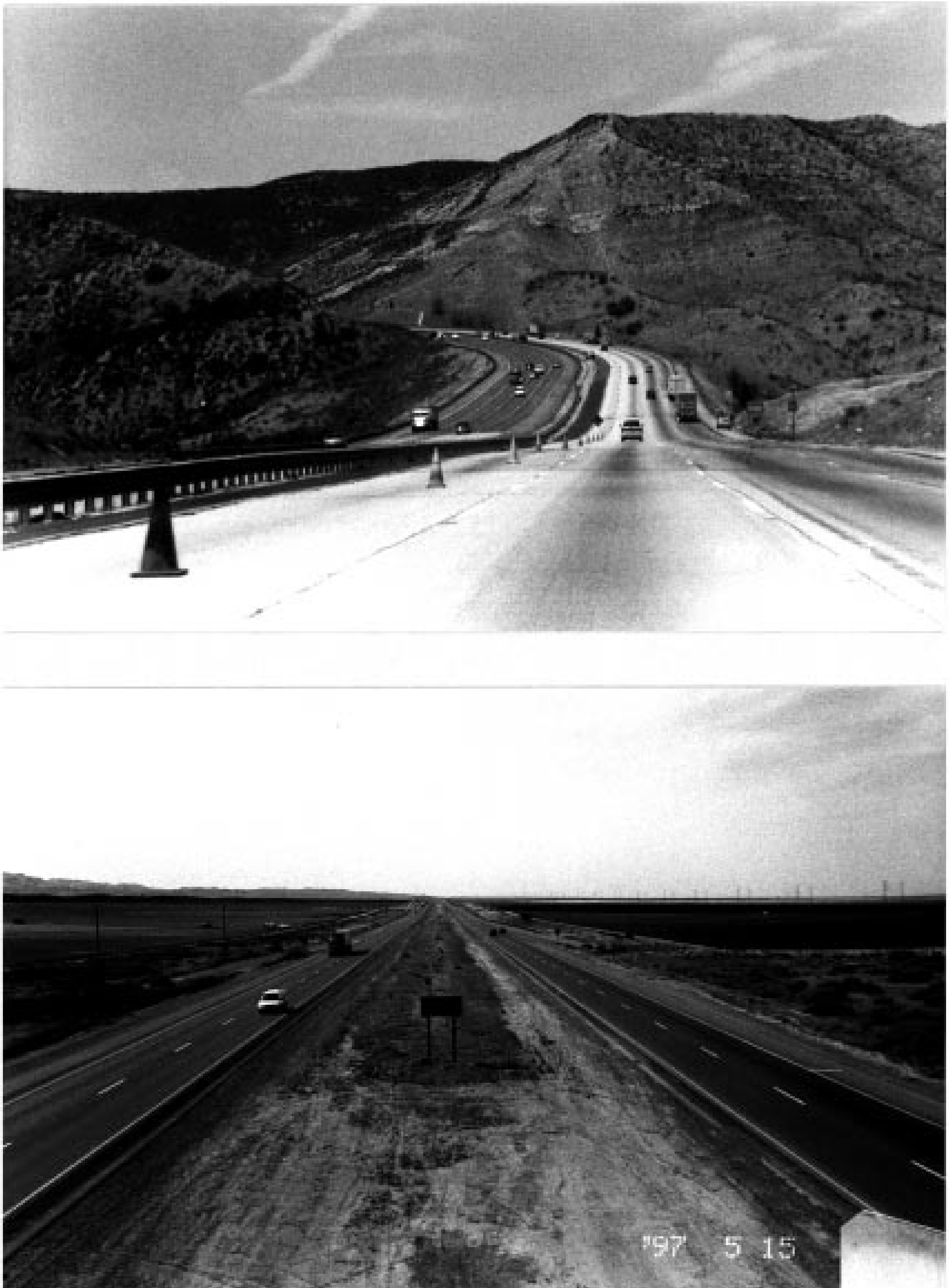
We chose three of the most heavily traveled inter-urban roadways in the state. Compared to other interurban roads in California, traffic volumes are high, but they are still far below those on urbanized roadways. As a consequence, they tend to be uncongested, except for the busiest vacation travel periods. At all three of the sites, trucks comprise a large percentage of total traffic (up to 20%), surrounding land uses are predominantly agricultural or fallow, and trip lengths are long. Interurban sites are the most economical as far as infrastructure costs are concerns, but are problematic with respect to attracting a large pool of participants who frequently traverse the roadway.

I-5/I-580 West Side Freeway

Santa Clarita to Livermore, 235 miles

The site is defined as the non-urbanized portion of the I-5 Freeway, beginning north of the San Fernando Valley and continuing along the I-580 extension to Livermore in the eastern portion of the Bay Area (Figure 6a). The route provides the fastest driving connection between San Francisco and Los Angeles, and is heavily used by vacationers,

5. Urban Truck Site: Terminal Island Freeway, Los Angeles



6a. Interurban Freeway, Golden State Freeway intercity trucks and agriculture related trips. The route passes through no cities at all, though does pass within 22 miles of Bakersfield (175,000 population, 1990), 55 miles of Fresno (354,000 population), 22 miles of Modesto (165,000 population) and 8 miles of Tracy (34,000 population). The roadway is predominantly 2 lanes in each direction, with 4 lanes in each direction in the portions closest to San Francisco and Los Angeles. Portions of the roadway are exposed to severe fog conditions in the winter and severe dust and wind conditions in the summer.

<u>I-15 Barstow Freeway</u>

San Bernadino County (SR 30) to Nevada Border, 178 miles

The I-15 freeway provides the primary driving route between Los Angeles and Las Vegas, along with the primary route for drivers continuing east to Colorado or the Grand Canyon region (Figure 6b). The route is heavily used by vacationers and intercity trucks. The route passes through sparsely or completely undeveloped regions, along with the cities of Barstow (population 21,000) and Victorville (population 41,000). The majority of the roadway has 2 lanes in each direction, with additional truck lanes in some locations. Portions of the roadway are exposed to severe dust and wind conditions in the summer.

<u>I-80 Freeway</u>

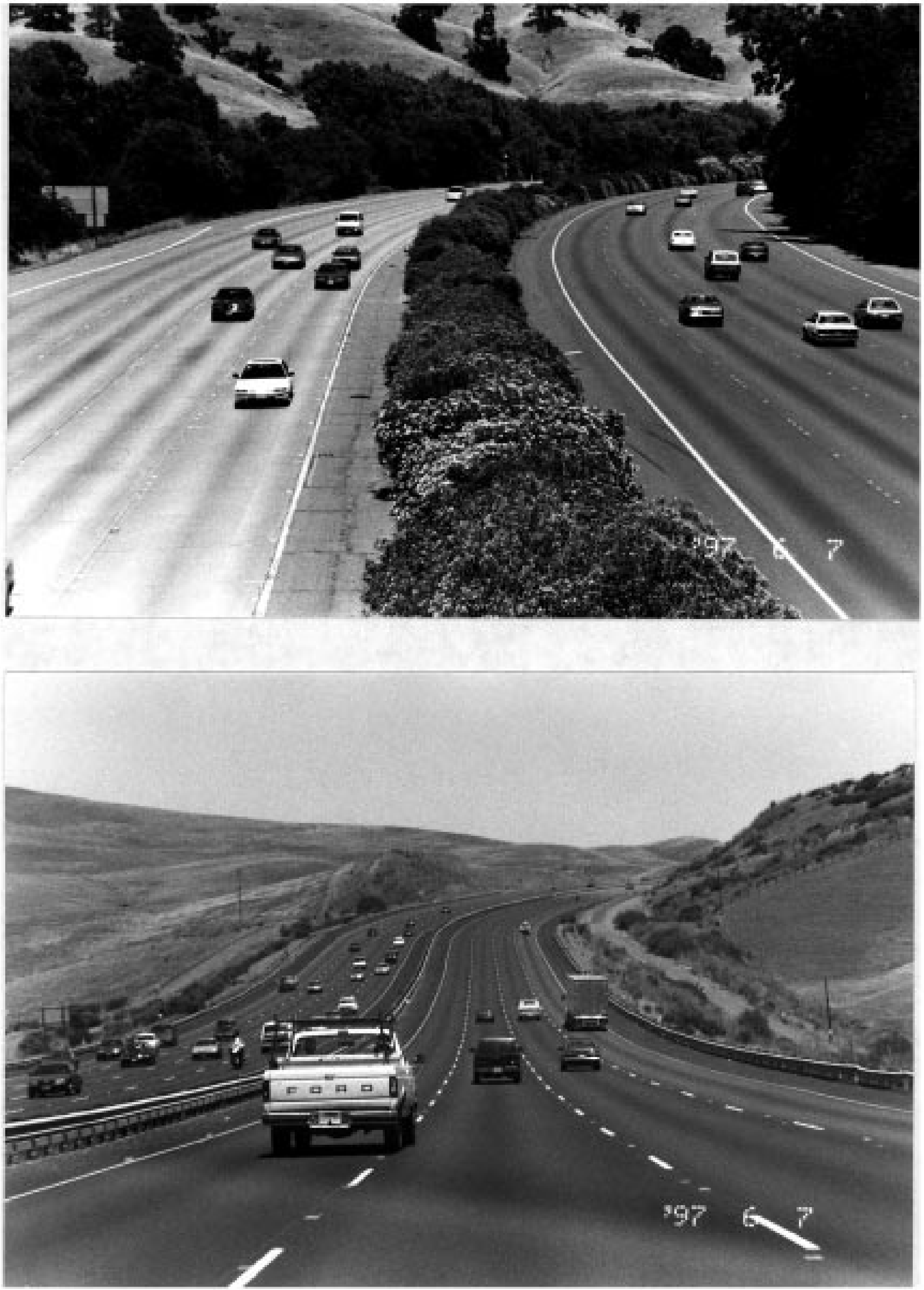
Vallejo to Davis, 32.6 miles

I-80 is the primary freeway connection between San Francisco and the state capital in Sacramento (Figure 6c). It also provides the initial leg of the fastest route from San Francisco to North Lake Tahoe, Reno and points east. In recent years, development has increased along the corridor, with rapid growth in the communities of Vallejo (population 109,000), Fairfield (population 79,000) and Vacaville (population 71,000) in particular. As a consequence, the roadway has some of the characteristics of a suburban commuter route, though it is still mostly rural. Of the three identified interurban roadways, if offers the greatest potential for attracting commuters as participants. However, it is also the most congested of the three routes (especially around Fairfield), and likely to have somewhat higher infrastructure development costs. Portions of the roadway are exposed to severe fog conditions in the winter.

4.7 Mountainous Freeway

California's mountain roadways experience severe weather conditions, including snow, high winds and fog, in addition to the challenges of tight radius curves and steep roadway gradients. The site selected exemplifies these conditions.

6b. Interurban Freeway, I-15 Freeway



6c. Interurban Freeway, I-80

I-80, Donner Pass

Sierra Nevada, Auburn to Truckee, 63.8 miles

This segment of I-80 begins in Auburn (east of Sacramento) and continues east to Reno Nevada (Figure 7). The entire segment is exposed at least occasionally to snow conditions in the winter, with snowfall in Donner Pass among the heaviest in the nation. The roadway rises to 7,239 feet in elevation at the pass. Most of the roadway has 2 lanes per direction, though portions have additional slow vehicle lanes. Traffic is at its worst at the start and end of snowy weekends, both due to the large number of skiers visiting the Sierras and due to the challenging driving conditions. During these snowstorms, chain requirements are often in effect.

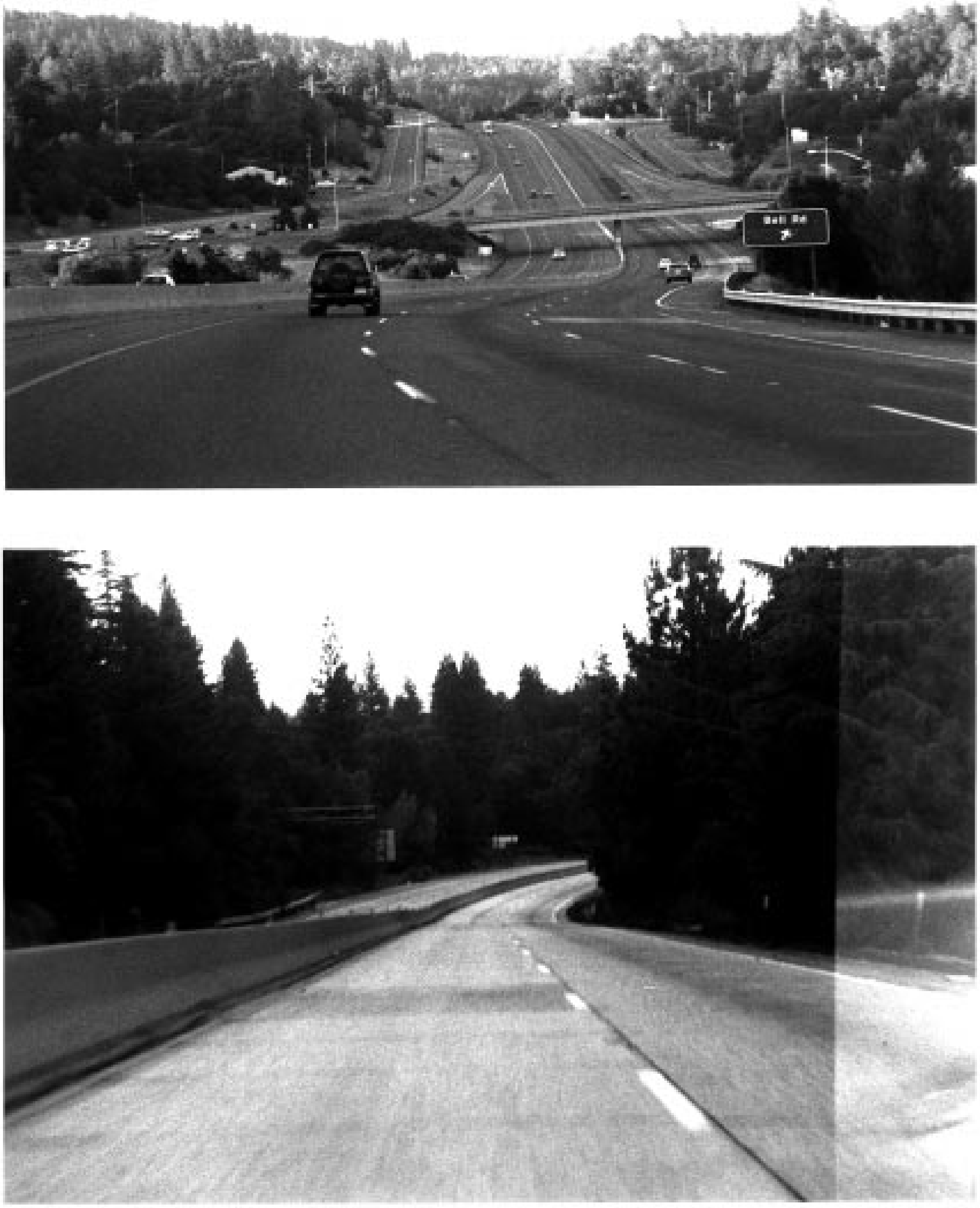
4.8 Unbuilt Site

Investigating unbuilt sites was beyond the scope of this project. One possibility would be to integrate an FOT with the construction of a new manual roadway. If this is the intention, candidates can be found among the unbuilt sites in the 1984 California State Highway System Plan (Caltrans, 1984). Examples include:

- 4 extension, Martinez
- 24 extension, Walnut Creek
- 84 freeway, Livermore
- I-710 extension, South Pasadena
- SR 30, Claremont
- Various routes in the Fresno and San Diego area
- Various rural routes

Some of these, such as SR 30, have been programmed for construction. Others have not been constructed for a combination of political and economic reasons.

It would also be possible to construct an AHS only test facility, which might later be transitioned to a fully deployed site or transitioned to a manual roadway. Numerous possibilities exist throughout the state.



7. Mountainous Freeway, Donner Pass, Sierra Nevada

5. AHS FOTs, INSTITUTIONAL ISSUES, AND THE PLANNING PROCESS

While much of the debate surrounding FOT deployment focuses on technical aspects, institutional and non-technical challenges will also be of great importance. The purpose of this section is to outline the key institutional and policy challenges that will influence the success of FOT execution in the near term. The discussion of these issues will begin with a brief overview of the general institutional issues associated with AHS and the planning process, derived primarily from the Precursor System Analysis studies. Having outlined AHS institutional issues in a broad sense, Section 6 will then analyze the issues that are specifically relevant to the selection of FOT sites in California. The relevance of these issues to individual sites is based primarily upon stakeholder interviews with relevant planners and operators from Caltrans district offices and regional MPO’s.

General AHS institutional issues were identified from research conducted by the Federal Highway Administration (FHWA) Precursor Systems Analysis Program. These issues served as a pool from which a specific set of issues was drawn and applied to the selection of FOT sites in California. A series of interviews was then conducted with Metropolitan Planning Organization (MPO) representatives and Caltrans planning and operating officials in the Los Angeles, Sacramento, San Diego and San Francisco areas regarding the institutional feasibility of specific sites.

5.1 AHS FOT Institutional Issues

Conceptually, “institutional issues” refers to the sum of concerns regarding the ability of current institutions to organize and implement a transportation project. As one precursor study points out (SAIC, 1994), “Automated Highway Systems will likely incur the most institutional, legal, and societal impediments of any Intelligent Systems and Technology Division user service.” While the discussion of these impediments below is based on analyses of AHS in general, the relevance for FOTs should not be overlooked. Therefore, the discussion of these issues will at times refer to both AHS and FOTs.

5.1.1 Resources--Human and Financial

Human resource limitations will be most obvious in two areas. First, most public agency personnel are already overburdened due to government cutbacks and downsizing. However, a greater problem may be a lack of staff with the technical expertise to make AHS deployment a reality. Successful design and implementation is unlikely if the responsible agencies lack the time and money, as well as the training and education, to integrate even a partially automated FOT.

As with all large transportation projects, financial limitations will be considerable. Cost-benefit analyses of AHS are limited at this point because so much is unknown about how such a system will be configured. What is obvious, however, is that up-front cost outlays will be substantial, while the benefits will most likely be realized later. PSA studies have noted that institutionally conservative public agencies typically approach such programs with caution. Furthermore, because AHS will most likely be funded much like conventional transportation projects, it will have to show that its benefits make it more appealing. Otherwise, it may be viewed as too big a risk given its costs (BDM, 1994).

5.1.2 Environmental Issues

Intense discussion surrounds the environmental impacts associated with AHS. Proponents argue that the negative externalities from vehicle travel will be reduced through continuous flow and reduced congestion, which will reduce emission levels and fuel consumption. In contrast, a variety of regional and local environmental interests will likely oppose an AHS FOT, arguing instead that it will lead to increasing ease of transportation, more vehicles on the road, and increasing reliance upon the automobile (Battelle, 1994). Generally, environmental pressures can be grouped under two categories (Delco, 1994):

- Air Quality and Emissions
- Infrastructure and Urban Form Issues

Air Quality And Emissions Issues deal with how much additional travel will be generated, by what means, and the impacts on air quality (from emissions) and fuel consumption. Opponents will likely argue that an FOT will lead to increases in the capacity of the transportation system, leading to increased emissions and fuel consumption, and contributing to diminished air quality. A likely additional argument is that AHS is not a substitute for mass transit, and is therefore a waste of funds that could be spent on upgrading the current mass transit system. While the objectives of an FOT may not include increasing capacity, it will nevertheless be opposed by environmentalists who see it as the first step toward an AHS that increases capacity.

Environmental Infrastructure Issues deal with the actual infrastructure changes required for FOT deployment, including the visual and seismic safety impacts on local neighborhoods. This category is primarily concerned with the physical spillovers from the construction or conversion of an FOT roadway. These infrastructure issues will further exacerbate concerns about the urban form and sprawl implications of freeways. Communities and neighborhoods adjacent to freeways typically experience lower property values and rapid decline due to their proximity to traffic, noise, and pollution. Increased through-put and infrastructure will most likely further these concerns and raise additional questions about the inequitable distribution of the negative externalities of traffic upon particular communities.

5.1.3 Legal and Liability Issues

Significant concerns are also likely to be raised about the legal and liability implications of an FOT. Such questions are inherently linked to risk and safety assessments. Specifically, for an FOT to be realized, it will have to secure the participation from one of two user groups—the individual driving public or some segment of commercial vehicle operators (such as shuttle drivers, bus drivers or truck drivers). Participation from members of these groups will depend on their perception of risks and liability in the event of an accident. For example, the potential liability from a large truck losing control on an FOT may make it difficult to obtain industry participation, not to mention the implications such an accident would have for public acceptance of an FOT. Similarly, the prospect of catastrophic failure, such as a multiple car collision, may deter the participation of the individual driving public. Thus, while an end-state AHS promises to increase roadway safety, the perceived initial liability could potentially make an FOT unattractive (BDM, 1994).

Khasnabis et al (1997) examined product liability and other legal issues associated with automated highway systems, identifying the following key issues:

〈 Federal involvement in planning an AHS would be classified as a "discretionary function", which would exempt the federal government of liability even in the event of negligence.

〈 State involvement in design and maintenance of traffic control devices, as opposed to the roadway itself, would be classified as a discretionary activity, and be exempt from liability.

〈 An AHS related accident caused by the interaction between vehicular and roadway systems, and not due to a specific defect of either on its own, would result in liability for either manufacturers or government.

〈 The lack of specific standards for maintaining an AHS would create legal ambiguity for resolving claims in the event of a maintenance related accident.

States have the power to claim sovereign immunity, which exempts them from liability in the event of accidents. However, most state legislatures have waived this right in the case of highway maintenance. It may be desirable for the state legislature to address the question of AHS related liability prior to the execution of an FOT, to clarify specific areas of liability. In addition, the state may wish to re-examine its policy of self-insurance in light of an AHS FOT. If the state ends up providing AHS equipped vehicles to the public, then it may incur additional liability. Furthermore, participants may find it difficult to insure the vehicles on their own.

Other important legal and contractual issues pertain to right-of-way acquisition and procurement, including “Buy America” policies, “brand name or equal clauses”, condemnation processes for right-of-way acquisition, acquisition of contaminated properties, and design/build procurement. Sheys and Gunter (1996) provide an excellent review of these issues within the context of transit projects. Like an AHS FOT, transit projects entail both the purchase of equipment and the construction of infrastructure, making this research especially relevant.

5.1.4 Organizational Coordination and Commitment

AHS presents a number of problems with regard to organizational coordination and commitment. Specifically, the difficulties come in coordinating efforts among various state agencies and outside organizations amid broad-based resource constraints (discussed above). For example, given funding and staffing restraints for state DOTs, it is difficult to foresee a significant transfer of resources away from ongoing projects to an AHS FOT. A state DOT, like Caltrans, which is itself constrained by limited funding, a current hiring freeze, and limits on outside contracting, has enough difficulty finding sufficient resources to complete conventional construction and maintenance projects. Adding AHS FOTs to their currently programmed projects will only exacerbate these problems.

At the same time, Metropolitan Planning Organizations (MPOs), which typically serve as partners to DOTs on large transportation projects, are unlikely to pursue AHS FOT's without the DOT's lead. As the primary intermediaries between local interests and state agencies, MPOs are pivotal to the institutional, societal, and political acceptance of an FOT. In California's case, if Caltrans is unable to marshal significant commitment for AHS FOTs, and local interests remain at best ambivalent towards the idea, MPOs are subsequently unlikely to devote their political and financial capital to an FOT.

Additionally, the transportation planning process is characterized by a lack of coordination between state and local agencies, between state implementation plans (STIPs) and local transportation improvement programs (TIPs), and a lack of clarity in procedures for dealing with new plans. The result is that DOTs and MPOs are often not sufficiently equipped to develop and deploy innovative, non-traditional transportation programs like AHS. Furthermore, it is highly unlikely that a single AHS template will work for all organizations. Rather, AHS adoption and implementation will inevitably vary according to the institutional arrangements in which it is formulated (Battelle, 1994).

Fortunately, templates do exist for the deployment of advanced transportation systems, particularly here in California. Projects like the AHS demonstration project on the I-15 in San Diego have laid the groundwork for overcoming these coordination and commitment issues. Learning from the mistakes and building upon the successes of previous ITS programs will be fundamental to success.

5.1.5 Public Acceptance

An AHS FOT will require significant changes in beliefs and behaviors associated with transportation among the general public. Public acceptance therefore deals with the broader perceptions on the part of the public about changes that an FOT will impose upon day to day lives. Many of the institutional issues already discussed above are relevant here. Safety will inevitably be the first and foremost concern of the driving public, as Horan and Martin note in their PSA study. This is particularly true for those individuals agreeing to utilize the FOT, as well as those who travel adjacent to it. Convenience is also an important concern. Public acceptance will in large part depend upon the extent to which an FOT is perceived as providing a safer, more convenient, travel route. Environmental issues, as discussed earlier, may also play a large role in determining public acceptance. Garnering public support could be difficult if an AHS FOT is popularly perceived as contributing to diminished air quality, higher emissions, and continuing urban sprawl – issues which remain at the forefront of transportation debates in almost all metropolitan areas (BDM, 1994).

Public acceptance issues yet to be addressed here include concerns about privacy and equity. Obstacles to public support of FOTs include concerns about intrusions upon privacy that such a system may entail. These concerns revolve around the loss of personal control required by the system and the ability of the system to collect data at check-in and check-out, to track vehicle position, and how the data might be utilized. For the individual driving public, AHS may be viewed as an intrusion of technology upon civil liberties. Concerns over the collection of financial, medical, and driving records of individuals to determine user qualifications and driver readiness have already surfaced, as noted in the PSA studies. More importantly, AHS will have to deal with a society that values the automobile as a symbol of individual freedom and independence. Many people are unlikely to surrender this independence in favor of outside navigation and control (BDM, 1994).

For commercial vehicle operators there is fear that AHS will allow government to more thoroughly regulate and tax private industry. Specifically, industry stakeholders are concerned with the protection of corporate and financial data. AHS may allow data to be collected on the number of vehicles operating on a given route, at what times, and the frequency of trips. Consequently, industry will be concerned about the information being used to increase government regulation, or being shared inappropriately with competitors. Similarly, individual truck drivers may view AHS as a means for regulatory agencies to more efficiently log their hours and mileage (BDM, 1994).

Similarly, a number of equity concerns may also arise with respect to an FOT. First, because an FOT will most likely be limited to a particular group of motorists or fleets, issues may be raised about what groups are restricted from using the FOT. These issues could occur between different groups within the driving public, between the driving public and the private sector, or within the private sector. Within the driving public, for example, if the cost of AHS-equipped vehicles (even with subsidization) is prohibitive to certain groups, an FOT could come to be perceived as a lane for the elite, or well-off in society. Similarly, if access is limited to private sector fleets, the individual driving public may oppose the FOT because it appears that government is promoting a business-only roadway. Within the private sector this could also be an issue if certain fleets are permitted access, while their competitors are not. In short, access restrictions necessary to the realization and control of an FOT may make public acceptance more difficult (BDM, 1994). The issue would certainly be exacerbated if the FOT entails using an existing lane, thus preventing most motorists from utilizing the automated roadway.

On another level, equity concerns are also likely to arise based on the location of access and egress points for the FOT. Given the likelihood that an FOT will have a limited number of exit and entry points, communities and neighborhoods that are bypassed may be opposed to the FOT. Such concerns, related to urban sprawl issues, are common for conventional transportation projects already. Thus, public acceptance of an AHS FOT will also depend to some degree upon the equity perceptions of the individuals targeted or not targeted for inclusion in the project.

In sum, the most difficult and complex of all institutional issues related to AHS FOT's may be public acceptance primarily because so many of the institutional issues discussed here will impact public perceptions. Safety, environmental issues, the perception that an FOT is competing with other needed projects, and privacy and equity concerns will all play into the equation that may or may not yield public approval.

5.1.6 Competition with Other Projects

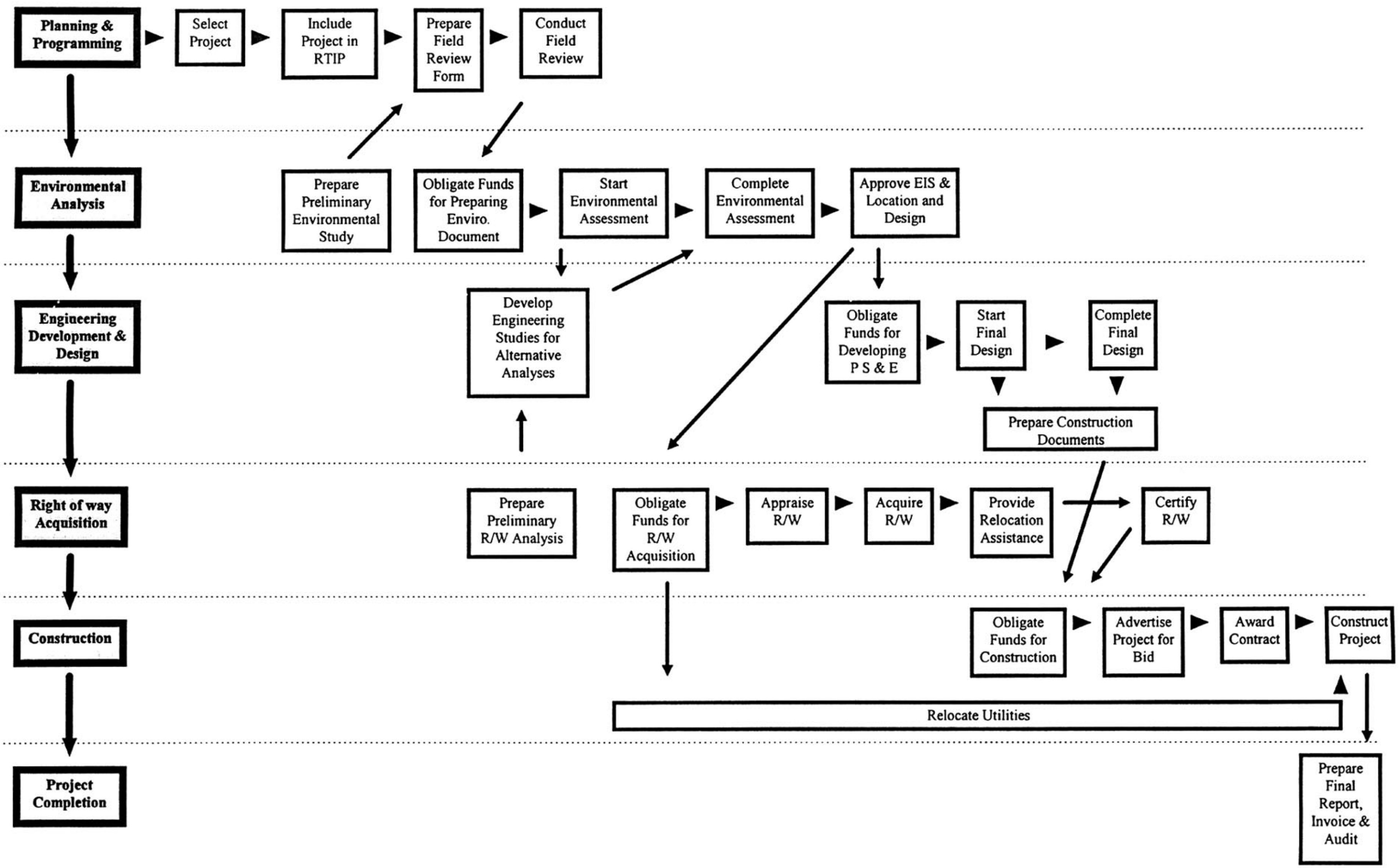
The problems an FOT presents to institutions geared toward other transportation projects have been indirectly addressed on several occasions. Competition between these projects and AHS is indicative of the schism between federal policy and local institutional capacity. At the state and local levels the difficulty for an FOT lies in becoming integrated into long term regional planning processes that were begun previously in response to the Clean Air Act Amendments (CAAA) and Intermodal Surface and Transportation Efficiency Act (ISTEA) of 1991. For example, many regional plans in congested areas are calling for a switch to rail projects as a means of addressing the same problems AHS proposes to work on. As a result, FOT efforts must play "catch-up" to these other regional planning efforts and must also deal with the potential political and public backlash if an FOT is perceived as a shift in commitment away from projects to which considerable resources have previously been committed (Calspan, 1994).

5.2 Implications for the Planning Process

Like conventional large transportation projects, the development of FOTs will inevitably have to navigate the planning process. Each of the issues outlined above will be particularly poignant at different stages of this process. The following outlines the various steps in the planning process and identifies which issues will be most relevant for each step (Figure 8).

1. **Planning and Programming:** This first step involves the selection of the project, getting the project included in the Regional Transportation Improvement Plan (RTIP), preparing the field review form, and conducting the field review.
2. **Environmental Analysis:** Step two includes the preparation of a preliminary environmental study, obligating funds for preparing the environmental document, completing the environmental assessment or Environmental Impact Statement (EIS), approving the assessment or EIS, and approving the location and design of the project.

II. Flowchart for Typical Planning Process and Project Development (provided by Caltrans)



3. **Engineering, Development and Design:** In conjunction with the environmental assessment or EIS, this step develops engineering studies for alternative analysis. Once the assessment or EIS is approved, the final design is started and completed and preparation of construction documents begins.
4. **Right-of-way Acquisition:** A preliminary right-of-way analysis is conducted in conjunction with the environmental assessment. Once the design has been approved, steps are taken to obligate funds, appraise, and acquire right-of-way.
5. **Construction:** Once the final design has been approved, relocation of utilities begins. Once construction documents have been prepared, and right-of-way has been acquired, the construction process begins. Funds are obligated, advertisements for project bids are sent out, contracts are awarded, and the construction subsequently begins.
6. **Project Completion:** Upon completion of the project, a final report, invoice and audit are prepared.

5.2.1 Institutional Issues and the Planning Process

As prelude to this discussion, it should first be recognized that the institutional issues outlined here should ideally be taken into consideration before the planning process is even begun. For example, if the right-of-way is not available, or environmental remediation is excessively expensive and cause huge time delays, it may not be advisable to start this process in the first place.

Second, the process outlined above is relevant only for new projects, or new facilities. Conversion and alteration of existing facilities or projects would most likely be able to circumvent some or all of this process. Thus, if FOTs can be layered onto existing facilities, the barriers and delays to deployment may be greatly reduced.

Recognizing this fact, the relevant steps in the planning process, as they relate to the institutional issues presented above, are outlined below.

Environmental issues will obviously be encountered throughout the environmental analysis phase, but may first arise when the project is initially selected, especially in areas where environmental interests keeps a watchful eye on transportation planning. The most significant impact these issues will have on the project is in additional costs required for environmental remediation, as well as time delays in conducting the EIS. In both instances lawsuits are not uncommon.

Public Acceptance Related to safety and environmental issues is public acceptance. The extent to which the project is environmentally controversial could have a profound effect on public support for the project. If additional public acceptance concerns, such as privacy and equity, arise as they are likely to do with an FOT, these could also impact the initial planning and programming phase. Public acceptance will also be a significant concern once the construction phase of the process begins and creates inconveniences such as traffic congestion, noise and dust.

Legal and liability concerns should primarily be addressed in the engineering and design phase of the project. The operator of the roadway will always be liable in certain instances, but much of this may be minimized through preventative design measures.

Organizational capacity and resource issues will predominate throughout the process when it comes time to obligate funds to conduct studies, acquire right-of-way, and begin construction. However, these issues will first arise in getting the project into the RTIP in the planning and programming stage. If the project isn't included in the RTIP it is essentially out of the loop in terms of funding prospects. However, if included in the RTIP, and funds are able to be obligated in subsequent phases, the primary capacity issue will be the availability of human resources to devote to construction of the project. In the case of Caltrans, which is currently under a hiring freeze, there oftentimes aren't enough people to go around.

Competition with Other Projects Lastly competition with other projects will be encountered early in the planning process in trying to include the project in the RTIP. If the project duplicates a project already included, it will be difficult to justify its subsequent inclusion as well.

In sum, the institutional issues outlined in this section will be encountered at different times throughout the planning process. The key to overcoming these issues as they arise will be in preparing for them before hand — most likely before the planning process is begun at all. Additionally, the planning process as it has been outlined here may be circumvented to some degree by layering FOTs onto existing facilities, plans, or programs.

5.2.2 Test Planning

Planning for an AHS FOT will require additional steps, needed to design and execute the test itself. For instance, not only must the roadway be designed, but the vehicle fleet must be designed as well (or, at least, modifications to a fleet must be designed). Additional FOT steps include:

- Definition of test goals, objectives and scope
- Creation of a test plan
- Search process to select a specific test site
- Roadway electronics engineering and design
- Vehicle engineering and design
- Vehicle manufacture
- Participant recruitment
- Execution of test
- Analysis of test results and documentation

All told, execution of an AHS test is certain to be a long process, requiring many years of advanced planning and negotiation.

5.3 Summary

The purpose of this discussion has been to identify the key institutional and societal aspects associated with AHS development and deployment. Foremost among these are public acceptance, environmental concerns, resource limitations, liability issues, organizational capacity and commitment, and competition with other projects. These issues are by no means mutually exclusive. For example, one cannot discuss public acceptance without discussing environmental concerns. Similarly, any discussion of organizational capacity and commitment would be incomplete without a related discussion of constraints on human and financial resources, as well as competition with conventional projects. In short, realization of an FOT will ultimately depend upon the ability of an FOT program to overcome the various entangled obstacles that will inevitably arise. While the number and complexity of the issues identified here may appear daunting, many of these issues inevitably accompany present-day transportation projects. In this respect, none of these challenges may be insurmountable.

6. EVALUATION OF POTENTIAL FIELD OPERATIONAL TEST SITES IN CALIFORNIA

The following defines specific characteristics of AHS test sites and AHS FOTs. These characteristics will directly affect the cost and usefulness of conducting an AHS FOT. Our assessment is based on six criteria categories, as described below and in Table 3. In general, each criterion is evaluated on a three-point scale, where:

● indicates that site is especially favorable for the criterion relative to other sites
☒ indicates that the site is neutral for the criterion relative to other sites
- indicates that the site is unfavorable for the criterion relative to other site

The classification is based on a mixture of quantitative and qualitative factors, based on interviews and site data collection (Appendix I and Appendix II).

Safety and Reliability These may be viewed as either positive, or negative, factors, depending on the nature of the test. We make assessments of the following:

〈 Visibility (fog, dust, smoke, etc.)
〈 Wind
〈 Severe rain
〈 Ice or Snow
〈 Roadway curvature
〈 Roadway grades
〈 Total traffic volume per lane

Higher traffic volume is viewed as a potentially negative criterion, as it may expose more vehicle to testing (this may have no consequence if the AHS lanes and entrances and exits are completely isolated).

Local Cooperation and Participation Environmental factors may work against sites and economic factors may work in favor of sites. Local support could also be generated if the facility will be available for general use after the FOT and the facility is desired by the community.

〈 Local concern over effects on trip generation or other environmental issues
〈 Ability to re-use facility in a way that community supports
〈 Ability to stimulate high-occupancy-vehicle or transit use
〈 Ability to support economic objectives of communities.

Test Cost The cost of the test includes infrastructure cost, fleet cost, and the cost of conducting the test. The cost of constructing the AHS test roadway is obviously site dependent, and should be a primary consideration in selecting a site. Calculating exact

Table 3. Definition of Criteria Classifications

Safety Criteria

Visibility

- ● Visibility is rarely a problem anywhere on the segment
- ☒ Visibility is occasionally a minor problem
- \- Significant visibility problems occur each year

Wind

- ● Wind is rarely a problem anywhere on the segment
- ☒ Wind is occasionally a minor problem
- \- Significant wind problems occur each year

Snow/Ice

- ● Snow/ice rarely or never occur anywhere on the segment
- ☒ Ice occurs occasionally during winter
- \- Ice and snow occur each year

Rain

- ● Annual rainfall is small (< 20"), and rarely occurs in summer
- ☒ Occasionally heavy rain, and annual rainfall is moderate (20-35")
- \- Heavy rainfall occurs each year and annual rainfall is heavy (.35")

Curves

- ● Roadway does not contain any tight radius curves
- ☒ Roadway contains a small number of tight radius curves
- \- Roadway contains a significant number of curves below standard

Grades

- ● Roadway contains no steep grades
- ☒ Roadway contains segments with steep grade, but as a small % of route
- \- A large % of route contains steep grades

Volumes

- ● Average daily traffic is generally below 15,000 vehicles per lane
- ☒ Average daily traffic is generally 15,000-25,000 vehicles per lane
- \- Average daily traffic exceeds 25,000 vehicles per lane

Table 3 (cont.) Definition of Criteria Classifications

Local Cooperation Criteria

Environmental

- ● Local opposition to environmental approvals is unlikely to be a serious obstacle
- ☒ Local opposition to environmental approvals will possibly affect project
- \- Local opposition is likely to affect project due to trip generation fears or other environmental factors

Facility Re-Use

- ● The ability to re-use the facility for another purpose is a strongly positive factor that would produce local support
- ☒ The ability to re-use the facility is a mild factor that would produce local support
- \- The ability to re-use the facility would not produce local support

HOV

- ● The test site is highly amenable to an HOV focus, and this focus would help attract local support
- ☒ The test site is somewhat amenable to an HOV focus, and this focus would possibly attract local support
- \- The site is not conducive to an HOV focus (e.g., if there is already minimal congestion or there exists an adequate HOV facility)

Economic

- ● The economic benefits of the test would likely attract local support
- ☒ The economic benefits of the test could have a somewhat positive affect on local support
- \- The economic benefits of the test would not produce local support

Table 3 (cont.) Definition of Criteria Classifications

Cost Criteria

Existing Lanes

- ● The site or test can likely be conducted on existing lanes
- ☒ Some segments of the existing highway might be devoted to testing
- \- Existing lanes cannot be used for testing

Structures

- ● New lanes can be constructed with minimal expense for new structures
- ☒ New structures would be required, but median or shoulders can be used to provide additional lanes in much of the highway
- \- Constructing new lanes would require significant expense for new structures

Re-Use

- ● Newly constructed lanes can be re-used after the test with significant benefit (e.g., they can be converted to HOV use)
- ☒ Newly constructed lane might be beneficially re-used after the test
- \- Newly constructed lanes might be re-used, but benefits would be small

Existing ITS

- ● Traffic sensors, high band-width communication and other ITS capabilities are in place throughout the highway (or will be in place)
- ☒ Some ITS capabilities are in place in the highway (or will be in place)
- \- ITS capabilities are minimal, if present at all

Vehicles

- ● Due to regular highway users, the test can be conducted with a small vehicle fleet
- ☒ The ability to recruit enough regular users is questionable
- \- The ability to recruit enough regular users is highly questionable

Research Facilities

- ● The highway is close to PATH facilities or to I-15 facilities (< 10 miles)
- ☒ The highway is close to another facility engaged in AHS related research
- \- The highway is not close to any facility engaged in AHS research

Table 3 (cont.) Definition of Criteria Classifications

Serve Real Trips

Transit

- ● The highway has substantial transit volume within a small number of fleets
- ☒ The highway has some transit volume, possible divided among fleets
- \- The highway serves few transit vehicles

Shuttles

- ● The highway has substantial airport shuttle volume
- ☒ The highway has some airport shuttle volume
- \- The highway serves few airport shuttles

Trucks

- ● The highway has substantial truck volume (> 10,000 trucks/day)
- ☒ The highway has moderate truck volume (4,000-10,000 trucks/day)
- \- The highway has few trucks (<4,000 trucks/day) or facility not designed for trucks

Commuters

- ● The highway is a regularly used commute corridor
- ☒ The highway has substantial commute traffic mixed with other purposes
- \- Highway traffic is primarily non-commute

Recreation

- ● The highway serves as a major route for recreational travelers
- ☒ The highway serves recreational travelers along with other purposes
- \- The highway predominantly serves non recreational trips

Long Trips

- ● The highway has the potential to serve a large number of long AHS trips (> 10 miles)
- ☒ The highway has potential to serve a large number of moderate length AHS trips (5-10 miles)
- \- The highway is likely to only serve short trips (< 5 miles)

Table 3 (cont.) Definition of Criteria Classifications

Conduct Test

Low Visibility

- ● The highway will definitely support testing under low visibility conditions
- ☒ The highway might be able to support low visibility testing
- \- The highway is unlikely to support low visibility testing

Wind

- ● The highway will definitely support testing under high wind conditions
- ☒ The highway might be able to support high wind testing
- \- The highway is unlikely to support high wind testing

Ice/Snow

- ● The highway will definitely support testing under snow/ice conditions
- ☒ The highway might be able to support snow/ice testing
- \- The highway is unlikely to support snow/ice testing

Mountainous

- ● The highway will definitely support testing under mountainous conditions (tight radius turns and steep grades)
- ☒ The highway might be able to support mountainous testing
- \- The highway is unlikely to support mountainous testing

High Volumes

- ● The highway will definitely support testing under high volume conditions (extended periods where manual lanes operate at capacity)
- ☒ The highway might be able to support high volume testing (operates at capacity at least on weekly basis)
- \- The highway is unlikely to support high volume testing (rarely operates at capacity)

Table 3 (cont.) Definition of Criteria Classifications

Conduct Test (continued)

Mixed Class

- ● The highway will definitely support testing mixed heavy-duty and light-duty vehicles
- ☒ The highway will support mixed heavy/light testing, but heavy percentage is likely to be small
- \- Site is not conducive to mixed class testing

Entry/Exit

- ● The highway can be designed with multiple exit and entrance points
- ☒ The highway might be designed with multiple exit and entrance points
- \- The highway is difficult to design with multiple entrances and exits

Link Level

- ● The highway is conducive to link level testing, including the possibility of a multiple lane AHS with automated lane changes
- ☒ The highway is somewhat conducive to link level testing
- \- The highway is not at all conducive to link level testing

Institutional

- ● The highway presents institutional challenges that will provide insights into future AHS deployments
- ☒ The highway presents some institutional challenges of interest, or institutional challenges are somewhat site specific and unlikely to shed light on deployments elsewhere
- \- Few useful insights will be obtained on institutional issues

Table 3 (cont.) Definition of Criteria Classifications

Impacts

Visual

●	Visual impacts on surrounding areas is not a major concern
☒	Visual impacts on surrounding areas is a possible concern
-	Visual impacts on surrounding areas is a definite concern

Congestion

●	Adding capacity will provide for reduced congestion
☒	Adding capacity may provide some congestion reduction
-	Adding capacity will have little if any impact on congestion

Construction Disruption

●	Disruption of traffic due to FOT construction will have minimal impacts
☒	Disruption of traffic due to FOT construction will be minor
-	Disruption of traffic due to FOT construction will be significant

Safety

●	The highway has above normal safety problems, which might be addressed through automation technologies
☒	The highway is typical with respect to safety

roadway costs is beyond the scope of our analysis. Instead, we evaluate sites relative to four factors:

- Potential for utilizing existing lanes for AHS.
- If newly constructed lanes, degree to which major structural changes are required (e.g., new bridges or retaining walls), or perhaps grade separated structures.
- Potential for re-use of the lanes after the FOT is completed (e.g., to be converted to an HOV lane).
- Existing ITS infrastructure that could be utilized in test.

Fleet costs depend more on the nature of the test than the site. However, different sites may require more or less participants, due to the frequency in which drivers traverse the site. A single assessment factor is used:

- Required pool of participating vehicles to conduct test.

The cost of conducting the test is somewhat site dependent, in that it depends on proximity to research facilities:

- Proximity to major AHS research facilities

Depending on the nature of the FOT, roadway characteristics such as grades and curves, and climatic characteristics such as snow, ice and fog, could be either positive or negative site considerations. These factors are discussed separately under technical challenges.

Ability to Serve Real Trips This is assessed relative to whether there exists a large population of potential participants in each of the following categories

- Transit fleets
- Airport shuttles
- Trucks
- Commuters
- Recreational trips
- Long-distance AHS trips

Ability to Conduct Desired Tests Most tests should be feasible at any of the sites, though certain test conditions are somewhat site specific:

- Low visibility conditions
- Icy conditions
- Mountainous conditions
- High traffic volume
- Mixed vehicle classes
- Entry/exit control
- Link level control
- Institutional

These criteria act opposite to the safety criteria, in that a challenging condition (such as wind) may create a safety challenge, yet also create further testing opportunity. Also, a site that presents an institutional challenge may be interesting for that portion of the test, but also significantly detract from accomplishing for technical test.

Direct Impacts of Test: The direct benefits correspond to some of the measures of effectiveness associated with highway projects.

〈 Visual impacts
〈 Congestion
〈 Safety
〈 Construction disruptions.

We assume that visual impacts and construction disruptions cannot be positive, and therefore a • rating reflects no impact. We assume that congestion impacts can only be positive, and therefore a **-** rating reflects no positive impact. For safety, we rate a site • if it has higher than typical fatal accident rates combined with challenging driving conditions (indicating potential for improvement). Otherwise, the site receives a neutral rating. We don't provide measures of pollution and energy impacts, as these are more debatable. The impacts are certainly related, however, to roadway congestion.

6.1 Assessment of Urban Commuter Sites

The urban commuter sites present the greatest deployment challenges, both in terms of infrastructure cost and garnering political support. For these reasons, we believe that neither site is viable. In general, the attractive feature of the urban sites is that it would be relatively simple to attract participants from any vehicle classification and there are few climatic or terrain challenges. The drawback is that the FOT would likely require construction of a grade-separated roadway, which would expose the project to environmental reviews and significant cost. Provision of dedicated on and off ramps could prove to be especially expensive. With average daily traffic in the range of 20,000 - 35,000 vehicles per lane per day, it would be impossible to perform an FOT within existing lanes. Though these costs might be recouped if the facility is later re-used, perhaps as an HOV roadway, the risks to completing the FOT on time would be unacceptable.

Of the two sites examined, the I-5 is somewhat more attractive, in that there is a prospect for future construction independent of AHS (it is currently undergoing a major-investment-study). Though the proximity of the I-80 site to PATH is attractive, it could easily face local political and legal challenge. And though these challenges may form an interesting institutional study, the local politics are so unique that they probably wouldn't provide much insight into AHS implementations elsewhere. Moreover, a project is just being completed in this corridor, and it would be difficult to begin another so soon afterward.

6.2 Assessment of Suburban Commuter Sites

The suburban sites are in general attractive candidates for FOTs. They provide few safety challenges; they have good potential for attracting commuters as participants; local cooperation is likely attainable and costs are generally low. At two of the sites examined (SR 73 and I-280) there is a prospect for using existing lanes for the test. The maximum daily traffic per day on 280 is just 14,000 vehicles per day lane; removing one lane would increase the traffic level to a modest 19,000 vehicle per day per lane. Traffic is even smaller on SR 73, with 6-10,000 vehicles per lane per day. In addition, space has been reserved in the median for expansion.

If dedicated on and off ramps are desired, some new construction would still be needed, which could prove complicated. At the I-15 site, past participation in the AHS demonstration makes the road a natural candidate. However, unless manual and automated traffic are mixed in these lanes, additional lanes would need to be constructed to separate the traffic. The drawbacks to these sites are that they are less conducive to testing with trucks and buses, and they may provide little in the way of direct benefits. Of the sites investigated SR 73 is especially attractive, due to existing ITS infrastructure and low traffic volumes. I-80 doesn't look viable due to the high cost of spanning the Yolo Causeway with an additional lane.

In the course of interviews, various other suburban sites were suggested around the state. In all cases, these locations are slated for construction of HOV lanes, but lack funding for construction. Examples include I-80 and US 50 heading east from Sacramento; US 101 between Petaluma and Santa Rosa; I-680 between Pleasanton and Fremont; the planned SR 30 in the vicinity of Claremont; and I-5 north of the juncture with I-805. The likelihood of local participation is quite high if the construction cost (or a portion of the cost) is paid by the federal government, and the facility is eventually turned over to local agencies for use as an HOV lane.

6.3 Assessment of Urban Shuttle Sites

The urban shuttle sites are heavily traveled urban/suburban roadways, so they share many of the same disadvantages and advantages as the urban sites. They offer few terrain or climatic challenges and have excellent potential for attracting participants. They suffer from high construction costs and potential construction delays. They also have very high traffic volumes, which peak in excess of 30,000 vehicles per lane per day. And though the 105 has HOV lanes, including freeway-freeway connection, capacity is not sufficient to use these lanes exclusively for an FOT. The key additional advantage is the potential for attracting shuttles and taxis as participants, whose fleets number roughly 1000 vehicles at LAX and at SFO. We believe that this advantage is not significant enough to outweigh the site challenges.

6.4 Assessment of Urban Transit Site

The I-10 busway looks to be an attractive site for specialized tests focused on transit vehicles. There are few climatic or terrain challenges (though a portion of the route is somewhat curvy), local cooperation should be positive, and there is a possibility for re-use of any newly constructed roadway as HOV lanes. Unless manual and automated traffic are mixed within the HOV lanes, new construction would certainly be needed. The site has sufficient bus traffic to make the test interesting, just two bus companies would have to participation (Foothill Transit and MTA), and the total fleet size would be manageable. The facility could also be used by automobiles traveling as HOV. The test would not be conducive to truck testing, though accommodations could likely be made for a limited number of vehicles.

6.5 Assessment of Urban Truck Site

SR 47 has some attractive features that may merit further investigation, primarily due to its isolation from other roadways and high truck volume (10-20% of vehicles). Traffic volumes are very low, but because most of the highway only has two lanes per direction, some new construction would be needed. Also, it may prove impossible to build the AHS across the Heim Drawbridge. The roadway is not especially conducive to attracting non-truck participants. Also, allowing for trucks could be problematic for construction, as trucks are not ordinarily allowed in left-hand lanes, and these lanes are not designed to support trucks. It should be considered only as a specialized test facility focused on commercial trucks shuttling containers to and from the port of LA/Long Beach.

6.6 Assessment of Interurban Freeway Sites

In many ways, these are the simplest sites, as they present few political or environmental challenges and are relatively inexpensive to construct. Some roadways also present a variety of climatic conditions, including ice, wind and fog, which may be important to testing the technical capabilities of vehicles. The drawback is that, with the exception of I-80, they are not conducive to attracting participants or to testing entrance/exit control rules. This alone may rule out many sites, unless the FOT is intended to test only small fleets of vehicles.

Of the three sites investigated, the I-80 site looks to be the most attractive. A joint powers board already exists in the corridor that might facilitate implementation. And it is the only one of the 14 investigated that had no major negatives. There are also some major employers in the corridor, which might facilitate attracting participants.

6.7 Assessment of Mountainous Site

Mountainous roadways, such as I-80, present tremendous cost and environmental challenges to new construction. They should only be considered if the AHS test is intended to operate in mixed traffic, or if construction would occur anyway, even if the

FOT is not conducted. Mountainous sites present great challenges in terms of safety and attracting participants, and being able to conduct a range of tests. However, they should be contemplated for tests focused on safety enhancement of more conventional vehicles. Hence, they may prove to be better sites for prototype testing with professional drivers than FOT testing with the general public. The I-80 Donner Summit site is attractive in this regard, assuming that the vehicles can be designed to meet the site challenges. However, the absence of major employers or significant commute traffic would make it difficult to attract participants.

6.8 Assessment of New Build Sites

We did not examine any specific new-build site. However, based on interviews, such sites seem viable provided that the roadway is already scheduled for construction, AHS funding can bridge a financial shortfall, and the facility can later be re-used for HOV traffic.

6.9 General Assessment

Table 4 provides a detailed comparison of sites according to all selection criteria, and Table 5 summarizes results by criteria category. The following sites show promise for use as an AHS FOT, provided that the site-specific challenges can be met:

Route	**Challenges**
SR 73	Operate FOT on existing lanes Sufficient to have minimal truck and bus participation
I-280	Operate FOT on existing lanes Sufficient to have minimal truck and bus participation
I-10	Mixed automated/non-automated on a barrier separated roadway is feasible, <u>or</u> Sufficient local interest in expanding HOV to 2 lanes per direction
US 103	Able to traverse Heim drawbridge Sufficient to focus on trucks only, and they want to participate
I-5/580	Attracting a sufficient number of participants
I-15	Attracting a sufficient number of participants
I-80 (Interurban)	Sufficient local interest (perhaps least challenging site)
I-80 (Donner)	Interest in a non-fully automated, safety oriented test

Table 4. Detailed Site Analysis

	Safety Factors							Local Coop				Cost Factors						Serve Real Trips						Conduct Test									Impacts			
	Visibility	Wind	Snow/Ice	Rain	Curves	Grades	Volume	Environmental	Re-Use	HOV	Economic	Exist Lanes	Structures	Re-Use	Existing ITS	Vehicles	Res Facil	Transit	Shuttles	Trucks	Commuters	Recreation	Long Trips	Low Visible	Wind	Ice/Snow	Mountainous	High Volume	Mixed Class	Entry/Exit	Link Level	Institution	Visual	Congestion	Const Disrupt	Safety
Urban Sites																																				
I-80 (SF East Bay)	☒	☒	●	●	☒	☒	-	-	☒	☒	-	-	-	●	●	●	☒	☒	☒	●	●	●	☒	-	☒	-	-	●	●	●	-	-	-	☒	-	☒
I-5 (Santa Ana Frwy)	●	●	●	●	●	●	-	-	☒	☒	-	-	-	●	●	●	●	-	☒	●	●	●	☒	-	-	-	-	●	●	●	-	●	-	●	-	☒
Suburban Sites																																				
I-15 (San Diego)	☒	☒	●	●	●	●	☒	●	●	☒	●	☒	●	☒	●	●	●	☒	☒	●	●	☒	●	☒	☒	-	☒	☒	-	☒	●	☒	☒	☒	●	☒
SR-73 (Orange County)	●	●	●	●	●	●	●	☒	-	-	☒	●	●	-	●	☒	☒	-	☒	-	☒	☒	●	-	☒	-	-	-	-	☒	●	☒	●	-	●	☒
I-80/US50 (Sacramento)	-	-	●	●	●	●	☒	☒	☒	☒	☒	-	-	●	-	●	☒	☒	☒	☒	●	●	●	●	●	-	☒	☒	●	☒	●	☒	☒	☒	☒	☒
I-280 (SF Peninsula)	☒	☒	☒	☒	●	☒	●	☒	-	-	☒	●	☒	-	-	☒	☒	-	☒	-	●	☒	●	☒	●	-	☒	-	-	☒	●	●	☒	-	●	☒
Urban Shuttle Sites																																				
I-105 (Los Angeles)	☒	●	●	●	●	●	-	☒	●	☒	☒	-	-	●	●	●	☒	-	●	☒	●	☒	☒	☒	-	-	-	●	●	●	-	●	☒	☒	-	☒
US101 (San Francisco)	☒	☒	●	●	☒	●	-	-	●	●	☒	-	-	☒	☒	●	☒	☒	●	☒	●	☒	☒	☒	☒	-	-	●	☒	●	-	●	☒	●	-	☒
Urban Transit																																				
I-10 (El Monte/LA)	●	●	●	●	☒	●	-	●	☒	●	☒	☒	-	●	●	●	☒	●	☒	-	●	-	-	-	-	-	-	●	●	●	●	●	☒	☒	☒	☒
Urban CVO																																				
SR 47	☒	●	●	●	☒	●	●	●	-	-	●	☒	●	-	-	☒	-	-	-	●	-	-	-	☒	-	-	-	-	●	☒	☒	☒	●	-	●	☒
Interurban																																				
I-5/580 (Golden State)	-	-	☒	☒	☒	☒	●	●	-	-	●	-	●	-	-	-	-	-	-	●	-	●	●	●	●	☒	●	-	●	-	●	-	●	-	●	●
I-15 (LA/Las Vegas)	☒	-	☒	●	☒	☒	●	●	-	-	●	-	●	☒	-	-	-	☒	-	●	-	●	●	☒	●	☒	●	-	●	-	●	-	●	-	●	●
I-80 (SF/Sacramento)	-	☒	●	☒	●	☒	☒	☒	●	●	●	-	●	●	-	-	☒	☒	☒	-	●	☒	●	●	●	-	☒	☒	●	●	●	☒	●	☒	☒	☒
Mountainous																																				
I-80 (Sierra Nevada)	-	-	-	-	-	-	●	●	☒	-	☒	●	●	☒	-	-	-	☒	-	☒	-	●	●	●	●	●	●	☒	●	-	-	-	-	☒	☒	●

Table 5. Summary Site Analysis

	Overall Assessment						Advantages	Disadvantages	Viability
	Safety	Cooperation	Cost	Real Trips	Testing	Benefits			
Urban Sites									
I-80 (SF East Bay)	●	-	-	●	-	-	Vehicle diversity; Close to PATH	Difficult politics; expensive	Not viable
I-5 (Santa Ana Frwy)	●	-	-	●	-	⊠	Vehicle diversity; needs improvement	Very expensive construction; slow	Only viable if re-used as HOV
Suburban Sites									
I-15 (San Diego)	●	●	⊠	●	-	⊠	Existing test site	Would need new construction	Possible
SR-73(Orange County)	●	⊠	●	⊠	-	-	Excess capacity (possibly use lane)	Few trucks/buses; few local benefits	Viable for light duty vehicles
I-80/US 50 (Sacramento)	⊠	⊠	-	●	⊠	●	Diversity in vehicle types	Expensive to build at Yolo Causeway	Not viable
I-280 (SF Peninsula)	●	⊠	●	⊠	⊠	-	Excess capacity (possibly use lane)	Few trucks/buses; few local benefits	Viable for light duty vehicles
Urban Shuttle Sites									
I-105 (Los Angeles)	●	⊠	-	●	-	⊠	Diversity in vehicle types	Expensive construction	Not viable
US101 (San Francisco)	●	⊠	-	●	-	●	Diversity in vehicle types	Expensive construction	Only viable if re-used as HOV
Urban Transit									
I-10 (El Monte/LA)	●	●	●	⊠	-	⊠	Excellent for transit test	Requires construction; no trucks	Possible for HOV/transit test
Urban CVO									
SR-47	●	⊠	⊠	-	-	-	Isolated from other highways	Bridge; short length	Possible for CVO test
Interurban									
I-5/580 (Golden State)	⊠	●	●	-	⊠	⊠	Low construction cost	Hard to attract participants	Viable for small fleet test
I-15 (LA/Las Vegas)	⊠	●	●	-	⊠	⊠	Low construction cost	Hard to attract participants	Viable for small fleet test
I-80 (SF/Sacramento)	⊠	●	⊠	●	●	●	Good range of conditions;low cost	No major negatives	Viable
Mountainous									
I-80 (Sierra Nevada)	-	⊠	⊠	-	-	●	Good for safety oriented test	Significant risks	Possibly viable for safety test

Though all of these sites are possibilities, the greatest promise may instead be at sites that are already programmed for HOV construction, but lack sufficient funding. These sites are predominantly in suburban locations experiencing rapid growth.

6.10 Regional Site Selection Considerations

In general, differences between FOT sites have less to do with the region than to do with the nature of the site, such as construction challenges, traffic volumes and traffic composition. These features differ significantly between urban, suburban and interurban sites, and less so between regions.

Fortunately, California offers many alternative sites that are capable of meeting a range of test requirements. And most of the sites share positive attributes:

- Minimal climatic safety challenges, with a short rainy season and rare ice or snow
- Proximity to AHS research facilities
- Generally positive attitude toward AHS and ITS, and strong commitment from state government.

Perhaps the only drawback to California is that no site provides for testing under icy conditions in a non-mountainous location. Whether this is a true drawback or not will depend on the test objectives. Otherwise, it appears that viable sites exist for almost any conceivable FOT.

Despite these comments, inter-regional differences exist in institutional issues. In Northern California, environmental opposition is an especially strong possibility if an FOT proposes to widen existing roadways, or is perceived as an effort to increase freeway capacity. In the case of the former, widenings could infringe on environmentally sensitive areas, such as the San Francisco Bay, land publicly protected against development, or protected wetland. In the case of the latter, capacity increases are likely to be perceived as contributing to urban sprawl.

An issue related to environmental opposition, that is also likely to arise in Northern California, is perceived competition with rail projects. In the San Francisco area, competition with BART could mean that transit operators limit services on corridors identified as potential FOTs. As a result, the possibility of using public transit buses in the test would be reduced. In other areas an FOT could be perceived as duplicating on-going commuter rail efforts, to which substantial resources have already been devoted.

Interviewees suggest that it will be difficult to create barrier-separated facilities in Northern California. Constraints on right-of-way acquisition, both in terms of availability and costs, are substantial. Furthermore, existing HOV facilities are almost exclusively continuous access (with the exception of the new I-80/Bay Bridge fly-over in Emeryville).

Unlike Northern California, several barrier-separated possibilities already exist in Southern California. The I-15 in San Diego and the I-10 El Monte Busway are strong candidates for initial FOTs. Both corridors have existing barrier separated sections, and both are already serving HOV purposes, allowing for FOT integration with on-going programs. Similarly, the I-105 Century Freeway, while not currently barrier separated, might offer that possibility to a future FOT, and it too has an HOV facility running the length of the corridor. Outside of these existing facilities, however, severe right-of-way constraints would make barrier separation difficult.

7. CONCLUSIONS AND RECOMMENDATIONS

We have little doubt that, under the right conditions, local agencies and California state government would participate in an AHS FOT. Based on our interviews, the federal government could greatly increase the chance of success by funding the construction of the test facility (or a large portion of the construction), and then turning the facility over to the local agencies upon completion of the test.

A number of institutional barriers would be greatly minimized through this approach. Safety concerns over mixed flow facilities would be averted. Environmental opposition to the construction would be minimized because the long-term use of the facility could be for environmentally friendly HOV purposes. If the FOT utilized transit, environmentalists might support (or at least not oppose) the project. Additionally, rather than being perceived as competing with other projects, the FOT would instead be aiding the earlier realization of additional HOV lanes. Perhaps most importantly, an FOT would be less likely to be perceived as a waste of public moneys and resources on “star wars-like” technologies. Instead, it would be pooling resources to achieve two objectives—the execution of an AHS FOT, and the construction of additional HOV lanes. As one interviewee commented, this is the type of funding judo that is necessary in today’s transportation environment.[1]

Based upon this suggestion, a number of sites were advanced by interviewees as likely candidates. This list is by no means exhaustive, but does give a sampling of the possibilities that exist for a future FOT/HOV facility.

- **US 50, Sacramento to El Dorado Hills:** Serves significant commuter traffic into Sacramento in the morning and out of Sacramento in the evening. It is approximately 35 miles long and is very conducive to an HOV facility--sufficient right-of-way exists in the median already. It is currently in the Project Study Report Phase, and is currently planned for being broken up into four segments, the earliest of which might be completed by the year 2000. With outside funding, the first phase could be delivered earlier than planned. It is included in the 1998 STIP, and the cost is estimated at around fifty million dollars.[2]

- **I-80, Sacramento to Roseville:** This corridor is more congested than US 50 and is experiencing more growth. It has reserved right-of-way, is a good HOV candidate, and would also offer testing possibilities under limited fog conditions. It is also a shorter corridor, approximately twelve miles in length. Like US 50, it serves traffic into Sacramento in the morning, and out of Sacramento in the evening.[3]

[1] Interview with Bruce Griesenbeck, SACOG, May 7, 1997.
[2] Interviews with Bruce Griesenbeck, SACOG, May 7, 1997 and Mark Leja, Caltrans District 3, May 8, 1997.
[3] Interviews with Bruce Griesenbeck, SACOG, May 7, 1997 and Mark Leja, Caltrans District 3, May 8, 1997.

- **Alameda I-680, Pleasanton to Santa Clara County line:** This has rapidly become one of the most congested corridors in Northern California, serving traffic into and out Silicon Valley. Early plans are exploring the option of a reversible HOV facility, but funding is not yet available (estimated at around 20 million). The corridor is approximately five miles long, but could be extended if necessary, and the right-of-way exists to accommodate such a facility.[4]

- **US 101, Petaluma to Santa Rosa (or Windsor) in Sonoma County:** There is a proposal for a HOT (high occupancy toll) lane to help increase capacity on this corridor, but it would take tens of millions of dollars to do it. Considerable debate exists as to whether or not there is even a market for toll lanes in this area, but the political will to explore the issue is evident. Right-of-way is thought to be available as well.[5]

- **I-5 in the San Diego area from the I-805 junction to Manchester Drive:** This is a five-mile corridor programmed and included in the RTIP that is scheduled to be in operation within five years. It would ideally be a barrier separated/reversible facility much like that on I-15 in San Diego.[6]

A second, less expensive, option would be to use an existing lane on an uncongested highway. Such a test could only be reasonably completed if it did not result in congested traffic on the remaining lanes. The drawback to this approach is that it is less obvious how to induce local and state agencies to participate in such a test. A financial incentive would certainly be needed, but this incentive may be difficult to directly link to the project. Potential sites include:

- SR 73 in Orange County
- I-280 in San Mateo/Santa Clara Counties

A third option is to create an AHS test on an inter-urban roadway. There are few local or state obstacles to this approach, provided that the federal government bears the cost. A major advantage is that construction costs would be low. Also, these roads provide the opportunity to test AHS on a variety of terrains and climatic conditions. However, it would be difficult to attract a large pool of participants (except on I-80), which may make it impossible to conduct such a test. Potential sites include:

- I-80 between Sacramento and San Francisco
- I-5 between Los Angeles and San Francisco
- I-15 between Los Angeles and Las Vegas

The I-80 site looks especially attractive in that it has a diversity of conditions, as well as the possibility of attracting commuters.

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[4] Interviews with Joel Markowitz and Jeff Georgevich, May 29, 1997 and Jim McCrank, May 30, 1997.
[5] Interviews with Joel Markowitz and Jeff Georgevich, May 29, 1997 and Jim McCrank, May 30, 1997.
[6] Interview with Stuart Harvey, Caltrans District 11, May 9, 1997.

The final possibility is to conduct a more specialized test focused on heavy duty vehicles. Two possible sites for such a test include:

- SR 47 near the Port of Los Angeles
- I-10 El Monte Busway

It is difficult to identify a specific incentive to attract local participation to the SR 47 route, though it has the attractive feature of being isolated from other highways. In the case of I-10, a suitable local incentive may be expansion of the facility from its current one lane per direction to two lanes per direction.

We judged the urban sites to be less viable for a test because the test could not be conducted without new construction, the cost of new construction is high and the test could be seriously delayed in the approval process.

As a final alternative, a safety oriented test under some form of partial automation in mixed traffic might be politically acceptable in various places. The I-80 Donner Pass roadway is a potential site, should there be a desire to take on particularly challenging conditions. However, the test would have to be conducted within existing lanes to be viable.

When the time comes to conduct an FOT, we recommend that the final site be selected through a competitive bid process. This is important for two reasons:

- To ensure that there is true local commitment to the project
- To minimize the cost of conducting the test

A major factor in selecting a site should be evidence that the project will be approved in a timely manner, which could be indicated if the proposed site had already survived environmental reviews or if the test can be conducted with minimal construction. We believe that a properly structured request for proposals would attract numerous applicants.

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APPENDICES

APPENDIX I: DETAILED DESCRIPTION OF FOT SITES

This section provides detailed information on the FOT sites. In addition to the descriptive information that follows, tables are provided for each site. The information provided is based on the State Highway Log, Caltrans Route Segment Report (1989), U.S. Census, California State Franchise Board, individual Chambers of Commerce for cities, and the HI-COMP congestion report (Caltrans). The tables include the following information:

General

- Route Number
- Year Built (Exact year was unavailable if built prior to 1964)
- Counties
- Dates of Major Repairs
- Mileposts that Define Start and End of Segment
- Major Freeway Interchanges
- Description of Roadway Pavement

Traffic Volumes

- Peak Hour and Daily Traffic, All Vehicles
- Daily Truck Volumes and Truck Percentages
- Daily Traffic per Lane

Highway Description

- Number of Lanes
- Excess Right-of-Way (width of right-of-way minus width of existing lanes)
- Congested Portions (locations, directions and hours)
- Accident Statistics ($1000 claim per mile per year and fatalities per 100 million vehicle miles, based on 1989 Route Segment Report; fatalities are averaged over three prior years; reporting no longer available)
- Number of Overcrossings, Undercrossings and Bridges
- Grade classification (representing steepness of highway) and terrain classification (representing steepness of surrounding land); steepest grade is provided on routes that are especially hilly.

Surrounding Area Description

- Climate Data (low and high temperatures, rainfall and snowfall)
- Population and retail sales of surrounding cities
- Major employers in vicinity of highway.
- Employment within zip codes that are situated within 1 mile of highway.

It should be noted that some of the measures provide only an approximate description of the highway, in terms of surrounding development and accident experience in particular. These can only be used to determine large differences between highways.

I.1 Urban Sites

I-5 Santa Ana Freeway

This segment of Interstate 5 passes through the industrial heart of Los Angeles, extending from East Los Angeles to Buena Park. It is one of the most heavily congested routes in the state. Daily traffic ranges from 21,250 vehicles per day/lane to 33,500 vehicles per day/lane. Truck volumes are also high, ranging from 7.2 to 10.6% of the traffic.

The surrounding areas are mostly in industrial use, with sound walls provided along a large portion of the freeway segment. The only major shopping area is the Citadel Mall in the City of Commerce. There are no major department stores. Major nearby trip generators include Rockwell International, Rancho Los Amigos Hospital and the Commerce Casino. The northern end of the segment is within a few miles of Downtown Los Angeles and the County/USC Hospital.

The highway has 18 overcrossings, 14 undercrossings and 9 bridges, and there is little excess right-of-way along the highway, making new construction especially difficult. There are no carpool lanes along the segment and driving on some of the shoulders is permitted during rush hours. HOV lanes are being planned for the section between the 605 freeway and the LA County line and interim HOV lanes are scheduled for construction as part of the 1996 STIP. The I-5 North Improvement Project currently underway at the interchange connecting the I-5 and State Route 91 will provide direct connections to HOV lanes. Sound walls are planned for construction at various places in Commerce and Santa Fe Springs in the 1996 STIP. Truck lanes are proposed on I-5 in Los Angeles in the 1997 draft RTP.

I-80 MacArthur Freeway/Eastshore Freeway/Bay Bridge

This segment of Interstate 80 links the city of San Francisco to the East Bay and further inland toward Sacramento through Pinole. The Bay Bridge is the bottleneck along this segment due to its high traffic volume and narrow width; other bottlenecks include the intersection with I-580 and Rte. 4. Like the Santa Ana Freeway, this roadway is highly congested. Daily traffic per lane ranges from 18,800 vehicles to 31,375 vehicles, with 4.1 to 7.3% trucks.

Sound walls exist over much of the route. Carpool lanes are provided in the vicinity of the toll plaza with a minimum occupancy of 3, and are in force for rush hours only. New construction is difficult in this corridor due to the proximity to the San Francisco Bay; a large number of overcrossings (8), undercrossings (14) and bridges (8); and limited excess right-of-way (ranging from 0 on the Bay Bridge to 100 feet, prior to construction of new carpool lanes). Likely opposition from local environmental groups is also a major factor making construction difficult.

This segment passes through urban and suburban areas and the surrounding land use includes residential, commercial and industrial. Seismic retrofit of the Bay Bridge is one of the projects underway, including possible replacement of the eastern end of the bridge near the toll plaza. In addition, carpool lanes are being added throughout the corridor, including a flyover connection close to the toll plaza. New interchanges are being constructed as part of the replacement for the Cypress Freeway (I-880).

I.2 Suburban Commuter

I-15 Escondido Freeway

This section of I-15 extends from Rt. 163 to the Poway road interchange. The Interstate 15 Express Lanes are an eight-mile-long reversible carpool facility constructed in the freeway median from the junction with I-15 and State Route 163 north to North City Parkway, with no freeway exits. The lanes route carpools, vanpools, buses and motorcycles south during the morning commute, 6-9 a.m., and north during the afternoon commute, 3-6:30 p.m. The lanes are also the site for the NAHSC automated highway demonstration. Changeable message signs are provided along the route. Traffic in the corridor is relatively light, with 8800 to 20,000 vehicles per day per lane.

The highway has significant excess right-of-way, ranging from 124 to 135 feet. However, because portions pass through rolling terrain, construction could still be challenging. There are six overcrossings and two undercrossings. The area surrounding the highway is not densely developed. The major employers are Palomar Pomerado Health Car, Hewlett Packard and Sony.

<u>I-80/US 50 Alan Hart Freeway</u>

The segment of I-80 starts from Rt. 113 and continues on I-80 (business loop) or US 50 to its intersection with I-5. The freeway has a wide median for much of its length. The surrounding land use is agricultural between Davis and the outskirts of Sacramento and urban in the city of Sacramento. Traffic levels are generally light, with 9,000 to 18,500 vehicles per day per lane. However, traffic congestion can be significant around holiday weekends.

The major construction challenge for the route is the Yolo causeway, spanning the Sacramento River flood plain. Otherwise, the right-of-way allows for some expansion, the number of overcrossings and undercrossings is small, and the terrain is flat.

There are no carpool lanes, but Investment Studies are underway to separately study carpool lanes from Davis to US 50 and on the US 50 Corridor, including the possibility of allowing single occupant vehicles to pay a toll to use HOV lanes. Transit options, including buses and light rail, are also being explored. The 1996 STIP proposes modification of the Mace Boulevard overcrossing from 4 to 6 lanes.

<u>I-280 Junipero Serra Freeway</u>

The I-280 segment from Rte 85 to I-380 passes through the Foothills of the Santa Cruz Mountains. The surrounding area is sparsely developed, but it is close to some of the major employment centers in Santa Clara County. Congestion is light, with just 8,000 to 14,000 vehicles per lane per day, less than half the traffic levels of the urban sites. Truck traffic is just 1.3-3.1% of the total, and there are no congested portions.

Though excess right-of-way exists throughout the segment, construction would be difficult due to rolling terrain and environmental challenges (including the San Francisco watershed). There are also significant bridges along the route. However, due to light traffic levels, the roadway would not be congested if one of the existing lanes were devoted to an AHS FOT.

The largest employers on the route are in the Palo Alto and Cupertino areas, including Hewlett Packard, Stanford University, Apple Computer and Tandem Computers. Major shopping centers are located in Palo Alto and Cupertino as well.

<u>SR 73 San Joaquin Hills Tollway</u>

This 15 mile toll road connects I-5 in San Juan Capistrano to SR 73 (Corona Del Mar Fwy). This toll road allows toll collection by the FastTrak method, in which subscribers are issued debit accounts and transponders, with the toll (ranging from 25 cents to $2) debited automatically form the account. The corridor passes through hills and is surrounded by sparsely developed residential areas near San Juan Capistrano, but is otherwise almost rural in nature. Traffic levels are very light, with just 6-10,000 vehicles per lane per day; only about 1% of the vehicles are trucks.

Because the highway is lightly traveled, it would not be congested if one of its three lanes were used for an AHS FOT. However, new construction would be relatively simple, due to the large width of the existing right-of-way, and its design, which allows for expansion (the space in the median is reserved for future transportation improvements like high occupancy vehicle lanes and transit options).

The corridor passes close to commercial centers in Newport Beach and Irvine. Major employers in the vicinity include UC Irvine, Pacific Mutual Life Insurance, Western Digital and AST Research.

I.3 Urban Shuttle

US 101/I-280 Bayshore Freeway

US 101 connects San Francisco International Airport with the City of San Francisco. The surrounding land is used for commercial and industrial purposes and closer to the City of San Francisco, used for residential use. Portions are surrounded by San Francisco Bay. The segment chosen continues on I-280 into the Downtown, which for a portion is a two tiered elevated structure, with northbound lanes along the lower tier. The freeway then continues on an elevated alignment and ends near downtown San Francisco. Traffic levels vary from light (about 10,000 vehicles per lane per day) to very heavy (32,000 vehicles per day), with heaviest congestion around South San Francisco and the 280 interchange.

New construction is extremely challenging, due to narrow right-of-way, proximity of San Francisco Bay, and a complicated interchange between I-280 and US 101. Heavy traffic levels make it impossible to use existing lanes on 101 for an FOT, though portions of I-280 have excess capacity.

By far the largest employer on the route is United Airlines, with more than 17,000 employees. A variety of taxi and shuttle companies serve the route. Yellow Cab operates more than 300 taxis, DeSoto Cab operates 97 taxis and Supershuttle operates 80 vans. More than 900 taxis serve the airport. There are no major shopping centers on the route.

I-105 Glenn Anderson Freeway

This is one of the newest freeways in Southern California. The freeway is itself is wide with the MTA blue line passing along its median and HOV lanes provided along the entire segment. These are also provided with separate entrance and exit ramps to I-110 and I-405. Southern California HOV lanes are operated on a 24 hour basis unlike their Northern California counterparts. The freeway is raised for most of its length and surrounding land is residential or commercial. Sound walls are provided where the freeway is lowered. The roadway already experiences significant congestion, with up to 32,000 vehicles per lane per day. Traffic is heaviest between the I-110 and I-405 interchanges.

Excess right-of-way exists throughout the corridor. Nevertheless, new construction would be difficult, due to large portions of elevated and viaduct construction. High traffic volumes would make it impossible to use existing lanes for an FOT.

The largest trip generators are in the vicinity of the Los Angeles Airport, including Hughes, Northrop Grunman and the Los Angeles Air Force Base. Taxis operate under a permit system that restricts each vehicle to one weekday per week, creating an institutional challenge to equipping vehicles. Suppershuttle and Primetime Shuttle both operate large fleets of vans.

The 1997 Traffic Systems Management Plan has provided for installing CCTVs as the top priority among 40 projects. The 1997 draft RTP proposes extension of the MTA Green Line from its location in the 105 median to LAX.

I.4 Urban Transit

I-10

I-10 is an urban commuter freeway with barrier separated carpool lanes along much of its length. Carpools and buses have separate entrances and exits at certain locations. Special bus stations are provided at USC/LA County hospital, CalState LA and El Monte. The El Monte Busway lane carries as many people as three regular traffic lanes during the peak hours. The El Monte Busway is the only HOV facility in Southern California that requires three or more people per vehicle. About 400 buses traverse the route each day in each direction.

The surrounding land is characterized by commercial and residential use. Sound walls exist along almost the entire stretch and Amtrak runs through the median of the freeway as well. Portions of the route are heavily congested, including the entire stretch from Alameda to I-710 eastbound in the afternoon. Traffic volumes are as high as 34,000 vehicles per lane per day.

New construction on the corridor would be challenging, due to a relatively narrow right-of-way and a large number of overcrossings (17) and undercrossings (7). Traffic levels would make it impossible to use existing lanes for an FOT. However, there is some local interest in adding lanes to the busway, which could possibly be used as part of an FOT.

Major trip generators are concentrated in the Downtown at the west end of the route. Other major trip generators are the USC/County hospital and Cal State LA.

Urban Truck

<u>SR 47 Terminal Island Freeway</u>

The extension of Terminal Island freeway passes through industrial use areas and the major landmarks are a container park and a chemical plant. Near the beginning of the freeway, a drawbridge across the Cerritos channel provides a major construction challenge. Traffic levels are very light, with just 2-4,000 vehicles per lane per day, with truck traffic in the 10-20% range. The right-of-way is narrow in parts, making new construction difficult. However, it might be possible to use an existing lane for an FOT without causing significant congestion.

I.6 Interurban Freeway

<u>I-5/I-580 West Side Freeway</u>

The section selected starts near Los Angeles national forest with several steep and winding curves. The north and south bound lanes are independently aligned and runaway truck ramps are provided for the steep downgrades (the 5.9% grade is among the steepest in the state). Once in the valley, the surrounding land is used for agricultural purposes and is sparsely developed. There are no major towns along I-5/580 segment until reaching Livermore in the Bay Area. Traffic levels are light, with just 4,000 to 16,000 vehicles per day per lane.

The freeway is subject to gusty winds and severe dust conditions, especially during summer months, and warning signs are provided to alert motorists. Fatality rates are somewhat higher than other roads. The median is typically wide except for the Grapevine area where the lanes are independently aligned and separate truck lanes are provided for the downgrade. On Rt. 580, Altamont pass is a major grade and the region is hilly. A Major Investment Study is underway to study gateway management strategies for Altamont pass and commute options. Overall, however, construction of FOT lanes would not be challenging, except in the Grapevine area.

<u>I-15 Las Vegas:</u>

This is one the chief routes to Las Vegas and beyond from Los Angeles. Like most interurban routes, traffic levels are light, except on days surrounding weekends. Traffic levels range from 6400 to 19,500 vehicles per day per lane, and there are no major congestion areas on weekdays.

The hills in San Bernardino provide the steep grades with the steepest being at Cajon pass (4.9%), where the freeway lanes are independently aligned. The remaining portion traverses the desert and is mainly flat, where new construction is relatively simple. There are only a few towns along the way: Victorville, Hesperia and Barstow. The largest employers are military: Fort Irwin and USMC Logistics Base. These might not be amenable to attracting a group of regular users. The extreme heat conditions create environment challenges, as does blowing dust. Fatality rates are higher than on other roads. Special truck lanes are provided for trucks and slower moving vehicles near the state line.

The 1996 STIP proposes modification of the interchange with Rte. 66 and a realigned interchange at the junction with Rte. 40. The 1997 draft RTP proposes extension of truck lanes on I-15. A Major Investment Study is also being conducted on the freeway.

I-80: Vallejo-Davis:

This segment is mostly flat, with some rolling portions. Unlike the other inter-urban roadways, there are several major towns along the route, and commute traffic is not insignificant. Traffic levels are moderate, with 14,500 to 20,000 vehicles per lane per day.

The freeway contains significant excess right-of-way over much of its route. This, combined with generally flat terrain, make new construction viable. Traffic is likely too heavy, however, to convert existing lanes to AHS FOT use. Fog conditions can be significant in the winter. Major employers include UC Davis, Kaiser Permanente and Marine World/Africa USA.

I.7 Mountainous Freeway

I-80, Donner Pass

The segment selected forms part of the route between Sacramento and Reno, Nevada. The freeway passes through Donner Pass, which is the highest point on the route (7227 ft.). The surrounding land is mainly forest and there are very few towns along the way. The route is subject to frost and chilly conditions during winter with the snow necessitating use of snow chains during the heavier snowfalls. The route is also characterized by the numerous steep grades (up to 6%) and winding roads. The highway alignment is independent at various locations, especially within Donner Pass. Traffic levels are generally light, ranging from 5500 to 8600 vehicles per lane per day, though traffic can be much heavier around weekends. Truck volumes range from 9-15%. Sound walls have been planned for Rocklin in the 1996 STIP.

Santa Ana Fwy

Route Number I-5 Route name: Santa Ana Year built: Prior to 1964
Counties: Los Angeles, Orange Major repairs 12/66, 04/83,04/86,05/86,08/75, 09/75
Milepost Start 42.1 (OC)
Milepost End 16.47 (LAC)
Major freeway interchanges: Rte 91, Rte 605, Rte 60, Rte. 710
Roadway pavement: Concrete (Less than 2" AC Surface), AC base and Surface (At least 7" thick) (on sections between OC 42.52 and LA 3.44 mileposts)

Traffic volumes:

Total				Trucks			
Peak		Daily		Daily		%	
Min	Max	Min	Max	Min	Max	Min	Max
11000	15700	155000	268000	15309	29694	7.2	10.6

Daily per lane			
Total		Truck	
Min	Max	Min	Max
21250	33500	1998	4152

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
3	several	4	several	3	several	5	13.05	3.40

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
3	11.35 (LA)	80	3.66 (LA)	34

Congested portions:

Direction	Segment	(AM/PM)	Hours
South	Rt 39 - Rt 91	PM	1540-1740, 1840-1940
North	Rt 91- Rt 605	PM	1600-1700
South	Rt 605-Rt 91	PM	1530-1800
South	Rt 710-Rt 605	PM	1430-1800
North	Rt 710-Rt 605	AM	0600-0900
North	Rt 605-Rt 91	AM	0545-0845
North	Rt 710-Rt 60	AM	0615-0800
North	Rt 710-Rt 60	PM	1700-1800
South	Rt 60- Rt 710	PM	1500-1830

Santa Ana Fwy

Accident Statistics (1989)

$1000 claims/mile/year	526-1366
Fatalities/100 million miles	.25-1.15

Overcrossings	18	Ped O/C	1
Undercrossings	14		
Bridges	9		
Grades	Flat	Terrain	Flat

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Annual Snow
LAX	75.3	47.2	12.1	0
LA Civic	83.8	48.5	14.7	0

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
Los Angeles	3,486,000	17,611,000	475
Norwalk	94,279	433,000	10
Downey	91,444	699,000	12.8
Buena Park	73,684	618,000	10.8
Montebello	61,400	586,000	8.5
La Mirada	40,452	246,000	8
Santa Fe	15,520	459,000	8.9
Commerce	12,423	339,000	6.6

Employment in Vicinity of Highway: 289,000

MacArthur Fwy/East Shore Fwy

Route Number I-80 Route name: MacArthur, East Shore Year built Prior to 1964
Counties: San Francisco, Alameda, Contra Costa Major repairs: 08/81, 08/89, 07/94, 05/79, 04/76, 97
Milepost Start 5.45 (SFC)
Milepost End 7.60 (CCC)
Major freeway interchanges: Rte 580, Rte 880, Rte 13, Rte. 123
Roadway pavement: Concrete (Less than 2" AC Surface), AC base and Surface (At least 7" thick) (on sections between ALC 1.554 and ALC 3.517, CCC 0.254 and 4.953 mileposts)

Traffic volumes:

Total				Trucks			
Peak Hour		Daily (AADT)		Daily (AADTT)		%	
Min	Max	Min	Max	Min	Max	Min	Max
10800	21800	144000	274000	6553	18688	4.1	7.3

- Daily per lane			
Total		Truck	
Min	Max	Min	Max
18800	31375	1005	2336

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
3	several	19	1.99-2.02 ALC	3	several	6	1.2-2.5 ALC	4.15

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
27	0.501 CCC	100	3.213 ALC	45

Congested portions:

Direction	Segment	(AM/PM)	Hours
South	Bay bridge	PM	1500-1930
North	Bay bridge	PM	1400-1800
South	123-580(s)	PM	1500-1900
North	580(s)-Rt 123	PM	1600-1800
North	580(n)-Rt 4	PM	1500-1800
South	Rt 4-Rt 580(n)	AM	0600-0900
South	Bay bridge	AM	0600-0900

Accident Statistics (1989)

$1000 claims/mile/year	$304-1000
Fatalities/100 million miles	0-1.3

Overcrossings	8	Ped O/C	0
Undercrossings	14		
Bridges	8		
Grades	Flat	Terrain	Flat/Some Rolling

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Annual Snow
SFO	71.4	41.9	19.93	0

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
San Francisco	723959	6636000	40
Berkley	102724	746000	10.2
Richmond	87425	560000	52.9
El Cerrito	22869	160000	3.7
Pinole	17460	186000	13.4
Albany	16327	69000	5.5

Employment in Vicinity of Highway: 236,000

Major Trip Generators

Name	
UC Berkeley	10802
Lawrence Berkeley Lab	3100
Alta Bates Medical Center	2400
Summit Medical Center	2000
Pacific Bell	2000
Levi Strauss & Co. Inc.	2000
Chevron USA Refinery	1620
Levi Straus & Assoc. Inc.	1600
CSAA Inter-Insurance	1600
Federal Reserve Bank of SF	1397

Escondido Fwy

Route Number	15	Route name:	Escondido Fwy	Year built	1982
Counties:	San Diego			Major repairs:	
Milepost Start	12.00 SDC				
Milepost End	18.18 SDC				
Major freeway interchanges:		None			
Roadway pavement:		Concrete (Less than 2" AC Surface)			

Traffic volumes:

Total				Trucks			
Peak Hour		Daily (AADT)		Daily (AADTT)		%	
Min	Max	Min	Max	Min	Max	Min	Max
107000	21800	10600	243000	8736	13365	3.9	6.1

Daily per lane			
Total		Truck	
Min	Max	Min	Max
8833	20250	728	1114

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
5	several	7	12.3	5	several	8	several	6.40

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
124	12.12	135	several	132.25

Congested portions:

Direction	Segment	(AM/PM)	Hours
N/A	None	N/A	N/A

Accident Statistics (1989)

$1000 claims/mile/year	$190-370
Fatalities/100 million miles	.27-.72

Escondido Fwy

Overcrossings	6	Ped O/C	0
Undercrossings	2		
Bridges	0		
Grades	Flat/Rolling	Terrain	Flat/Rolling

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Ann Snow (in)
San Diego Air	75.5	48	10.36	0

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
San Diego	1,110,549	7,868,000	376.3
Escondido	55,388	1,311,000	36.2

Employment in Vicinity of Highway: 38,100

Major Trip Generators

Name	Employees
Palomar Pomerado Health	3500
Hewlett Packard	2465
Sony Technology Center	2338
GDE Systems	700
Superior Ready Mix Concrete	375
Alcoa Electronic Packaging	344
Berryman and Henigar	330

Alan S. Hart Fwy

Route Number I-80 / US-50 Route name: Alan S. Hart Fwy Year built Prior to 1964-1971
Counties: Solano, Yolo, Sacramento Major repairs:
Milepost Start 38.21 (SOC)/I80
Milepost End 2.48 (SAC)/I50
Major freeway interchanges: Rte 113, Rte 50, Rte 5
Roadway pavement: Concrete (Less than 2" AC Surface), AC base and Surface (At least 7" thick) (on sections between YLC 6.358 and YLC 10.150 mileposts)

Traffic volumes:

Total				Trucks			
Peak Hour		Daily (AADT)		Daily (AADTT)		%	
Min	Max	Min	Max	Min	Max	Min	Max
4600	12000	48000	121000	4368	10384	8.5	12.7

Daily per lane			
Total		Truck	
Min	Max	Min	Max
9167	18500	936	1503

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
3	several	6	9.4 YLC	3	several	6	9.13-9.36 YLC	3.29

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
32	9.179 YLC	90	1.355 SAC	60

Congested portions:

Direction	Segment	(AM/PM)	Hours
North	99-Jct 80/80b	PM	1545-1800
South	Jct 80/80b- 99	AM	0715-0815

Accident Statistics (1989)

$1000 claims/mile/year	$91-340
Fatalities/100 million miles	0-1.05

Alan S. Hart Fwy

Overcrossings	2	Ped O/C	0
Undercrossings	3		
Bridges	8		
Grades	Flat	Terrain	Flat

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Annual Snow
Sacto Airpt	93	37.6	17.14	0
Davis	94.3	36.3	17.26	0.1

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
Sacramento	369,365	2,507,000	99.1
Davis	46,209	955,000	8.6

Employment in Vicinity of Highway: 63,500

Major Trip Generators

Name	Employees
State of California	36116
County of Sacramento	11587
Sacramento City Unif Schools	7000
UC Davis	6795
Sutter Health	5975
Raley's/Bel Air	4900
City of Sacramento	4400
California Almond Growers	800
MTS Inc.	700
Sacramento Live Ltd.	600
Crystal Cream & Butter	410
Affordable Health Care	360

Junipero Serra Fwy

Route Number I-280 Route name: Junipero Serra Fwy Year built: 1967-73
Counties: San Clara, San Mateo Major repairs: 02/91, 07/67, 10/69, 08/69, 09/73, 10/67,
Milepost Start 10.74 (SCC)
Milepost End 21.02 (SMC)
Major freeway interchanges: Rte 92, Rte 84, Rte 35
Roadway pavement: Concrete (Less than 2" AC Surface), AC base and Surface (At least 7" thick) (on sections between ALC 1.554 and ALC 3.517, CCC 0.254 and 4.953 mileposts)

Traffic volumes:

Total				Trucks			
Peak Hour		Daily (AADT)		Daily (AADTT)		%	
Min	Max	Min	Max	Min	Max	Min	Max
8500	11500	77000	111000	1155	4362	1.3	3.1

Daily per lane			
Total		Truck	
Min	Max	Min	Max
8100	13875	144	545

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
4	several	5	8.2-10.5SMC	4	several	5	8.5-10.5 SMC	4.1

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
58	18.900 SMC	132	19.910 SCC	76.36

Congested portions:

Direction	Segment	(AM/PM)	Hours
N/A	None	N/A	N/A

Accident Statistics (1989)

$1000 claim/mile/year	$36-$393
Fatalities/100 million miles	0-1.92

Junipero Serra Fwy

Overcrossings	8	Ped O/C	0
Undercrossings	25		
Bridges	4		
Grades	Rolling/Some Flat	Terrain	Rolling/ Some Flat

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Annual Snow
SFO	71.4	41.9	19.93	0

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
Sunnyvale	117,229	1,230,000	22.8
San Mateo	85,486	933,000	16.1
Redwood City	66,072	800,000	34.5
Palo Alto	55,900	987,000	26
Cupertino	40,263	468,000	10.4
San Bruno	38,961	473,000	6.5
Menlo Park	28,001	352,000	6
Los Altos	27,299	140,000	6.4
Burlingame	26,801	444,000	6.1
San Carlos	26,167	282,000	5.7
Milbrae	20,412	131,000	3.3

Employment in Vicinity of Highway: 246,000

Major Trip Generators

Name	Employees
Hewlett Packard	5000+
Stanford University	5000+
Hewlett Packard (Cupertino)	3600
Apple Computer	3500
Tandem Computers	3000
Space Systems/Loral	1500-2000
Varian Associates	1500-2000
Roche Bioscience	1000-1500

San Joaquin Toll Way/Corona Del Mar Tollwy

Route Number Rte. 73 Route name: Corona Del Mar Fwy Year built: 1996
Counties: Orange Major repairs:
Milepost Start unknown
Milepost End unknown
Major freeway interchanges: Rt. 55, Rt. 405
Roadway pavement: unknown

Traffic volumes:

Total				Trucks			
Peak Hour		Daily (AADT)		Daily (AADTT)		%	
Min	Max	Min	Max	Min	Max	Min	Max
unavailable	unavailable	36,431	59,571	About 400	About 600	About 1%	About 1%

Daily per lane			
Total		Truck	
Min	Max	Min	Max
6000	10000	About 70	About 100

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
3	several	10	toll plaza	3	several	10	toll plaza	3.00

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
268	various	298	various	280

Congested portions:

Direction	Segment	(AM/PM)	Hours
N/A	none	N/A	N/A

Accident Statistics

$1000 claims/mile/year	unavailable
Fatalities/100 million miles	unavailable

San Joaquin Toll Way/Corona Del Mar Tollwy

Overcrossings	3	Ped O/C	0
Undercrossings	9		
Bridges	0		
Grades	Rolling	Terrain	Rolling

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Annual Snow
Long Beach	82.7	45.3	12.22	0

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
Irvine	110,330	1,288,000	43.1
Costa Mesa	96,357	1,861,000	15.8
Mission Viejo	72,820	686,000	18.1
Newport Beach	66,643	878,000	24.7
Lake Forest	50,700	289,971	12
Laguna Hills	46,731	368,000	11
Laguna Niguel	44,723	369,000	14.9
Laguna Beach	23,170	174,000	9.7

Employment in Vicinity of Highway: 274,000

Major Trip Generators

Name	Employees
UC Irvine	12000
Pacific Mutual Life Insurance	1800
Western Digital Corp.	1500
AST Research	1500
ARV Housing Group	1300
Toshiba America Information	1126
Los Angeles SMSA Limited	1000
Health Care of Laguna Hills	996
Saddleback Mem Med Center	848
St. John Knits Inc.	800
Taco Bell Corp	800

Bayshore Fwy /John F. Foran Fwy

Route Number US 101/I-280 Route name: Bayshore/John Foran/James Lick Year Built: Prior to 1964
Counties: San Mateo, San Francisco Major repairs: 01/85, 03/94, 10/69, 08/70, 03/68, 08/72, 2/76
Milepost Start 19.12 SMC
Milepost End 7.54 SFC
Major freeway interchanges: Rte 380, Rte 280
Roadway pavement: Concrete (Less than 2" AC Surface), AC base and Surface (At least 7" thick) (on sections)

Traffic volumes:

Total				Trucks			
Peak Hour		Daily (AADT)		Daily (AADTT)		%	
Min	Max	Min	Max	Min	Max	Min	Max
6600	21300	79000*	257000	0	11671	0	6.5

Daily per lane			
Total		Truck	
Min	Max	Min	Max
10000*	32125	0	1459

* Recorded prior to closure of 280 in 1989 due to earthquake

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
2	several	6	21.0-21.2	3	several	6	21.0-21.2	3.8

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
22	5.951 SFC	99	4.241 SFC	50.33

Congested portions:

Direction	Segment	(AM/PM)	Hours
North	92-South SF	AM	0630-0830
North	92-South SF	PM	1645-1830
South	South SF-92	AM	1600-1830

Accident Statistics (1989)

$1000 claim/mile/year	$255-$1805
Fatalities/100 million miles	0-2.80

Bayshore Fwy /John F. Foran Fwy

Overcrossings	8	Ped O/C	1
Undercrossings	4		
Bridges	0		
Grades	Flat/Some Rolling	Terrain	Flat/Some Rolling

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Annual Snow
SFO	71.4	41.9	19.93	0

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
San Francisco	750,000	6,640,000	42
South SF	54,312	553,000	30
San Bruno	38,961	473,000	6.5
Burlingame	26,801	444,000	6.1
Milbrae	20,412	131,000	3.3

Employment in Vicinity of Highway: 348,000

Trip Generators

Name	Employees
United Airlines	17212
Raychem	2749
Genetech	2445
Franklin Resources	2410
American Airlines	2100
Pacific Bell	2000
Roche Biotech	1900
Intuit	1800
CSAA Inter-Insurance Bureau	1600

Bayshore Fwy /John F. Foran Fwy

Major Airport Shuttle Companies

Name	Vans
Supershuttle	80
Bayporter Express	40
Lorrie's Travel and Tours	28
South and East Bay Shuttle	21
Door-to-door Airport Express	20
American Airporter	15
Yellow Van & Tours	13
Other	56
Total	217

Major Airport Tax Companies

Name	Taxis
Yellow Cab Cooperative	301
DeSoto Cab Company	97
Veterans Taxicab Company	83
National Cab Company	82
Luxor Cab Company	81
United Cab Company	62
Town Taxi	38
Sunshine Cabs	25
Pacific Cab Company	25
Citywide Cab Company	23
Others	137
Total	954

Glenn Anderson Fwy (105)

Route Number I-105 Route name: Glenn Anderson Fwy Year built: 1993
Counties: Los Angeles Major repairs:
Milepost Start 0.5 LAC
Milepost End 7.39 LAC
Major freeway interchanges: Rte. 405, Rte. 110
Roadway pavement: Concrete (Less than 2" AC Surface)

Traffic volumes:

Total				Trucks			
Peak Hour		Daily (AADT)		Daily (AADTT)		%	
Min	Max	Min	Max	Min	Max	Min	Max
3800	17000	42000	215000	7150	11741	5.9	6.6

Daily per lane			
Total		Truck	
Min	Max	Min	Max
4500	32125	600	1459

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
2	0.5	6	2.60-2.99	2	0.5	6	6.11-6.52	4.5

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
88	1.2	124	7.4	101

Congested portions:

Direction	Segment	(AM/PM)	Hours
unavailable			

Accident Statistics (1989)

$1000 claims/mile/year	unavailable
Fatalities/100 million miles	unavailable

Glenn Anderson Fwy (105)

Overcrossings	8	Ped O/C	0
Undercrossings	4		
Bridges	1		
Grades	Flat	Terrain	Flat

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Annual Snow
LAX	75.3	47.2	12.11	0

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
Los Angeles	3,486,000	17,610,800	475
Inglewood	114,583	394,000	9.3
Hawthorne	71,349	476,000	6
Gardena	49,847	365,000	5.3
El Segundo	15,233	198,000	10.9

Employment in Vicinity of Highway: 225,000

Major Trip Generators

Name	Employees
Hughes Electronics	16500
Northrop Grumman	3000
Los Angeles AFB	2600
Xerox Corporation	2400
Valley Health Services	1596
Mattel Inc.	1500
Carondelet Health Care	1350
Chevron USA	1300
Daniel Memorial Hospital	1200

Major Airport Van Companies

Name	Vans
Suppershuttle LA	no data
Suppershuttle SF	no data
Primetime Shuttle-SF/West LA	137
Suppershuttle OC	70
Best Shuttle	50
Golden Shuttle	50
Suppershuttle SG	32
Metropolitan Express	20
Roadrunner Shuttle	20
Southern California Coach	19
ABC Shuttle	15
Coast Shuttle	15
Shuttle One	15

Major Airport Taxi Companies

Name	Taxis
LA Taxi	326
Checker Cab	290
Bell Cab	250
Independent Cab	250
Yellow Cab	200
Valley Cab	100
United Checker Cab	70
Total	1486

Notes: Los Angeles has 1800 vehicles licensed to operate from LAX. These are divided into A,B,C,D,E categories. Only 1 category can pick up passengers at LAX on a given day. Out of these, about 1000 are owner operated and the reast are company owned. Most companies are authorized a larger number of vehicles than they have on the streets. United Checker, LA Taxi and Yellow cab are owned by the same company and account for 596 vehicles.

San Bernardino Frwy and San Bernardino Busway

Route Number	I-10	Route name:	San Bernardino Frwy	Year built	Prior to 1964
Counties:	Los Angeles		San Bernardino Busway	Major repairs:	11/72, 01/74, 03/73,
Milepost Start	16.97				
Milepost End	28.61				
Major freeway interchanges:		Rt. 5, Rt. 101, Rt. 60, Rt. 710			
Roadway pavement:		Concrete (Less than 2" AC Surface)			

Traffic volumes:

Total				Trucks			
Peak Hour		Daily (AADT)		Daily (AADTT)		%	
Min	Max	Min	Max	Min	Max	Min	Max
14900	19300	218000	281000	10125	18265	4.5	6.5

Busway Traffic Volumes:

Total			
Peak Hour		Daily (AADT)	
Min	Max	Min	Max
700	1750	3350	13700

Daily per lane			
Total		Truck	
Min	Max	Min	Max
17308	34250	1012	1825

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
4	several	7	25.0-25.2	4	several	7	27.14	4.75

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
12	21.41	116	27.14	36.00

San Bernardino Frwy and San Bernardino Busway

Congested Portions:

Direction	Segment	AM/PM	Hours
West	El Monte- 710	AM	0630-0930
East	710-El Monte	PM	1530-1915
West	Soto-Alameda	AM	0630-0830
East	Alameda-710	PM	1515-1900

Accident Statistics (1989)

$1000 claims/mile/year	$753-$804
Fatalities/100 million miles	.7-.93

Overcrossings	17	Ped O/C	4
Undercrossings	7	Ped U/C	1
Bridges	1		
Grades	Flat	Terrain	Flat/Rolling

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Annual Snow(in)
Los Angeles	83.8	48.5	14.7	0
Pasadena	88.5	42.5	20.32	0.1

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
Los Angeles	3,486,000	17,611,000	475
El Monte	106,209	764,000	9.8
Alhambra	82,106	735,000	7.7
Monterrey Park	60,738	216,000	7.8
Rosemead	51,638	190,000	5.2
San Gabriel	37,120	192,000	4.2
South El Monte	20,850	88,100	2.9

Employment in Vicinity of Highway: 198,000

San Bernardino Frwy and San Bernardino Busway

Major Trip Generators

Name	Employees
Southern California Edison	4200
Intercon Security	2000
Nadell & Co.	1500
GUESS Inc.	1400
White Memorial Med Center	1400
Rykoff-Sexton Inc.	1000
San Gabriel Med Center	650
International Medication Sys	525
Coca Cola Bottling	500
Plastic Dress Up Co Inc.	420

Bus Lines Using Route

System	Lines	Buses Assigne	Buses/Day	Peak/Hour
Foothill	480,481,482, 486,488,492, 493,494,495, 498,499	139	442	129
MTA	483.484,485, 487,489,490, 497	75	360	51

Seaside/Terminal Island Fwy

Route Number 47/ US 103 Route name: Seaside /Terminal Island Year built 1974
Counties: Los Angeles Major repairs: None
Milepost Start 0.00 LAC
Milepost End 1.59 LAC
Major freeway interchanges: None
Roadway pavement: Concrete (Less than 2" AC Surface)

Traffic volumes:

Total				Trucks			
Peak Hour		Daily (AADT)		Daily (AADTT)		%	
Min	Max	Min	Max	Min	Max	Min	Max
1500	3350	11300	22000	1809	4661	10.4	19.1

Daily per lane			
Total		Truck	
Min	Max	Min	Max
1883	3667	302	777

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
2	1.19-1.59	3	several	2	1.19-1.59	3	several	2.86

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
5	3.58	48	1.59	16

Congested portions:

Direction	Segment	(AM/PM)	Hours
N/A	none	N/A	N/A

Accident Statistics (1989)

$1000claim/mile/year	$53-244
Fatilities/billion miles	0-7.90

Seaside/Terminal Island Fwy

Overcrossings	2	Ped O/C	1
Undercrossings	0		
Bridges	1		
Grades	Flat	Terrain	Flat

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Annual Snow
Long Beach	82.7	45.3	12.22	0

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
Los Angeles	3,486,000	17,611,000	475
Long Beach	429,433	1,574,000	66

Employment in Vicinity of Highway: 87,000

Major Trip Generators

Name	Employees
McDonnel Douglas	19000
City of Long Beach	4203
CSU Long Beach	4032
Long Beach Med Center	3706
Veterans Affairs Med Center	2747
St. Mary Med Center	2000
Bank of America	1923
GTE California	1700
Edison International	1365
Long Beach City College	1221

Note: most generators are not adjacent to freeway

Truck Data

Approximately 55 trucking companies work in the port area, with 5-250 vehicles/fleet
The top 20 companies operate approximately 1300 trucks

Seaside/Terminal Island Fwy

Major Trucking Companies at Port

Name	Trucks
California Cartage	450
Express Intermodal	250
Lodi Truck Service	150
City Distribution	130
Intermodal Container	100
Mendez Trucking	90
Shippers Transport Express	90
Fargo Transport	66
Fritz Transportation	63
CSX Intermodal	60
Transport Express	60
Phoenix PDQ	54
La Salle Trucking	50
Container Care	46
Keep-on Trucking	45

West Side Fwy / William Elton "Brownie" Brown Fwy

Route Number I-5/I-580 Route name: William Elton "Brownie" Brown/Westside Fwy Year built Pre-64 to 75
Counties: Los Angeles,Kern,Kings,Fresno,Merced,Stanislaus,San Joaquin,Alameda
Milepost Start 53.57 LAC
Milepost End 13.22 ALC Major repairs: 015/70, 10/67, 09/66, 12/94, 02/70, 08/67, 09/70, 11/67
Major freeway interchanges: Rt. 99, Rt. 205
Roadway pavement: Concrete (Less than 2" AC Surface), AC base and Surface (At least 7" thick) (on sections)

Traffic volumes:

Total				Trucks			
Peak Hour		Daily (AADT)		Daily (AADTT)		%	
Min	Max	Min	Max	Min	Max	Min	Max
1650	13900	13600	126000	3387	25839	9.5	33

Daily per lane			
Total		Truck	
Min	Max	Min	Max
3714	15750	998	1771

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
2	several	4	several	2	several	4	several	2.79

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
72	several	129	4.27 MRC	103

Congested portions:

Direction	Segment	(AM/PM)	Hours
N/A	None	N/A	N/A

Accident Statistics (1989)

$1000 claims/mile/year	$5.5-388
Fatalities/100 million miles	0-5.2(most 1-2)

West Side Fwy / William Elton "Brownie" Brown Fwy

Overcrossings	56	Ped O/C	0
Undercrossings	47		
Bridges	14		
Grades	Flat to Mountainous	Terrain	Flat to Mountainous

Steepest Grade: 5.9%

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Ann Snow(in)
Bakersfield	98.9	38.4	6.14	0
Livermore	89.5	35.8	14.48	0.1
Corcoran ID	99.1	36.1	7.17	0.1

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
Bakersfield	174,820	2,071,000	94.2
Santa Clarita	110,642	1,077,000	41
Livermore	56,741	465,000	19.9
Tracy	33,558	295,000	9.7
Los Banos	14,519	109,000	7.2
Avenal	9,770	8,000	19.3
Patterson	8,626	unavailable	1.7

Employment in Vicinity of Highway: 78,000 (mostly Livermore and Santa Clarity)

Major Trip Generators

Name	Employees
Bolthouse Farms	2000
Specialized Distribution	1200
State Farm Insurance	1120
Memorial Hospital	1100
San Joaquin Hospital	1039
Dole Bakersfield	1000
Chevron	846
CalResources	830

Barstow Fwy

Route Number 1-15 Route name: Barstow Fwy Year built Pre-64-76
Counties: San Bernardino Major repairs: 11/69, 12/72, 10/65, 02/69, 03/69
Milepost Start 8.09 SBC
Milepost End 186.24 SBC
Major freeway interchanges: Rt. 215, Rt. 40
Roadway pavement: Concrete (Less than 2" AC Surface), AC base and Surface (At least 7" thick) (on sections)

Traffic volumes:

Total				Trucks			
Peak Hour		Daily (AADT)		Daily (AADTT)		%	
Min	Max	Min	Max	Min	Max	Min	Max
3550	8200	25500	108000	4796	22050	12.1	22.5

Daily per lane			
Total		Truck	
Min	Max	Min	Max
6375	19500	1199	3938

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
2	several	4	several	2	several	4	several	2.40

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
74	several	129	186.24 SBC	101.00

Congested portions:

Direction	Segment	(AM/PM)	Hours
N/A	None	N/A	N/A

Accident Statistics (1989)

$1000 claims/mile/year	$20-422
Fatalities/100 million miles	0-3.9(most 2-3)

Barstow Fwy

Overcrossings	20	Ped O/C	0
Undercrossings	3		
Bridges	6		
Grades	Flat/Rolling	Terrain	Flat/Rolling

Steepest Grade: 4.9%

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Annual Snow
Death Valley	115.1	39	2.19	0

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
Fontana	103,261	553,000	36
Hesperia	50,418	154,000	48.9
Victorville	40,674	690,314	42.3
Barstow	21,472	335,000	23.2

Employment in Vicinity of Highway: 42,500 (mostly Fontana)

Major Trip Generators

Name	Employees
Fort Irwin National Training	7340
USMC Logistics Base	2591
Factory Merchants Mall	1200
Hesperia Unified School Dist	1100
DynCorp	1000
GTE	965
St Marys Desert Valley Hosp	900
Santa Fe Railway	750
Yellow Freight	720
Barstow Unified School Dist	680

I-80 between Rt 29 and Rt 113

Route Number I-80 Route name: I-80: Rt. 37 to Rt. 113 Year built Prior to 1964
Counties: Solano, Napa Major repairs:
Milepost Start 5.63 NPC
Milepost End 38.21 SLC
Major freeway interchanges: Rt. 505, Rt. 680
Roadway pavement: Concrete (Less than 2" AC Surface), AC base and Surface (At least 7" thick) (on sections)

Traffic volumes:

Total				Trucks			
Peak Hour		Daily (AADT)		Daily (AADTT)		%	
Min	Max	Min	Max	Min	Max	Min	Max
8300	14400	87000	165000	11625	27500	12	16

Daily per lane			
Total		Truck	
Min	Max	Min	Max
14500	20000	2000	3500

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
3	various	4	various	3	various	4	various	3.33

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
unavailable	unavailable	unavailable	unavailable	unavailable

Congested portions:

Direction	Segment	AM/PM	Hours
N/A	None	N/A	N/A

Accident Statistics (1989)

$1000 claims/mile/year	$41-440
Fatalities/100 million miles	0-2.3 (most<1)

I-80 between Rt 29 and Rt 113

Overcrossings	22	Ped O/C	0
Undercrossings	5		
Bridges	1		
Grades	Flat/Some Rolling	Terrain	Flat/Some Rolling

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Annual Snow(in)
Fairifeld	88.9	37.3	22.12	0

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
Vallejo	109,199	582,000	49.4
Fairfield	77,211	784,000	36.3
Vacaville	71,479	534,000	22.9
Davis	46,322	955,000	8.6
Suisun City	22,686	48,000	3.6

Employment in Vicinity of Highway: 64,500

Major Trip Generators

Name	Employees
UC Davis	6795
Kaiser Permanente Vallejo	2000
Marine World Africa USA	1000
Lucky Distribtuion	700
North Bay Medical	657
Westamerica Bank	530
Kaiser Permanente Vacaville	500
Anheuser Busch	500
Alza Corporation	430
OEA Aerospace	400

I-80 Donner Pass

Route Number I-80 Route name: Alan S. Hart Year built Pre-64 - 73
Counties: Placer, Nevada Major repairs: 05/74, 10/87, 09/73, 10/64, 10/92
Milepost Start 20.13 PLC
Milepost End 14.16 NVC
Major freeway interchanges: None
Roadway pavement: Concrete (Less than 2" AC Surface), AC base and Surface (At least 7" thick) (on sections)

Traffic volumes:

Total				Trucks			
Peak Hour		Daily (AADT)		Daily (AADTT)		%	
Min	Max	Min	Max	Min	Max	Min	Max
3400	4950	22000	45500	2241	7084	9	15.4

Daily per lane			
Total		Truck	
Min	Max	Min	Max
5500	8625	788	1181

Lanes								
Left - Min	Location	Left - Max	Location	Right-Min	Location	Right-Max	Location	Average
2	several	3	several	2	several	3	several	2.11

Right of Way -Excess (feet)				
Min	Location	Max	Location	Average
17	33.35	139	52.95	75

Congested portions:

Direction	Segment	(AM/PM)	Hours
N/A	None	N/A	N/A

Note: congestion can occur during holiday weekends, especially during snow storms

Accident Statistics (1989)

$1000 claims/mile/year	$74-161
Fatalities/100 million miles	.48-2.4

I-80 Donner Pass

Overcrossings	20	Ped O/C	0
Undercrossings	5		
Bridges	1		
Grades	Mountainous	Terrain	Mountainous

Steepest Grade: 6.0%

Climate

Station	Avg High (July)	Avg Low (Jan)	Annual Rain (in)	Ann Snow (in)
Auburn	92.8	36	35.93	1.4

Surrounding cities

City	Population	Retail Sales (million $)	Area (sq. mi)
Roseville	44,685	1,036,000	30.2
Rocklin	18,806	126,000	12.8
Auburn	10,653	126,000	6.2
Truckee	3,484	111,000	6.1

Employment in Vicinity of Highway: 41,400

Major Trip Generators

Name	Employees
Roseville Community Hosp	1200
Horizon West, Inc.	757
Sutter Health Comm. Hosp	605

Note: List includes Roseville, which is not directly on segment

APPENDIX-II: INTERVIEW TRANSCRIPTS

I.1 Methodology

The institutional evaluation was based on a combination of literature review and personal interviews. AHS institutional issues were identified from research conducted by the Federal Highway Administration (FHWA) Precursor Systems Analysis Program. These issues served as a pool from which a specific set of issues was drawn and applied to the selection of FOT sites in California. A series of interviews was then conducted with Metropolitan Planning Organizations (MPOs) representatives and Caltrans planning and operating officials regarding the institutional feasibility of specific sites. For each site, where possible, interviews were conducted with both an MPO and Caltrans representative. As an example, for a site in the Los Angeles area, representatives were consulted from both SCAG and Caltrans District 7.

Interviewees were provided with background materials in advance. Each interview began with a similar format, with the following comments:

1. Research involves chicken and egg problem in that we want to focus on institutional issues without a set definition of FOT configuration, yet many of the institutional issues depend upon configuration issues.
2. Regardless, we are trying to isolate the technical variables so we can discuss non-technical variables.
3. Funding: the consortium anticipates it will fund the FOTs, but are interested in finding out what possibilities exist for a local match.
4. Assumptions: barrier separated roadway utilizing vehicles not owned by private citizens, i.e., buses, transit vehicles, CVOs, van pools, highway maintenance vehicles, etc.

I.2 Sacramento

<u>Bruce Griesenbeck, Sacramento Association of Governments (SACOG) -- ITS 5/7/97</u>

About FOTs in general: I'm concerned about how to perform a test of a barrier separated roadway. It sounds like more of a demonstration project because it doesn't make sense to do a test that requires the kind of massive construction that a barrier separated roadway would entail. FOTs in the historical context of ITS are typically things that come and go in a relatively short period of time. An AHS FOT doesn't sound like this type of thing. Given the prospect of failure, you would want to avoid the situation where the FOT ends and you leave this barrier-separated roadway just sitting there. This could result in a lot of political bad feelings. Calling it an FOT doesn't sound right. I would call it a demonstration project. Another issue is that there's no way to launch an FOT that takes a lane. It would have to be an added lane. HOV lanes that have taken a lane have flopped here, so I doubt if an AHS FOT lane would make it past the talking stage.

About I-80 Auburn to Reno: This stretch of roadway is three lanes both ways most of the time (two lanes in places), is rural, and is subject to a lot of adverse weather in terms of snow and rain, and is heavily traveled by recreation/vacation traffic going to Lake Tahoe and Reno. This stretch is for the most part totally out of our jurisdiction. It is within a regional transportation area no in our jurisdiction. It's more an issue for the Sierra Counties Consortium and Placer County—they would be the best to speak to about institutional issues. Only Auburn is in our jurisdiction and most of the issues we deal with there deal more with funding type priority issues rather than the corridor type of issues you are dealing with here.

About I-80 Vallejo to Sacramento: As you identify in your briefing packet, only part of this stretch is in our jurisdiction—the other part being in MTC's service area. Our portion would extend from Sacramento to Davis. The interesting part about this section is that there is an institutional infrastructure history already in place with the Capitol Corridor Joint Powers Board (which encompasses all the counties along this corridor) which is substantial. They are dealing with intercity rail issues. SACOG and MTC and Caltrans also worked awhile ago on a corridor plan for this corridor, so there is a significant history here for looking at this roadway for projects as you are now. This corridor is three lanes both ways most of the way. The California Highway Log would be a good source for you to get. There are a lot of places where there is considerable median making it feasible for an extra lane most of way.

Safety Issues: rain and some standing water at times, plus fog is a major problem particularly along the Yolo Causeway from Davis to West Sacramento. The Causeway is over a marsh area and flood plain. Only a shoulder lane on one side could make it a tough possibility. But, it is a pretty straight road. There is substantial truck traffic and it is fairly windy as well. From my experience there is so much local traffic mixed in along this corridor that there is a lot of weaving and lane changing going on. If barrier separated an FOT might be feasible, but its a rough area for mixed flow.

Environmental Issues: I've heard a number of different things with regard to local environmental groups. Their first and foremost concern is air quality and second is transportation and land use type of issues. We did an ITS Early Deployment Plan that included a work scope and user services analysis. AHS dropped out pretty early as something not feasible for the Sacramento area. Comments made were that AHS will just put more cars on the road , which isn't viewed as a good policy for public agencies to be forwarding. One of the key discussions revolves around what to do with all these additional vehicles once they leave freeways and highways and hit the local streets. The reason that you probably haven't seen a lot of outward objection yet is that there is no actual AHS project yet. If an FOT came here you'd see significant concern arise. I don't know if that would stop an FOT or not. (here we mentioned the NAHSC shift in emphasis toward short-term deployment and safety) One area where a connection might be made is with respect to this Capital Corridor that I told you about. The issue is to what extent AHS would be viewed as competing with other (conventional) projects**,** to which resources are already committed. AHS is viewed as a "train" of automobiles, which environmentalists are likely to respond that why not just go to actual trains instead. Emphasis on safety is better as long as it isn't just rhetoric used by AHS advocates, in which case it would be seen as a Trojan horse. Another issue to consider is that the Causeway is over a preserved march/wetland and flood plain area that includes a bird sanctuary. A deal has already been struck between politicians and policy makers to preserve this area, so if you tried to widen the Causeway for instance, you might push these environmental buttons as well.

Public Acceptance: There are a lot of commuters along this corridor. The only market for CVOs that I can think of is for commuter van pools and charter buses serving the commuter and recreational community. There's also a lot of occasional/frequent business travel to and from the Sacramento area. There are no transit operators other than cross-country transit like Greyhound. (note: he says more about public acceptance in general in his comments about environmental issues, equity, and when he talks about the problems of taking a lane).

Human and Financial Resources/Organizational Capacity: (note: we reminded him here that the Consortium/Federal Government would pay for most, if not all, of the FOT but would be interested in local match possibilities; we also asked to what extent SACOG has the organizational capacity to oversee an FOT)   We're different from MTC as an MPO. MTC is a statutory MPO. SACOG exists by virtue of a slim MOU between the counties and cities we serve. It's a bureaucratic difference, but it has its real world ramification—namely, that we are largely *reactive* or *responsive*, rather than *proactive*, to the cities and counties we serve. In other words, we're more market driven. We are much less proactive than MTC is. They cut a more prominent course in ITS in their region. Our involvement has been more to work with local communities to improve street traffic and integrate flow with freeways. We wouldn't have an oversight role and would instead defer to Caltrans District 3. If Caltrans wasn't interested in it, we wouldn't do it either. They (Caltrans) would have to take a lead and define what our role would be. We're usually more of a facilitator in this region, trying to make sure locals don't get steamrolled, but also trying to make sure money is there to assist Caltrans projects. We take our cues on projects from Caltrans. I don't see us ever taking a lead role on AHS.

Privacy and Equity: From an equity standpoint and FOT would definitely be unworkable if it was a take-a-lane scenario. If it adds a lane, and people feel it is their money going to construct it, and that they then were restricted from using that lane, it could be a major problem to obtain public acceptance. To me the problem lies in the nature of the test—it's a short-term test for special class operators, but who gets to use it after the test is over. This is another environmental issue. If you bill it as a test, what happens afterward? There would have to be a real commitment to it being used I the long term somehow. The nation may see it as a test, but this area will want to see how it benefits/doesn't harm the area in the long term.

Legal and Liability Issues/risk management: There are a huge number of these concerns. To the extent that an FOT is something where you have to make an active decision to relinquish control, whoever builds it will end up being a target for when things go wrong. But, if control is in the vehicle, and it's personal control, the question is how much liability does the provider of the road have? If there is in-road control, road providers will be highly liable. Even at the low end of the risk scale, there is still considerable risk with an AHS FOT. Its one thing if someone has an accident through personal negligence or negligence by another driver. But, once a public entity is controlling it, it becomes a huge issue. What you should do is probably have an FOT for accidents—this is a joke but it is probably more true than you think.

Private Sector Participation (fleets): one impediment to CVOs is the weigh station area around Cordelia, which is slated for pre-pass, which may be relevant for an AHS FOT. The problem is you'd have to let trucks out of the FOT to enter the weigh station. And I can't see trucks wanting to be part of this. They usually want maximum flexibility, which AHS won't give them. Plus, they pose so many different safety problems. It is worth noting that there are more vans coming to Sacramento, and more buses headed from here to the Bay Area. (note: perhaps one of the incentives for truck participation would be if they were allowed a pre-pass, i.e., could bypass the weigh station by using the automated highway, but this would require a great deal of cooperation with regulatory agencies both at the federal and state levels).

Scenario Two: (here we asked if these issues changes under a different scenario—the first scenario we presented was the most likely FOT configuration of barrier separated testing adaptive cruise control/longitudinal control with minimal lateral/collision avoidance controls, with users being fleets as opposed to private citizen vehicles. The second scenario would still be barrier separated, but now with mixed traffic to include commuters.) The only real change I can think of here would relate to equity issues, and that would be in a positive direction, but safety and legal/liability issues concerns would also increase negatively.

Scenario Three: (mixed flow, mixed traffic—note: we won't be presenting this scenario anymore because its very undefined and seems to convolute the issues.) I guess this could be done with existing roadways but what prevents people without the AHS capability from maneuvering right into AHS lanes. (we pointed out here that this was exactly what it was intended to do—Automated and non-automated vehicles maneuvering together on the roadway). I don't see how it would be any different from what's out there now other than mucking things up with more than they are now with the introduction of automated vehicles and controls.

Other (public acceptance): The more we talk, the more I'm rethinking some of my reservations about take-a-lane scenarios. If structured as a true test and people were made to understand it was a short-term sacrifice, which would require political champions (entrepreneurs) to back the project, it might be a better sell. Assuming a core group of relatively influential officials backed it, it would be more feasible than adding a lane. Developing those champions to convince the public and take the heat is the tough part. Overall in this area, transportation used to be the number one issue, and may be again with the recovery of the economy. As long as I've been here though, transportation has never been the number one issue for elected and non-elected officials. So champions may be tough to find right now. The other thing here is that due to changes in budgeting over the last era in the state, local governments are hurting badly. So they are likely to be concerned about big projects with big price tags and will look at matching with a very skeptical eye. They won't see it as a priority, especially since AHS is likely to be forwarded by large corporations, the federal government and/or state government. Amidst such skepticism, from the public and local government, it would be tough to get an official to risk their political capital on an AHS FOT.

Other Corridors/Areas for Possible FOTs: US 50 from Sacramento to South Lake Tahoe is a possibility. It is a rural highway outside of Sacramento where HOV work is going on. There is a project nominated for the future, which proposes to add a lane. We're in the process of developing nominations for the State Transportation Improvement Plan (STIP). We've also completed a corridor study of identified I-80 or additional HOV lanes. Neither of these HOV projects is funded yet and we're waiting to see how much might be allocated to these projects from the STIP, but it most likely won't be all of the funding needed, or even close. One issue is treating future HOV lanes as "HOT lanes" since people are also becoming aware of tolling options. Again, its a leap from there to AHS FOTs though. One suggestion might be to do the FOT in conjunction with these add-a-lane/HOV projects that will be constructed. This would have some appeal since, for instance, you could use the lane for a test initially, and then it could revert to an HOV lane once the test is completed. Of all the possibilities for an FOT I can think of, this is probably the most realistically plausible option. It would be a bit of funding judo, which is necessary today, especially if the Consortium chipped in to help fund these projects as a means of being able to conduct the FOT. There's going to be considerable shortfall for the US 50 project (which needs about $50 million in total), but its impossible to know how much until we know how much is in the STIP for us regionally. If the Consortium was able to help offset this shortfall in exchange for conducting an FOT, it would be more realistic given the funding environment today. The big variable is how much will come from the STIP. But, for an honest test of AHS, what you should probably be looking for is situations such as these HOV projects that haven't been funded yet.

Mark Leja, Caltrans District 3, 5/8/97

Funding: (we noted here that the majority or all of the funding would most likely come from the Consortium, but that they would of course be interested in local match possibilities as well). This is of course going to be a big issue. Obviously, the most desirable FOT would be barrier-separated, but that will significantly limit your options in California since not many such facilities exist here. It will take significant capital construction and investment to create a new facility. I-15 is fortunate because the structure is already in place, but that type of structure does not exist up here. If an FOT requires the construction of a barrier separated facility you are looking at a major investment, and the funding issue then becomes much more than merely an institutional or non-institutional issue—it's a substantial reality check for the whole project.

Auburn to Reno: to build here would involve such huge costs and construction in an *environmentally* sensitive area. We've already spent billions just improving the existing pavement. We're talking $250,000 per lane mile just to do that, and a million dollars per lane mile for new construction. This corridor is six lanes (three in each direction) most of the way. Adding another lane would require additional lengthening of bridges, outside widening, right-of-way purchasing, and the costs would therefore be phenomenal. The other option is to take a lane and we all know how difficult that is politically. The political reality check makes an FOT here seem pretty unfeasible. It would be cost prohibitive. It could possibly be done in the long run, but not as an FOT. You need something where you don't have to build a new facility for the FOT.

HOV multi-use/conversion: I think its a realistic decision not to utilize vehicles owned by the general public. If you stick with fleets you can control the test better and follow-up better. The biggest challenge is to identify the easiest corridor to build such a facility. The issues here are having enough existing right-of-way, with minimum alteration to crossings/bridges, and in a situation where you pick corridors identified for HOV use. Corridors ear-marked for HOV use already have the existing right-of-way, the dirt's sitting there ready in the middle of the road in some cases, and it is usually just a funding issue in terms of getting enough money to start construction. These HOV corridors are good candidates. The ones here are continuous flow (not barrier separated). If packaged correctly though, a barrier could be put in place (at not too high a cost) while the test was in process, and then the barrier could be removed when the lane reverted to an HOV lane. This is a realistic option also because all future widenings through Caltrans will be for HOV lanes, not for adding main line lanes.

Environmental Issues—Auburn to Reno: This corridor would have to be widened unfortunately, but I can see why it would be a great test bed for AHS under mountainous conditions. Unfortunately, its just not feasible to have an FOT on this corridor. The environmental constraints are large. It is pristine country over the Sierra Nevadas and through National Forest Area. There are already restrictions on things so simple as signing. To purchase right-of-way for widenings, which would be necessary, you have to identify the impacts, try to avoid them, and where you can't avoid them, you have to mitigate them. To even attempt mitigation you really have to have a great project politically. The only other way to avoid these constraints is not to widen the roadway, but that isn't an option for an FOT in this corridor. The geography is also difficult to work in—you have to build retaining walls and aqueducts because it's mountainous area. I think it would be more practical for you to consider already earmarked corridors for things like HOV lanes so you could bill the FOT as an "interim test."

Vallejo to Sacramento: This at first glance is a little more feasible. Our jurisdiction ends at the Yolo County line, just west of Davis. One of the institutional barriers is the crossing of jurisdictional lines. There are sections on this corridor that are already at capacity, so you'd definitely have to do some widening. You have the same widening issue problems as before, but it would be easier to widen for a barrier-separated facility in this corridor than from Auburn to Reno. Right-of-way would have to be acquired. The big challenge would come along the stretch of the corridor in District 4 from Davis into the Bay Area just because the traffic is so heavy here already. The big problem for us at District 3 would be expanding the Yolo Causeway. It would be pretty expensive to do, so the portion of the corridor in District 3 that would be feasible is going to be pretty short if you exclude the Causeway—maybe only five miles so before the Davis area. Ideally you would want to conduct the test on the whole corridor, but I'm not sure what kind of distance is desirable. The section I think that would be most feasible in District 3 would be the stretch from just west of Davis to the Yolo Causeway, and ending before the Causeway around the Yolo and Solano county lines. I believe the right-of-way exists there already. With respect to District 4, the development that exists right off the freeway on that stretch would make any portion very difficult.

Possible Other Sites: We do have some Sacramento area corridors under consideration for future HOV lanes. One possibility is from I-80 from downtown to Roseville, and the other is on US 50 from downtown to El Dorado Hills. Both of these corridors are used by commuters traveling into Sacramento in the morning, and out of Sacramento in the evenings. Both serve bedroom communities and there are lots of housing developments in these areas, which is why there are so many commuters. Its 35 miles from El Dorado Hills to the downtown area, and it is very conducive to an HOV facility. There's sufficient room in the median already. It's already in the "Project Study Report (PSR) phase. It's broken into four segments and we're working with SACOG and El Dorado County. It's included in the 1998 STIP and we need a total of about 50 million dollars for the whole corridor. (Note: this is the same stretch that Bruce Griesenbeck from SACOG referred to in an earlier interview). The biggest constraint right now is building a local consensus. We're talking about ten years to complete all four segments. The earliest phase would be programmed for construction by the year 2000. With additional outside funding this first phase could be viable for early delivery before 2000. The local consensus (public acceptance**)** issues mainly have to do with which segment to do first, and also whether or not to do US 50 before or after I-80. The I-80 corridor (Roseville to Sacramento) is more congested and is experiencing more growth, so maybe we should do it first, but we are realistically trying and planning to get both into the STIP. The I-80 stretch has reserved right-of-way and is pretty straight with very little geography problems. Testing of AHS under fog conditions could be done here, and it would be a good thing to test because a person would really have to have faith in the system if he/she were going to let their vehicle go flying on through thick fog.

Public Acceptance/Equity Concerns: One of the institutional challenges to any barrier separated facility is that you inevitably face public opposition from the communities which you bypass. This has huge equity and public acceptance implications. This would be one of the drawbacks to utilizing an HOV lane for the FOT. The HOV lanes here are not typically barrier separated, so temporarily barrier separating them for the FOT would bypass certain communities. HOV lanes are supposed to be accessible. You would also have to face an institutional challenge that we call *empty lane syndrome*, where a huge and costly construction project is completed and the lane is perceived as sitting empty. This could be a big problem for an FOT, and its already a problem for HOV lanes. We have people here who complain about the lanes not being used enough, to which we usually answer “ride together then.” People get upset when public funds are used and they can’t utilize the lane.

Bus Corridors: The challenge to even just using a bus lane—and both of these corridors have light rail in operation along them which is proposed for expansion—is that if you build something portrayed as good for bus riders you could be stealing business from rail. And large amounts of money are already committed to rail expansion as I said. Thus, you have competing projects. A bus corridor is likely to be seen as a “train” of buses, in which case, even in the short term for a test, people and elected officials will want to see dollars spent on light rail rather than pavement. It becomes a significant environmental issue.

Fleet Possibilities: There are regular commuter buses from Roseville on I-80 and from El Dorado Hills on US 50, that are well used during peak periods. There are six lines in operation from El Dorado Hills and there is likely to be more growth in this area making more lines a possibility. But, buses are viewed as a good viable alternative on this corridor. I use it myself quite a bit actually. There are a number of large van pools as well. There’s a large state employee work force and the state encourages pooling. Our electric utility (SMUD) provides a similar service to its employees. Caltrans operates the state vans, but riders pay for gas and service. SMUD’s vans are probably their own. The I-80 corridor is a significantly used trucking route between here and Reno and Salt Lake City, and from there into the interior of the country. Some larger trucking companies have regular routes. The other primary option is tour buses to Tahoe and Reno that make frequent/regular gambling tours and are very reliable in terms of schedule. So there are some good options there for utilizing fleets.

US 50 - Which Segment to Build First?: The issue here is should we build the segment near downtown or build a segment for bypassing congestion instead, i.e., one of the outer segments. The difficulty is prioritizing each segment, where to build from a staging standpoint, where to build by need (congestion), and where are there local funds to help. For example, El Dorado county has funding available right now to help build a segment, but they aren’t going to want their dollars going to spend money in Sacramento on the Sacramento segment. Yet, they are the farthest out and lowest priority in terms of need. We’ll most likely end up building two of the segments at the same time—one downtown, and one farther out.

Safety: Anywhere in this area visibility, due to fog, is going to be a safety concern. There are always safety issues with barrier separated facilities as well in terms of having full shoulders for in the event that someone breaks down inside the facility. And there need to be release valves for emergency vehicles and breakdowns. Some shoulder width is going to be necessary, which exacerbates the right-of-way problem. The HOV option we’ve discussed probably doesn’t usually have this kind of space since we only use pavement markings to delineate the HOV lanes up here. We don’t need the space for this “continuous access design.” Lane width is 12 feet and shoulder width on the inside lane is 10 feet, and there isn’t much separation from mixed flow. The barrier base in some places may not allow enough room for enough shoulder. I know that this is more of a technical restriction and that we’re talking about non-technical issues, but its directly related to safety concerns. Early design is the key. One thing that would help would be significant incident notification. If AHS FOTs put in an incident detection system as well it could be a huge help to making the roadway safer and encouraging FOT use. All of this could then be linked to our traffic management centers and would be a further test of AHS technology to test for detection. The I-80 and US 50 corridors are under current surveillance, but it’s only at about 30 to 40 percent of what we want it to be.

Resources: One of the challenges Caltrans faces now is added work load when we still don’t have additional staff and there is a hiring freeze. We hire consultants with some additional money to help. AHS’s additional workload would require consultants (like from the Consortium). It’s difficult for us to redirect current staff and is an uphill battle politically. We constantly must answer questions about why are we working on certain projects when we can’t solve current problems. The potential solution here is to have another agency, like SACOG, be contract managers over the consulting firms hired to do the FOT. SACOG’s procurement process is more streamlined than ours and that would be a more viable situation. SACOG would be the lead on the contract process with consultants, but Caltrans would still have oversight. We could just do it ourselves, but if you want local support, especially on HOV conversion for AHS FOT use, SACOG would be a better front politically at the local level. In terms of training, our engineers could do it, but they're already working on other projects and can't be diverted to a project like an FOT. We have a new Traffic Management Center in the works too, and they are needed there with that implementation and conversion. But, a new TMC in operation by 2000 would help get technologies like AHS in place.

Organizational Commitment: I myself am supportive of AHS, as is Caltrans for the most part I believe. It is where we are going with transportation management, so we might as well get our feet wet now in my opinion. My peers have a real challenge dealing with everyday problems like rebuilding from this last winter's storms, so we're stretched pretty thin. Plus, we have a tremendous construction project and a lot of other things that are higher priority right now. The workload curves always move out and are staring you in the face constantly. Three to four years from now it doesn't look as if we'll be that busy, but that's because scoping and programming are in process for that time right now. Additional resources will have to come from the private sector due to an increased workload—that's realistic for a future that includes an AHS FOT.

Legal and Liability Concerns: These mainly have to do with the state highway system. We're self-insured and liable for the state highways. Constructing and testing an FOT would be a concern in terms of how the test was conducted and who is overseeing it. We'd want to indemnify the state on a number of levels, which would be an issue in court. Any agreement has to go through cooperative agreements, particularly where money changes hands. I would have get approval from my supervisor at Caltrans headquarters, Jim Borden—Program Manager for Traffic Operations. He would be a part of running legal. There is always going to be significant liability when doing a test with "live subjects." Say for example a bus full of gamblers slams into another vehicle due to the FOT. It would be hard for us to avoid being liable in that case in a court of law.

Other Environmental: Only issue we haven't talked about is air quality which is of course a big issue for all of the Central Valley. If you redirect HOV lanes it could cause a stink and make the FOT a hard sell. However, this is not a back breaker, but a small hurdle. You would definitely want to enlist the support of local air quality boards in terms of getting their agreement that there will be little or no impact.

Public Acceptance/Equity: Empty lane syndrome is something to watch out for. And from an equity standpoint, the FOT could be perceived as a facility for well-to-do commuters in the suburbs, not for people who can't afford to live out in the suburbs.

Privacy: An issue in the vehicle, but this is a general issue for AHS at large. It will depend upon technology and configuration. If the vehicle system is given over to the highway system's control, there are likely to be large privacy concerns about the use of the information processed when control is transferred.

Private Sector Participation: I see this is primarily relevant for the fleets that would use AHS. You won't get any capital dollars out of them. The only way to market it will be to have design by the private sector, which will make it more politically viable.

Funding: Keep in mind, if you come to the table with significant capital dollars to contribute, there will inevitably be competition to appease you if it helps people get projects done earlier. Thus, interim redirection or conversion of HOV lanes is a strong possibility. It will be a challenge, but with financial backing for construction, people will be more likely to make things work and to become involved. And frankly, if this is to be the future of transportation management, there will have to be significant investment from the federal and national levels, because there isn't money available within the state. Otherwise, it's just lip service and technology for the sake of technology.

I.3 San Francisco Bay Area

Jeff Georgevich and Joel Markowitz, Metropolitan Transportation Commission, 5/29/1997

I-280: Costs are always going to be a huge constraint if you consider in environmental mitigation, purchases of right-of-way—not a lot for your million. In terms of right-of-way, there is constrained right-of-way on north and south end. There's a watershed in the middle and there are a lot of concerned interests that are watching what's going on there. Just impeding the view of the watershed is a big deal. They will have to deal with the same thing as any other construction of a highway, and the watershed will make it difficult. New construction in that corridor—ridge side as opposed to the bay side—will be opposed because the development has been constrained toward the Bay side. The environmental review could be hung up for a while. It would encourage too much growth on that side. If you tried to take an existing lane, the congestion is already huge at the south end and you're not going to help that, along with all the equity issues of take a lane amid this congestion. It would be a major fight. The social and community issues are there too—the middle area is very high income (Palo Alto and north) and they are very active in terms of avoiding any further highway activity. There are two gorges that you go over with bridges and I think the right-of-way is already tapped out, so that's a real tough engineering concern. From a market perspective, serving fleets isn't real feasible there. There's not commercial activity along this corridor—there is along the 101 and the El Camino Real, and there are very few cross-peninsula routes. Public Transit is limited because it's too far from the population centers. The market from S.F. to Palo Alto or Silicon Valley is an open stretch right now, so what advantage does AHS offer. San Bruno is around S.F. airport and there would be a lot of problems with the ends, as there always is with AHS. The southern part is severely congested going north in the mornings.

I-80 S.F. to Pinole: if reversible, if you are barrier separated, that might make all of these a better sell. The only reversible lanes are Bay Bridge and the Caldecott tunnel. The HOV lanes—big section opened this month, but the final project won't be done until 1999. There are some huge structural adjustments to make around Bay Bridge and in the Berkeley area. There is a physically separated structure that exists here. If thinking about a reversible, you might think about this—very similar to I-15 situation in San Diego. Currently, it opens as HOV from 5 a.m. to 7:00 p.m. at night as a special policy and demonstration. Your FOT would have to be integrated with this—making it an FOT exclusively would be very difficult. This is the home of the "screaming greenies" as they are called in the area. If you ever wanted to engage the environmentalists in this area, this is the corridor to introduce controversy. If focused on transit and HOV it would be a better sell. The other problem is it's already built out with no median and very little right-of-way. The other problem is that this is already feeding a bridge that isn't expanding, so you don't want to be too successful and end up increasing capacity, even accidentally. As background, MTC was sued by environmental organizations in the late 80's about air quality conformity, and lost, but it tapped our funds. They are now going to sue again. They are very actively watching our investment decisions. It's not just that their home is in Berkeley, they are all over the area and keeping a close eye on everything—pertains to all sites. If something is safety oriented, you could do it, but if it looks like SOV you have a tough fight. Right-of-way precludes new construction and you'd have to weave the FOT into the HOV use.

I-5/I-580: If this is for safety—to get trucks through fog and dust, you could sell it. But, if it looks like capacity building, you can't do it easily. And it's an area where light rail is going and could be seen as competing with the train as well. The agencies trying to fund the train would fight this as well. The Altamont Pass is in this area. There's a split that connects the two freeways. It has high winds and fog and is subject to a lot of incidents. Because of the pass, there are tough topographic constraints, but there is room to construct new right-of-way by blasting into the mountain. There are going to be environmental concerns once you drop into Livermore valley dealing with growth and land use issues. And commuter rail service will compete with this and be up and running before an FOT. Of everything with transit, the I-80 option is probably the best with AC Transit if it could be worked with them—they can feasibly run enough buses through there to warrant it, but it parallels the BART route, so it's competing here again. AC Transit is reconfiguring its routes now, and it's in public hearing process, and it's probably financially imperative not to duplicate BART or increase service where BART is already doing so.

I-80 Vallejo to Sacramento: We have rail service here as well and it would be a competition issue again. There is some intra-urban Greyhound service, but not substantial. From Fairfield south there are occasional commuter buses and Vallejo has a lot they run into BART station, but otherwise there isn't much. We rely on the train for that kind of commuter. It's a very heavy truck corridor again. If there is something about safety you can do for fog conditions, then you might be able to do it, but it will be hard to sell it because platooning trucks in fog doesn't give the illusion of safety. Truck fleets are better option here.

I-880 East Shore Freeway south of Bay Bridge: a great deal of congestion as Cypress structure is completed (when completed will be more direct and will help). The Port of Oakland is the major destination right in the middle of all this. Truck access to Port of Oakland and Richmond is a major issue where AHS FOT might help. When you are talking to safety, mixed flow of trucks isn't always the best sounding alternative—incidents are always highly volatile.

Golden Gate Bridge: Too narrow (sub-standard lane width), and it's environmentally a very sensitive area along that 101 corridor. There are HOV lane segments north of the Golden Gate Bridge that may be a possibility. With G.G. Transit, they don't have a severe bus congestion problem north on 101, but in the south area it's pretty congested and you couldn't take a reserved lane all the way to the bridge. It would need right-of-way too, and that's very constrained in this area. At the receiving end, what happens when you dump onto the bridge, and afterward onto regular old S.F. streets. Northbound you have the same issues once you are into Marin County with environmental constraints.

Internal to the Port at Oakland: not public, but could be done. Jurisdiction is with the Port itself. There are seven public roads, but very little public traffic. We have good relations with the Port and they participate on helping us find options. Not the volume of the Alameda Corridor if thinking comparatively.

Scenario Two (mixed flow, but not barrier separated/dedicated): this opens up more possibilities like the big MUNI operations in San Francisco. Would be an awesome test with all the people and vehicles in this area, but probably not very feasible. Most of our HOV lanes are continuous access (constant in and out with no physical barrier). Its a visual barrier only. The only exception is the Bay Bridge flyover which is barrier separated—goes over I-80 distribution center and then drops back down to earth in Emeryville—will open in 1999. It's fully funded, and it's a big project in an earthquake prone area.

Proposed/Planned HOV lanes: One corridor that might be a possibility, from a conceptual standpoint, is Alameda I-680 from Pleasanton to Santa Clara County line—northern Silicon Valley—where there is a great deal of congestion. We're looking at reversible HOV here and don't have any funding yet. If you guys came to the table with some money, you might be able to find partners to do an FOT. The conditions would be that it would have to be mixed flow from the beginning to relieve congestion. They haven't received funding (need about 20 million), but it is in the serious planning phase. It's about four or five miles I think (just a guess), but could be longer. The south end is more congested—big hill and lane narrowing. The Sunol grade is the real bottleneck.

Sonoma County: We are looking at a congestion pricing HOV lane in this area, and are strapped for money. I can't see where and how an FOT would fit. It's not in engineering phase yet—just the policy study phase.

Future: We are looking at revising our twenty year plans in the next several months, and possibilities could arise, but what we know now is the two possibilities mentioned.

Additional issues: The one other issue in the Bay area is sprawl. AHS is seen around here as encouraging sprawl and it's going to be a real battle. If done for transit purposes you can get around this maybe. What the redirection means is not clear. If it means slower speeds its hard to see how to justify it. But, you can't be capacity oriented in the Bay Area, which is clear with respect to AHS. One other thing is that with the recent Supreme Court ruling on engineering, hanging an FOT on a Caltrans construction plan will be difficult, because they are now forced to do it themselves, and they can't do current projects in a timely fashion due to funding and staffing constraints. If it all has to be done by Caltrans engineers, this may all be irrelevant.

Jim McCrank, Caltrans District 4, 5/30/1997

I-280 Cupertino to San Bruno: This is particularly busy around the 92, particularly during peak periods. And it's very heavy again north of 380, but I don't know if you would have it go that far. Safety is a key issue here with the foggy conditions, and every now and then we get some icy conditions (rare, but have to prepare for it). Usually the fog is a problem in the early mornings, particularly around a bridge at the north end of Crystal Springs. You are also running right along the ridge side of the peninsula. The recent redirection of the Consortium is important here in the Bay area. This is one of the highest standard freeways and was built in the late 60's/early 70's. There is a lot of earth movement, which is gradual, especially north of 92 which requires on-going maintenance. You might have some structural issues to deal with here. In some areas it's fairly wide, but generally you'd have to do some construction which is very expensive in this type of terrain. From Woodside to north of the 92 is the San Francisco Watershed and there are some extreme runoff structures here that could be a problem. The problem is that you can't really do barrier separation without widening. So, you probably can't do an FOT for any significant length at all—only for short stretches. Most of this corridor is under capacity anyway. If you tried to take a lane you would push it to capacity and taking a lane is probably not politically feasible anyway. Environmentally, you are likely to encounter problems, but no different from any other area. The watershed area is very sensitive. But, these issues aren't going to make or break the project. Rather, they will probably just make the process take longer. In terms of legal and liability issues, I don't see anything major to deal with here that we don't already have to deal with on conventional projects. In terms of resources and organizational capacity, these will always be constraints, but they aren't project killers. If the project is funded, we'll find a way to do it, even amid the recent Supreme Court decisions. A lot of it will depend upon the scope of the study. We manage to do more with little all the time and still get things done. Regarding public acceptance, if billed as a demonstration for safety purposes, and its not done on a prime commute corridor, it may be able to work. 280 is a more acceptable site than others. You'd never do it for capacity reasons on this corridor, however. If handled correctly, public acceptance won't be a show-stopper. There is almost nothing in terms of fleets—either buses or trucks. There isn't even significant delivery truck traffic because the corridor is away from the major population centers. In the north there are shuttles to SFO, which might be a possibility, but only north of 380 which I don't think you've included here. The major problem for 280 is going to be that there are no fleets to use, so you'd have to use private commuter traffic.

I-80 S.F. to Pinole (including Bay Bridge): There is some HOV going in here, and some sections have just opened there. The major safety issues would be just that it's heavily traveled with a lot of incidents. It's almost always high volume, which makes it more dangerous. Any hiccup has a major effect on traffic through here. Barrier separation would help alleviate such issues, but I don't know if it's possible on this corridor for structural reasons. The problem is that to widen for HOV lanes we've already taken all the available right-of-way. HOV lanes are continuous in this area, and there isn't really sufficient room for barriers. With barriers the shoulder would be significantly reduced which wouldn't allow you any breakdown or pull-out areas. The flyover might be a possibility. It raises up out of the median in the Emeryville area near the Bay Bridge. It is just going in now and is planned for 24-hour HOV use for buses and carpools. It's less than a mile long, so an FOT wouldn't be real meaningful here. Legal and Liability and Resource issues are the same for all these roadways (see above). In terms of environmental issues and public acceptance, any widening will infringe upon the Bay, requiring us to replace wetland, which is very costly and volatile politically. We were taken to the mat over the flyover and it only sold because it was for HOV only. Plus, anything that blocks the view of the Bay will be severely opposed. This would be a major issue for this corridor.

I-80 Vallejo to Sacramento: Our portion is from Vallejo to the Yolo County line. The safety issues for this corridor are minimal other than when you get into the mountains between Vallejo and Fairfield which is a fault zone with a lot of slides. It's not very level and there is a lot of on-going construction in this area. There is some fog, especially from Vacaville to Davis. The structural configuration is going to be one of the main constraints. There's a lot of right-of-way—it's just farmland for the most part. Take a lane would make it at capacity and the locals (public acceptance) are sensitive about this anyway, so it would have to be some type of add a lane situation. In terms of fleets, I don't really know of any in this area. There are a few transit buses for shorter trips and some long haul trucking, and then there's the Sacramento/Capitol related traffic which involves some commuter vans.

I-580/I-5 Bakersfield to Livermore: Our portion would be from where the 580 hits the 205. This stretch is where the Altamont pass is going down into Livermore. It's subject to high wind conditions and heavy fog and some possible ice conditions. Otherwise our stretch of this is so small, I don't see any huge problems.

I-680 Pleasanton to San Jose (Silicon Valley area): This has potential because it has become the second highest congested corridor in the Bay area, largely due to people going from San Joaquin into the Silicon Valley. Something needs to be done to improve the flow in this area, but there is no funding for any of the plans for HOV yet. Physically, there's enough right-of-way because it's relatively under developed and most of it is owned by the City of San Francisco which makes the acquisition of the right-of-way a little simpler. From an environmental/public acceptance standpoint, the public wants something to help here, so it's likely to be favorable. You'd have to be careful about perceptions of the empty lane syndrome given the capacity problem here. There isn't a lot to worry about in terms of safety here because it's the safest freeway we have. There are plans for HOV lanes here, but no money as of yet. Alameda and surrounding counties are trying to work together to release funds to help alleviate the congestion problems here.

Other Sites/HOV Integration: Can't see anything that would be better than what we've already discussed. We really don't have anything extensive for HOV that has been funded yet. There's a proposal for a HOT lane in Sonoma County on 101. But, there are a lot of issues to deal with first here in terms of if there's a market in this area for paying the tolls. We are looking for any way to increase capacity in this area, and need the money first, hence the tolling idea. It would take in the tens of millions of dollars. But, at least the political will is there. The right-of-way is tight through there, but we could probably find room. The proposal calls for it being barrier separated, but we're not sure if there is sufficient room for that yet. If so, it would be a good fit for an FOT or demonstration of AHS. Like I said, the key issue now is money. The stretch I'm talking about would run from Petaluma to the Santa Rosa area, and we'd like it to go all the way to Windsor. So, it would be about twenty-five miles maximum, and there isn't near enough money for that yet. We are also looking for any funding we can get for the corridor we talked about on I-680. 680 is more promising than 101 because it has more right-of-way, needs more help due to congestion. So, if AHS proponents can help with funding, it is likely that you could persuade people to let you do an FOT.

New bay crossing: This is still very much under consideration only. It requires a vote of the people, and the political will isn't there yet. It would stretch from 380 on one side to 238 at the widest point of the bay. It would be a joint transit bridge. It's physically feasible, but it could be ten years before it even comes to a vote. Just the east end of the Bay Bridge was a billion and a half dollars, so the cost would be at least that, although it would be a little easier because the water is shallower in this area.

I.3 Los Angeles Region

Richard Spicer, Southern California Association of Governments (SCAG), 4/17/1997

SCAG RTP: I like your conceptual piece about the institutional issues with respect to FOTs, but I have a few questions. Are these full or minimal systems? We have similar commuter type environments outlined in the SCAG RTP, which has a number of sites that could be possibilities for AHS in the future. But, right now there is nothing in the RTP for AHS. If we get the grant we've applied for, we may consider it as part of the RTP, but we are just starting to integrate this. The grant would at least give it a place under the MIS and "corridor preservation." Bob Huddy is very skeptical about its potential, but we are going to look at it.

Arterial Issues: What is the relationship with the arterials? Your examples are all stand-alone and don't deal with the interface with arterials. And there is a large history of Caltrans and other engineers thinking about freeway enhancements without thinking about the impacts on arterials.

Barrier Separation: You can say that it needs to be barrier separated conceptually, but practically, in terms of entry and exit, this is a prototype only. How do you have a ready-made site that you can isolate and also use?

Safety: One of our major concerns is safety, and another is convincing people to accept giving up control of their vehicle. I think that the new safety redirection of the consortium is an astute adjustment. We think getting a closer link between research vision and practical reality is a good step. Our impression is that safety isn't being considered seriously enough in the context of phasing in a partially automated system—not a fully automated system. If this continues it could undermine the popularity of AHS, as has been shown in the media. You should try to crawl, then walk, then run—not try to run first.

Public Acceptance: There is a lot of exposure in this region now to ITS, and the audience is becoming aware and beginning to understand. To build off this into AHS is better than creating a gap in perceptions. AHS needs to be connected to other programs and objectives. Every public agency is struggling to figure out how to do conventional projects, so AHS can't afford to be seen as "Star Wars," which would be a major obstacle.

Environmental Issues: Our main question here is are the benefits really there for air quality? Over two to three years it wasn't on a list of benefits and now it is. But, how do you measure it for AHS is the issue? It is certainly on the radar screen with some people and the issue is how to test emissions equipment and demonstrations. The issue is how to get new technologies integrated so people are interested in them from a clean fuel vehicle standpoint.

Equity: For this MPO equity will always be a policy issue. We've before included performance indicators to evaluate projects and this is especially done for air quality. The idea is to use these indicators on every project, and one of the indicators is equity. We will always have to deal with access issues, especially with respect to elected officials who are sensitive to such issues. Some would say that any new technology initially serves the higher end market, but as it is used over time, the price goes down, making it available to a wide market. In short, it seems to be market driven.

Transit Applications: Transit would be better than using private vehicles, especially with respect to equity. It won't remove such issues, but the investment would look less disproportionately geared to those with higher incomes.

El Monte Busway: It's near capacity now and doesn't have many stops, but does have a significant stretch that is barrier separated.

Other Work: Are you aware of other funded work to look at undeveloped sites? The reason I ask is that previously we had made several proposals, but the consortium's thinking is not complete on this. From a California perspective it would be nice if Phase II were in California, and encompassed the commuter typology and configurations related to sites like you've provided here. The five types of sites help loosen people's thinking, so that is a positive thing. The Interview Briefing Packet is good for that from an education standpoint.

Narasimha Murthy—LA County Metropolitan Transportation Authority (MTA), 5/29/1997

Background: We have divided the county into six regions and have a tiered approach to dealing with ITS. So, related to this, I have some ideas about this AHS idea. The non-technical issues can put a brake on the whole process.

MTA's ITS efforts: We have a traffic system management program. Tier one addresses major traffic improvements along existing arterials. Tier two deals with improvement with bus movement through the arterials. Tier three is computerizing the system where we can monitor what's happening on the streets. The 4th tier is ITS and Advanced Technology. That's where our ITS program comes. It's a multi-modal program focus. We've spent over 360 million on these programs thus far. ITS probably got about 25% of that money, maybe a little less. Those moneys are being used to liberate federal funds to come into the county. We have countywide guidelines we use for implementation. We are dealing with non-technical issues like who gets what information and for what purpose will they use it, like when we computerize this. The main work of MTA is to distribute state, federal, and local level funds. There aren't jurisdictional issues really. We oversee the projects in the six areas. We have an area team that oversees the expenditures of money. So it's multi-jurisdictional, but we oversee it. Most of the larger cities have some kind of ITS projects—LA, Pasadena, Arcadia, Long Beach. They have traffic operations centers moving toward ITS, but not completely. We have some tier guidelines we've put together that I can send for you to review. I have a list of all ITS projects you can have. Most of these have to do with transit, signal synchronization, etc., dealing with buses, the train lines, and arterials traveled by transit. Tier 4 is most relevant to you.

Tier 4: ITS projects include situations such as where Caltrans might come to us for funds in the future to make it operational—we can request funds to be used in our area. The Traffic Management Center in District 7 has MTA funding that Caltrans requested. All these TMCs and ITS projects are funded in part through MTA, so we're usually involved indirectly.

APTS and Buses: Most projects are involved in preemption—dealing with signals and kiosks and information, and our own monitoring of what's going on in the streets. We're also involved in multi-model ATIS projects. MTA in general funds the transit and highways in the area, in terms of roadway construction like for widening and purchasing right-of-way.

I-710: I am very surprised that the 710 isn't on your list of sites because it's the shortest stretch and it's the heaviest truck route in the county. It would be the easiest route because it's where they need the most help. The trucks are going between the two ports, so it's a very fixed route, and would be very easy to monitor. SCAG has done a study of the 710 and about the truck routes. Spicer would be a good contact here.

Non-technical issues: Believe me, technical issues won't stop FOTs, but non-technical issues will.

El Monte Busway: This is the most traveled busway in the county. MTA, Foothill Transit, and Pomona Valley all operate on this route, as well as other operators, and vans. The one key element would be who is funding the FOT. It would require a multi-jurisdictional approach because the local cities will want to participate along the way, because there are spillover effects, and they need to be brought up to speed on the learning curve. They will want to know what the local benefit is of the project—not just the regional benefits. It would be MTA, as operator of vehicles, Caltrans with the roadway, and the municipalities that have access to the roadway. Consensus building will need to be a key aspect of selling this project. Funding will be a big part of this, in terms of how it can be sustained over the years, or over the course of the test. Operations costs, and who will bear them, will be a huge concern. The locals become very volatile because local politicians can portray it as a waste of money on a transit route and the result is the derailment of the project if enough communities feel the same way. You will be involved with the operations people of MTA to conduct an FOT. You should talk to the real operations people to figure out what they think will be needed. They don't have a real pulse for ITS right now. They are more concerned with day to day activities of existing roadways. This roadway could be no problem if you can bring some money to the table and can avoid local dissent. I don't really see any other problems with this stretch because an FOT would really fit in with our multi-modal focus. The only problem is bringing everybody into the program at the beginning and starting from there to deal with the institutional issues from the beginning. This will be true of any site in the county. These issues have to be looked at in the long-range. Technical issues can be dealt with in the short range, but institutional issues have to be thought of in the long-term to make sure it's not derailed politically.

I-15 to Vegas: If you look at the newest issue of Urban Transportation Monitor, you will get a picture of why you should look at longer trips for AHS. The access, egress, and traffic flow issues make short trips unfeasible. It needs to be a time-based, or trip-based trip FOT so that you know what types of drivers are using it, where they are starting and ending, and so you know what kind of effects you are having on capacity and safety. Otherwise, you can't prove or show benefits. Recreational routes are a good category for this type of test. You know the two types of destinations and who and why people are going. Las Vegas works that way—you know how you can enhance the capacity and safety of these routes—can make space for better flow on these longer trip routes. Rural routes should be avoided if not recreational because we don't have the capacity on these routes. You need to select long-distance heavy traffic routes, or else it's a waste of money.

SR-14: Would be a good candidate up in the Lancaster area. It's straight and narrow and with extremely heavy recreation and truck volume. Increasing the capacity and relieving commuter congestion would be a big help here.

I-105: Not much bus traffic, so you won't have good control over who's on it. One of the things you need to do is provide some real traffic data about who's using a roadway—statistics—so that when you give your examples you are dealing in reality—not just talking hypothetically.

New Issue: another issue is what I call literacy management. Today people don't understand our current signs, so how do they understand something like AHS and ITS and with whatever tests emerge. Literacy management is a key element. The car pool lanes cause a lot of problems, particularly in multi-cultural societies. The ramp meters alone cause a lot of problems—think about the complications that mean for AHS, which would multiply the complexity tremendously. This isn't just marketing—it's education. People can screw up the best-designed system no matter how well prepared you are. The three-plus lane has been frustrating for people because some people are jumping on there and having to go all the way to El Monte, because there's no where to get off and they didn't realize that. Or they've been fined because they didn't realize it's a three-plus lane.

Pat Perovich and Frank Quon, Caltrans District 7, 5/30/1997

Fleets: Airport shuttles and taxis are prevalent in LA so you need to look for a stretch of roadway that builds upon this need. A good example would be out of Ontario on the I-10, or the 118 near the I-5.

Construction Issues: Adding a lane is extremely expensive. Retro-fitting requires that you take something away, which isn't easy politically. Structural widening is also a major expense as you are aware, even for just laying an HOV lane on an existing metropolitan freeway.

HOV: (Note: we didn't even prompt this here) We would probably initially suggest using an HOV planned for construction before it opens officially as an HOV lane. The problem here politically would be the deference away from HOV for FOT purposes—people usually want HOV lanes to open when they are ready. But, to demonstrate the FOT first would be preferable and would allow you to do it with barrier separation. The 110 transit way is barrier separated in parts, and the El Monte Busway is the majority of the way. Both have potential heavy transit and carpool volume. One issue would be if you tried to kick carpools off the busway.

El Monte Busway: I think you'd want to look at the piece from 710 east. It has a huge buffer. The other portion is more narrow and curvy. There is talk of going to two-lanes at two-plus occupancy instead of one lane three plus occupancy. The problem is that we have an arrangement with the MTA as to what level of bus service is provided. So, traffic would most likely have to be mixed because you couldn't kick carpools off for political reasons. If we go to two lanes, one could be for buses and one for carpools and you probably have enough room to even barrier separate one of the lanes for the FOT use here. If you did buses, then you could use the inside lane and put the cars closer to the mainline lanes, which would alleviate a lot of safety concerns. One thing to remember is that you will have to heavily involve the CHP. They won't enforce this area without a turnout. So, if you do away with the shoulders and turnouts, they won't do the enforcement. So, if you take the buffer they aren't likely to be cooperative. They must have enforcement/refuge pockets. One option would be the HOV option we discussed above—there might be room.

Urban Areas: Otherwise, in urban areas there simply isn't the right-of-way you'd need to do the FOT. Orange County has some new HOV that might be a possibility. If you are set on having a barrier separated lane you should come up with some big money. Sound walls are a huge expense and we're probably talking one million dollars per lineal mile. You'd be more competitive with local match (80 fed/20 local), but that is also a hard sell. (Quon left)

General Institutional Issues: The problem with AHS that would hold for FOT's is that it's seen as a demonstration right now and not a lot of serious attention is given to it. We may not have the expertise here at Caltrans and would have to rely on the people sponsoring AHS. The systems may work on a college campus, but the freeways are very harsh environments. There is so much uncertainty. We have this problem with even the simplest demonstration, like metallic reflective striping. While an FOT is a great idea, it will be approached very cautiously. Freeways can eat up new technologies very fast. Legal issues have to be dealt with early and practically, and at the local level. Much of this will determine what are the actual goals of the project. That will determine what details are needed physically, which is necessary before you even start to deal with the institutional issues.

Environmental Issues: From an air quality standpoint, if you keep things flowing, you are okay. But, if you increase capacity, it will be highly controversial. We don't write EISs for ITS right now, but that is being challenged right now. Sometimes we have to do mitigation, but it's the same as for any construction project. There are construction issues related to water quality as well. Land use and urban form aren't really substantial issues here. One thing you might do is look at using electric vehicles. SCAG is very interested in getting to 10% electric vehicles use by 2005, which is pretty ambitious. This could be a good incentive mix with AHS, because there is talk of letting electric vehicles on HOV lanes even with only one occupant. There's few manufacturers so it would be more controllable.

US 103 Long Beach: The main problem here is that there are a lot of trucking companies to deal with. How are you going to get all of them to cooperate and participate, or any of them for that matter? Why should they do it? How would they train the drivers? Does it limit them in terms of what trucks can use this area? Do you limit it to certain types of truck? And there's the whole independent truckers vs. fleets issue to deal with. How do they instrument the trucks? How does it affect productivity from the fleet operator's perspective? These are just some of the complex questions you'll have to deal with. Another will be how to maintain the trucks. There are problems also with the locals. And some trucks can go faster than others, so how would it work? The problem with dealing with the trucking industry in general is that it tends to resist anything like this, especially if it's "automated." The drivers don't want fixed speeds; some move slower due to loads; tankers have different limitations on turning speeds; so loads are also a problem. Government agencies always want to track the loads, and we want to enforce and monitor better, which truckers resist obviously. So, while an FOT might help us see if AHS could be of use to our monitoring and enforcement efforts, why would truckers and trucking companies want to participate? Drivers don't want anyone to know where they are, and then you also have to deal with unions. Even with UPS, if they think it's an invasion of their privacy it will be a tough sell. You might convince fleet operators because they could track their drivers better, but the drivers aren't going to go for this. Plus, the entire industry is going to want to know where the FOT is leading to in terms of long-range advantages/disadvantages. Automation isn't usually a popular concept with workers and unions.

I-5 Santa Ana Freeway (LA County): The problem here is no medians left there for a stand-alone lane. Orange County might have some space left, which might be a possibility. If you need a stand alone lane, you need median and right-of-way, and there just aren't any here. And if there's a freeway interchange in the corridor, you have to deal with access/egress and structural changes. Purchasing right-of-way is a huge expense as well, but is required for widening.

Reversible Lanes Issue: We don't use them here in Southern California because of several issues; when would we close the freeway to reverse gates; there are bridges in the way in the middle; we don't have the width and we don't have median shoulders anymore; we don't have the lanes to give up because our congestion periods last all day long in both directions. Bedroom communities offer the only possibilities, but we don't have the room and there are structural impediments like bridges.

I-30 (210 Extension): This could be a possibility for reversible HOV that could be integrated with AHS. The flow on this corridor would be heavily directional, which is conducive to reversibility. It is a ways off, but at least there's the room there and you wouldn't be dealing with having to take away from existing freeways.

I-105: Would have to be mixed flow on HOV lanes, like the El Monte Busway. There's a lot of room and enforcement areas, so it's feasible physically. Airport shuttles would be good fleet possibilities if you could persuade them to participate. Private cars aren't a real possibility yet I don't think. This stretch is geometrically okay and if you could make it so shuttles could get to and from the airport more quickly, it would be a good sell.

I-15: There are some very significant safety issues to deal with here. There are too many speeders and the drinking element is a real danger. There are also a lot of steep grades that make certain speeds very difficult for charter buses and trucks, which are your only fleet possibilities here. There are the climbing lanes there already, but like I said, not all trucks and buses can go the same speeds, especially depending upon loads. Buses break down a lot on the way to and from Vegas as well. I really think the grades would be a huge structural problem. If you could get a lot of private vehicles automated, this might be a better possibility, but then so would a lot of other places. And not all cars can go the same speeds up and down hills as well.

I-710: There are similar issues here as to 103 with the trucking industry. And there isn't room that I know of to have a stand-alone lane. Another issue with trucks is that you don't want them in the median lanes. When they have to weave back and forth across all the lanes of traffic they become a huge disruption. Plus, the structure of these lanes can't hold them, in terms of the pavement width. So, you'd have to modify medians, and also the drainage sections. Its just not a good idea to use trucks.

Bob Huddy and Richard Spicer, SCAG, 6/12/1997

Initial Comments: The first question we have is are you talking about an FOT which utilizes platooning? The question I always have about "car trains" is where do I park them.? I say that as a joke, but it raises some practical concerns about what happens at the ends. Most auto makers aren't willing to do platooning because of the liability and safety problems, so we are then just talking about pace-setting and adaptive cruise control. Also, with regard to construction of any new lanes, the costs would be so large, by far more than a factor of ten, that is simply isn't feasible. The cost of adding one lane for AHS on the entire system here in California by 2020 would be something like $250 billion dollars.

HOV Integration: There are some opportunities for utilizing HOV facilities in this region, but they are limited. Transit applications are a good idea. The I-10 comes to mind because of the busway. Because of safety issues, you want both a controllable fleet and a controllable facility. Some of the transit operators are very interested in ITS and we want to continue legacy projects. We have some relationships with MTA already in place that might facilitate this arrangement.

I-10 El Monte Busway and I-110 Transitway: I think that MTA and Foothill Transit would be positively inclined to participate and LADOT, Torrance and Gardena, as well as the MTA, would be also for the 110. The 110 has bus volumes of around 20-22 per hour during peak periods. The 10 has volumes close to capacity now of about 70-80 peak hour buses. The advantage of the 110 is that there is relatively little demand during the off-peak periods and it would be cheaper and safer to do the operational modifications as a result.

Transit Operators: The transit operators would be open to discussion for the potential legacy projects and increased safety operations. We're equipping buses now with autonomous blind spot detection, so this would be another legacy extension of such a project. Safety is a major concern for these operators. The 110 would be safer because it is fully looped. The Busway isn't looped (it is older). For safety reasons you could probably get Caltrans to buy into this as well. Inter-departmental integration with the bus people is sometimes difficult because different bus systems will have different issues.

Public Acceptance: A main concern here is with other HOVs. The non-transit HOV volume on the 10 (a three-plus occupancy facility) is about 1500 during peak periods. For the 110, which is a double-lane two-plus facility, the volume is somewhere over 2000 during peak periods. One issue is that with most transportation technologies it takes four to five years to get people to realize that the system's there and to get used to using it. But, with HOV, this process is only taking a year. The I-210 HOV lanes are a good example.

Legal and Liability Issues: These will depend on the degree of hands off/feet off control and if the facility is separated or not. This isn't a major issue though. Because it's a "test," the operators will all want protection, such as bonded insurance, but any FOT for anything requires the same thing.

"Operational" test: My concern is that the test needs to actually be operational in terms of actually improving safety and/or throughput. It needs to be more than just hooking it all up and seeing if the light comes on. An FOT shouldn't stand for "fiddle or tinker." We need to see before and after results and benefits. Performance has to be the key. Otherwise, it's not going to work. We need to see benefits that can be used to show why further investment is justifiable in ITS. These benefits would include an increase in safety through the reduction of accidents and injuries, improvements in fuel consumption and air quality, and less stress on the driver (good for union support).

Unions and CVOs: The unions will be one of the key groups to deal with. You will have to get the buy-in of unions and the same goes for CVOs should they be targeted for participation. One thing to remember with CVOs is that they won't run on isolated facilities anyway, so transit operators are really the only identifiable fleet.

Public Acceptance: Public acceptance is not so much of a problem with transit applications geared toward improving safety. Such applications are likely to be popular. Utilizing independent systems is key—not roadway systems. I know a lot of people working on AHS talk about roadway systems, but they are too locked into institutional thinking. The application of an FOT is not going to be separated on something like the El Monte Busway. Autonomous systems offer great safety, improved traffic, and fewer incidents.

Mixed Flow: Unless you run the FOT at midnight, which you would really only want to do initially, it is going to have to be a mixed flow system. That is the only way to make an operational test as we've discussed. The advantage of a mixed facility is that non-transit vehicles could serve a control group. We have on-line transit systems on both the 10 and 110 to build off of. These two sites are good because they are already mixed. AHS isn't going to be done as a separate system. It is going to be layered onto existing systems.

Safety on 110: There are potential hazards here because there are some mixed flow areas that are very congested, and as more arterials open up there could be more problems. There is virtually no shoulder in some of these areas, which is also true for the 10, but the 10 is better equipped because it has the buffer lane on the other side.

Other Sites Evaluated: The main problem for US103 is that working with CVOs is going to be a huge difficulty, and probably isn't feasible. For the I-5 in LA County there just isn't enough right-of-way, if any, to support an FOT facility. And where it does exist, the price is so huge that it isn't feasible. The I-105 Century Freeway is a possibility. Airport shuttles and taxis are a good fleet option. There are major cross-overs where the north-south freeways come in, which could raise some safety concerns, but there are HOV connections for the 110 and 710. There are already problems with cars being backed up from the Sepulveda Blvd. (airport) exit to the 405 because of the airport. This could cause some design and safety problems. Otherwise, there aren't a lot of other problems for this facility.

I.4 San Diego

Stuart Harvey, Caltrans District 11, 5/9/1997

I-15 Demonstration (how does it relate to FOTs): It possibly relates with some manipulations being necessary. It is already barrier separated and right now accommodates principally commuter traffic, but is closed to traffic mid-day. It could be adapted to meet FOT conditions. It will remain closed in off-peak because that was the original concept, and it has to be closed for reversal. Prior to AHS we used the mid-day for maintenance. Right now peak period operation is modified with a congestion pricing demonstration that began last December, with full implementation to occur later this year. Its success will determine whether that project continues. It is supposed to ultimately use electronic toll taking. Right now it's a permit for $70 (which we have now learned is being increased to $80) a month with a placard showing on the car. The transponder operation will come in a couple of months. There is no expiration date and the sponsoring legislation lasts until January '98, but is expected to be extended. Getting back to the demonstration, we will be able to look at two different technologies for lateral control, both of which will be demonstrated. The first is a line of magnets in the center of the lanes combined with a sensor in the vehicle that will read and follow the magnets. The second uses metallic reflectors imbedded in the traffic stripe and utilizes radar (This is the 3M/Ohio State work). There are some problems still with the second with the stripe not adhering properly and with the correct disguise for it because it's in the middle of the lane.

After the Demonstration: I am sure there will be some continuing activity at some level. Some infrastructure will remain. For example, some buildings at the South end of the facility being used by the Consortium will remain. We will be installing a closed-circuit series of TV's cameras along the route and these will stay. They have also added quite a bit of temporary concrete barrier that would not have been installed but for AHS. These barriers are not really in line with our normal criteria for the corridor, but we had to do it for two miles of the corridor, which is intended for removal after the demonstration (but could possibly remain). It will remain as an HOV-peak period lane and will also serve as a test bed for new technologies, which it has been doing for some time. PATH has done a lot of development work on this stretch for years. There is nothing in the mill that I know of that would prohibit it from being an FOT should that intention be forwarded.

AHS Manufacturers: The lanes have been reserved by a number of manufacturers for some time, including PATH, Toyota, Honda, Buick, and Ohio State. There will even be a demonstration, I think by Toyota, of an automated maintenance vehicle that picks up trash. There will of course be a demonstration of platooning of at least a half dozen vehicles.

Sum: In sum, I think that the I-15 Corridor will remain one of the top candidates for future AHS projects.

Institutional Issues-related to I-15

Public Acceptance: Frankly, the AHS demonstration has really had a very subdued exposure, meaning that we do not really have a good reading yet on political and public acceptance issues. Early on there were local officials who expressed concern about this type of "star wars" technology being done while there are potholes and bridges falling apart. It has not yet been adequately addressed yet. It is an opportunity for marketing for inevitable serious considerations that might be raised. It should be marketed practically in terms of how AHS will improve safety, which should be the number one selling point of AHS. Another selling point is how it can make the commute better, even just by getting the car around congestion. An FOT will have to be marketed well.

Environmental Concerns: There were not really any significant environmental issues for the demonstration because it utilizes already existing roadway. And the few areas where we needed to get clearance simply were not a problem.

Jurisdictional Issues: These would come mainly between Caltrans and SANDAG, but the coordination was simplified by the fact that Caltrans owns the facility. With the exception of overlap on the congestion-pricing project, SANDAG really is not involved in the demonstration because they do not operate any of it. The exception, however, comes when the demonstration spills out onto surface streets. The north end spills out on to a Park-and-Ride lot with exits/entrance on surface streets that may cause some interference with normal traffic. The City of San Diego has to be dealt with then. There is sure to be some adverse reaction from the public due to the interference and SANDAG could potentially help clear the political path because they provide a good forum for getting information out and keeping the public well informed.

Private Sector Interaction/Resources Issues (w/ Caltrans and PATH): This relationship is a little blurred because we are partners in the consortium. Funds for infrastructure and staff support come locally through the Office of New Technologies at Caltrans Headquarters in Sacramento. What isn’t effective is that Caltrans is providing quite a bit of staff support, but we do not have the ability to do this long term. So, it is going to mean the redirection of people, which is not feasible with Caltrans right now. The way much of this has been handled is through the local Caltrans office by using outside funds to bring in private contractors. For example, the design aspects of the demonstration are being shared with Bechtel, but are using in-house staff here at Caltrans in San Diego. This was done by the Office of New Technologies who arranged with Bechtel to provide some design services, sent the plans to the local office of review, and then advertised the contract locally. It is a good model for public-private interaction because it allows local owners and operators to have some oversight and control. The downside is that it takes additional staff or the setting aside of other projects—either way Caltrans is negatively impacted in terms of staffing. There needs to be some way to supplement local district staffing and resources. Working with the Office of New Technologies has helped because they have some dedicated staff for consultation and help. Our contact person has been Hamed, as well as Randy Woollee. Here again, in terms of marketing, there needs to be proactive presentations with respect to public acceptance, and these will need to be continually polished if we are to get cooperation and support from outside sources and other agencies. Technical coordination has been nearly flawless thus far, but non-technical coordination will be the key.

Legal and Liability Issues: In my practical view, the consortium has been overly paranoid about the liability issues. The major concern is that any problem could tarnish the whole program. So, for example, they are concerned about an errant vehicle, so we added two miles of temporary concrete railing. We have taken a number of unusual precautions to make sure as vehicles leave the freeway for something like the park-and-ride lot that these vehicles are isolated from public traffic. That may lead to potential public complaints. The north end is where there is a mix with public traffic, so we had to develop a way to get into the staging area so as not to mix traffic. On the south end it is more secure because vehicles are able to exit and get into the staging area without being on surface streets. A lot of energy has been focused on the ends of the corridor. The issue once you are on the corridor is adding additional barriers. As I understand it, the arrangement at the north end is to close for a period of hours one of the ramps to public traffic. The demonstration is after 9:00 a.m. and should be over by the afternoon, and will then run in the evening again after 6:30. A lot of design remedies were there to deal with liability issues and we used an engineering approach to get around them.

Other Potential Sites: I really cannot think of any in the San Diego area. There is no other area where we segregate traffic enough to avoid mixed flow. The only exception is where we separate car and truck traffic in the south near the border, but it's not really a candidate site. It's a port of entry and the customs agency deals with commercial traffic, and it is logically only open to commercial traffic.

New Construction/Widening: This would increase the possibilities such as public transit and van services that serve the airport would be one location where you could separate certain vehicle types. That would use Harbor Drive in San Diego and would only be a couple of miles long. Fleets and public transit are pretty substantial in this area.

I-5 to LA: an interesting possibility here is that the border patrol is building something like this at the checkpoint at Camp Pendleton. They have been forced to accommodate commuter traffic to decrease delays to daily users—the brainchild of some congressman. They have plans to expand the number of lanes to make an accelerated commuter lane. It's on the drawing board and some of it may even be under construction right now. There is a possibility for an automated lane here perhaps.

New HOV lanes/projects: I have heard of some barrier separated/reversible projects on I-5 from the junction with I-805 to at least Manchester Drive five miles north. You should talk to Carl West at 688-6681, our Planning Division Chief. This is programmed and is in the regional transportation plan. It will probably be operation in five years. Carl probably even knows of other possibilities. This I-5 project would fall in this category and would be viable sooner if the Consortium could help advance the timing. Five-year time-frames are compatible with an FOT probably, especially since time-frames, if left to themselves, often slip. Having other participants helps keep focus. I cannot think of other sites right now, but others may know of some.

11. APPENDIX III: IN-VEHICLE ELECTRONICS

Over the last few decades there has been a steady increase in the number of electronic components that go into automobiles and there has been a steady shift from mechanical to electronic controls to improve the performance of vehicles. The availability of electronic devices on vehicle models may influence the character and costs of an FOT. For instance, the FOT may be designed around a vehicle model that already has a high sophistication in baseline electronic equipment. Because these vehicles tend to be in the luxury or high-performance market segments, the vehicle may affect driver behavior and participation independently of the automation features.

Of late computer processors have been used for air-bags, engine control and anti-lock braking systems (ABS). Collision warning systems are also available on both an aftermarket and, for select models, original-equipment basis. This section reviews some of the available technologies with the purpose of identifying the inherent capabilities of unmodified vehicles, as they exist today.

III.1 Braking

The braking system is an energy conversion device, which converts the kinetic energy (momentum) of the vehicle into thermal energy (heat). In contemporary braking systems the master cylinder is power-assisted by the engine and thousands of pounds of force are applied on all four wheels. Present-day braking systems are divided into two sub-systems for the front and rear wheels. This improves the reliability of the braking system. If one system fails the other can provide a back up (AIS, 1995).

The brake system comprises the following basic components. The "master cylinder", which is located under the hood, and is directly connected to the brake pedal, converts the foot's mechanical pressure into hydraulic pressure. Steel "brake lines" and flexible "brake hoses" connect the master cylinder to the "slave cylinders" located at each wheel. Brake fluid, designed to work in extreme conditions, fills the system. "Shoes" and "pads" are pushed by the slave cylinders to contact the "drums" and "rotors", thus causing drag, which slows the car (AIS, 1995).

There have been marked changes in modern braking systems. Disc brakes were introduced in the early sixties. Bendix and Kesley-Hayes were the two US pioneers and Bosch pioneered in Europe (Rineck, 1995). Compared to drum brakes, disk brakes provide a marked improvement but at higher cost per wheel. They provide shorter stopping distance, higher torque for more compact and lighter packages, and higher resistance to thermal fade. Disc brakes allow greater air ventilation compared to drum brakes and they can rapidly fling off any water (AIS, 1995). Disk brakes were introduced on the Ford Thunderbird, Lincoln Continental and Chevrolet Corvette in the US in the mid sixties and by the late sixties they had become fairly standard on the front wheels where 60% - 70% of the braking power is concentrated. But it was not until the late seventies that disk brakes were a standard feature in rear wheel brakes (Rineck, 1995).

In the nineties ABS was introduced. ABS systems use computer controlled valves to limit the pressure delivered to each slave cylinder and, thus, no matter how hard the pedal is pressed, each wheel is prevented from locking up. Speed sensors measure wheel speed, and then transmit this information to an electronic control unit. The electronic control unit receives information from the sensors, determines when a wheel is about to lock up (i.e. if any wheel is going much slower than the others). Also, it detects any malfunction in the ABS. The electronic control unit then activates the brake pressure modulator which quickly releases brake pressure to that wheel and then reapplies it independent of the driver's brake pedal effort. It does this on-and-off, braking many times a second (much faster than humanly possible) until the computer is satisfied that all four wheels are slowing at about the same rate (AIS, 1995).

The technical concept is quite old. In 1936, Bosch was awarded a patent for an electrohydraulic brake ABS. ABS became a production item for aircraft by the late 1940's and early 1950's. In the 1950's, the US manufacturers Ford, Kelsey-Hayes and Chrysler experimented with mechanical and analog electronic brakes. In 1969 Kelsey-Hayes Sure-Track single channel, vacuum powered, rear wheel ABS was introduced on the Lincoln Continental MK III. ABS was introduced by Bendix on the Chrysler Imperial in

1971. These early ABS's with limited performance soon faded out. In 1979, Bosch introduced an all-digital electronic ABS system in the 1979 Mercedes Benz. ABS was introduced in 1985 on U.S. cars, beginning with the Continental MK VII featuring a Teves ABS (Rineck, 1995). ABS are now widely available as either a standard or optional feature on automobiles. ABS are required on heavy-duty-trucks, and are manufactured by Eaton and Rockwell WABCO for truck applications.

ABS systems vary, usually depending on how many sensors are used (input to the computer), and how many "channels" of hydraulic brake-pressure operation (output). A typical description is "4-sensor, 3-channel ABS." Some cars have a yaw sensor that tells the ABS computer if you are in a turn (and weight is being transferred side to side). The major manufacturers of ABS systems are TRW, Rockwell and Bosch. The other manufacturers are Bendix, Kelsey-Hayes and Teves. In the future ABS will likely be able to interact with other systems in the vehicle such as suspension systems and power steering systems (Keebler, 1986).

The BMW 318, 325, 328, and M-class have a Siemens engine management system and the BMW 528, 540, 740, 750, 840ci, 850 have a Bosch engine management system that controls the ABS, electrically assisted power steering, the suspension and the engine with an on-board computer. Mercedes Benz too has ABS on all its models but the engine management system to control the various sub-systems is available only in the S-class range.

III.2 Steering

The power steering system enables the driver to turn the front wheels to control the direction the vehicle travels. The rotary motion of the steering wheel is changed to linear motion in the steering gear. The force applied to the steering wheel is multiplied by the mechanical advantage of the steering gear that, in most vehicles, is a rack and pinion type. Most modern cars have power steering in which the force exerted by the driver on the wheel is assisted by hydraulic pressure from an electric or engine-driven pump (AIS, 1995).

Hydraulic assist requires the constant circulation of hydraulic oil through the directional valve to meet the feel and response requirements. This flow combined with system back-pressure draws power from the vehicle. Pumps are mounted to the internal combustion (IC) engine in conventional cars. Therefore, hydraulic efficiency decreases with engine speed (AIS, 1995).

Electro-hydraulic power steering only draws power on command. The electronic controller requires less than 4 Watts under a no-steering input condition. This dramatic decrease from conventional steering is the basis of fuel economy savings. Electro-hydraulic power steering, or electrically assisted power steering (EAPS), uses a sensor on the shaft to provide an electronic control unit (ECU) with information on the steering wheel movement. Electronic power steering replaces the hydraulic cylinder with an electric motor, which gets its power from the car battery and alternator. When the steering wheel is turned, a sensor detects the motion and gives the electrical assist motor enough power to turn the wheel. Not only does the motor have to change the direction instantly, it has to deliver exactly the right amount of torque at all times (Keebler, 1986).

Electric power steering requires very little power on average but has high demands during certain steering conditions. Electric power steering can require upwards of 3000 Watts. These types of loads are of very short duration. This maximum power requirement drives the design of the motor (AIS, 1995).

The electronic steering can be programmed in a number of ways. The carmaker can provide the lightly assisted steering required by performance drivers or the full assist steering demanded by luxury car owners. With a different program the steering assistance can be proportional to vehicle speed. The driver can have maximum power while parking (Keebler, 1986). Electric power steering has several other advantages. The steering feel has greater flexibility; system weight is reduced, and it doesn't leak. Electric power steering is engine independent which means if the electrical system fails it could continue operating (AIS, 1995)

EAPS are being developed by TRW, GM, Bendix, Lucas and Bosch. Electric power steering is available in Mercedes Benz C-class, E-class, V-class and G-class cars. In transit applications, automated steering has existed for about 20 years within the German “O-Bahn” system (M.A.N. and Daimler-Benz). Both mechanical and electronically guided steering exists, with the electronic systems tracking current carrying wires imbedded in the roadway. These systems are intended to improve steering accuracy, allowing buses to travel within narrower (hence, less expensive) tunnels (Elias, 1995).

III.3 Power Train Control

The steady increase in the use of electronic components is very evident in the engine control systems that have been introduced and are likely to be introduced in the near future. At present, electronic controls and systems are in the process of becoming essential and integral parts of our vehicles whereas they were previously replacements for corresponding mechanical systems. The electronic systems in the vehicle will be interconnected with each other to a much greater degree than was previously the case (Zabler, 1992).

Electronic engine control systems increase the performance of the engine. With electronic ignition and automatic controlled fuel injection system, engines can give good performance in acceleration and inertia stability with lower fuel consumption, and higher output power. Distributorless ignition modules for electronic valve timing, throttle control, traction control and engine cooling system sensing and control are now available (Delco, TRW, Rockwell, Siemens, Bosch). For better fuel economy many devices that were driven directly by the engine will now be electrically driven. That way the speeds of the waterpump and cooling fan, can be varied to match the load or switch off if not needed (Kassakian 1996)

Power electronics in future automobiles will perform two major functions: the simple on/off switching now performed by relays and manual switches, and load controlling with logic inverters and D.C.-D.C. converters (Delco Electronics, TRW, Rockwell and Bosch). In today's engines, a camshaft acts on the valve stems to open and close them. The crankshaft drives the camshaft through gears, chain or belt. The timing of the valves opening and closing is controlled by the camshaft design and is fixed relative to the piston position. This means that the engine performance is optimal only over a narrow range of engine speed. This problem is overcome with electro-mechanically actuated valves which are not related to the crankshaft position and can operate optimally at all engine speeds, torque levels, temperatures and any other design variable. They can also be made part of a closed loop control system (Kassakian 1996).

A cruise control system provides autonomous but casually supervised control of the speed of a motor vehicle moving at highway speeds, even over varying terrain. When the brake is applied, the system must relinquish speed control until told to resume. The system must also steadily increase or decrease speed to reach a new maintenance speed when directed to do so by the driver. The cruise control system is capable of maintaining the car speed, but when the brakes are pressed it temporarily reverts to manual control (Shaw, 96). Cruise control systems are now available in most cars as a standard or optional feature. Major manufacturers include TRW, Delco, Rockwell, Siemens and Bosch.

Future cruise control systems will be adaptive. They will have the capability of distance extraction and image processing and environment recognition (Madea, 1995). Adaptive cruise control systems with forward range sensors, electronic throttle control and limited-authority electronic braking assistance have been introduced in Japan by Mitsubishi, and are likely to be introduced on other luxury car models in the near future in both Europe and Japan. They could maintain the relative speed and distance between vehicles in the same lane (Barret, 1995).

Electronic suspension is available in the Chevrolet Lumina and all Mercedes Benz and BMW models. Electronic distributorless ignition is available in all Mercedes Benz, BMW models and Toyota models. Electronic Traction control is available on all Mercedes Benz, BMW and Volvo models. In fact, the Mercedes Benz S-class and all BMW models have a complete engine management system that interlinks all the various subsystems. The BMW 750il and 850ci even have an electronic throttle.

Automatic transmissions are one of the oldest forms of driver automation, and are available as either a standard or optional feature on most car models. However, automatic transmissions are not widely used in the heavy-duty-truck and bus segments, though they are available. Eaton's "AutoShift" has a fully automated clutch, with the exception of initial engagement from start. Spicer's "AutoMate-2" (Dana Corporation) automates shifting between the top two gears on a 10-speed transmission. Both transmissions modulate clutch engagement according to throttle demand, which is communicated electronically from the engine via the SAE J1939 data bus. Though these transmissions could not support full automation from start, automation could be achievable once vehicles reach a set speed.

III.4 In-Vehicle Communication

Communication for automotive body control systems, such as power windows, power seats, power doors, ABS, electric power steering and engine management systems based on an in-vehicle network are being developed. It possible to build an automotive control system that reduces the number of wiring harnesses and weight below those of the conventional automotive body electronics. The communications transmitters and receivers can be integrated on-chip. This offers the advantages of small size and high reliability of the electronic control unit based on an in-vehicle network and all the systems can be integrated into one system (Siemens, 1996).

There is a trend towards localized control of loads in the distribution systems of automobiles. The present network drives control loads through manual switches or relays. Wiring is aggregated at a fuse box from where it travels to the electrical loads. But future designs will employ a communication bus to transmit signals from point-to-point control switches to remote power switches in distribution boxes. The power bus will fan out to the loads through the communication switches under control of the communication bus. In the distant future, loads will connect to the power bus at their location in the vehicle. Such an architecture easily accommodates options and system change (Kassakian 1996). Accordingly, electronic signal-processing components, for example, which were previously located in central control units, will be moved to the periphery where they are mechanically and electrically integrated with the sensor or actuator directly at the point at which they are actually required (Zabler, 1992).

III.5 Vehicle-to-Roadside Communication

Seimens, Rockwell and Delco are among the companies working on vehicle-to-roadside communication systems. Systems have been developed for such applications as electronic toll collection, truck weigh-in-motion, local traveler information, in-vehicle messaging, and route guidance systems. Electronic toll collection and commercial vehicle operations systems are currently the most prevalent.

In an electronic messaging system, poor visibility and driver inattentiveness are mitigated by providing the information inside the vehicle. The message is displayed so that the driver has a much higher probability of receiving sign information and in a way that minimizes information overload or irritation to the driver. Fog, dust and smoke do not interfere with the message. A voice message of 5 seconds would allow a flexible vocabulary for conveying sign messages. To make the system as flexible as possible, the voice message would be broadcast as compressed voice data with channel encoding for error correction. This approach is more flexible than defining a fixed set of codes for voice message broadcasting that become obsolete as signs are defined in the future (Kady, 1996).

Electronic messages can also be made dynamic. Electronic messaging systems have the ability to instantaneously change the content of sign information based on sensor inputs. For example, a dynamic sign can monitor ice on the roadway and transmit the message "icy bridge" only when ice is present, rather than "watch for ice on bridge." This reduces the frequency of receiving the "watch for ice" message, increasing the information content of the sign. The driver is now more likely to react to the potentially dangerous situation and take actions to avert an accident. Dynamic messages can also be of value in providing convenience information. Freeway exits for stadiums and other high traffic areas can be dynamically changed to direct traffic from one exit to another. This dynamic rerouting can help even-out traffic flow on the adjoining surface streets (Kady, 1996; Rockwell, 1996).

An audio message can also be broadcast to the vehicle, providing additional information to the driver. Voice warnings interrupt conversations and music and will make important warning messages such as "stopped traffic ahead" even more noticeable (Kady, 1996; Rockwell, 1996).

Another mode of communication being considered is through the cellular phone in the vehicle. Signals would be transmitted from a base station in a cellular communications system. A device is embedded into a cellular phone installed in a vehicle. When this vehicle is traveling through a cell territory, the device receives those signals and calculates the attenuation of those signals to locate the current vehicle position (Song, 1994).

Vehicle-to-roadside communication systems can also be used for automatically contacting an emergency response team when a vehicle's airbag is deployed and send confirmation back to the vehicle once the response team is on its way. It can also send medical information about the driver to the ambulance. In addition, a driver can independently summon police, medical or roadside assistance with the push of a button with the system providing the vehicle's location to the emergency service (Rockwell, 1996). As mentioned earlier, these systems are still being developed, though Cadillac's "Onstar" system has some of these capabilities.

III.6 Vehicle-to-Vehicle Communication

The intention of vehicle-to-vehicle communication is to provide information such as speed, braking condition and steering condition to other vehicles in the zone of relevance and increase road safety. In systems where a direct antenna or other such narrow beam systems are employed, communication between vehicles to the side cannot be accomplished without the use of a separate side system. Outside of the normal communication range, a multi hop system might be used, communicating through intermediate vehicles. These systems are not currently available as a commercial product and are not close to commercialization.

III.7 Collision Avoidance/Warning Systems

Collision warning systems alert drivers to probable collision and increase their time to react. The sensors used within such systems have already been incorporated in demonstration AHS vehicles, and will likely be important in a future AHS FOT.

Many of the new technologies are spin-offs from the aerospace and defense industries and have the potential of increasing the sophistication of the present safety systems. However, the challenge is not only in bringing these new technologies to market at affordable prices, but also in integrating them with the design of today's vehicles, designing the system to work with the driver to anticipate accidents, and facilitating more precise vehicle control in collision avoidance.

Collision avoidance systems are being developed by various organizations based on different technologies. The "Forewarn" system being developed by Delco consists of three subsystems: a Crash Avoidance Processor (CAP), an object detection sensor set and a driver warning module. The vehicle will contain three obstacle detection sensors, two forward and one rear. The rear sensor and one of the forward sensors employ microwave radar, while the remaining front sensor uses a laser radar. Vehicle speed, steering wheel position, throttle position are provided to the CAP as inputs. The inputs are used in the crash avoidance algorithm to predict whether the vehicle is on a collision path with an object, determine the impending collision timing, and differentiate between objects not in the path. Visual warnings are presented on a heads-up display (HUD), which is driven by a graphics generator. The audio warnings comprise a series of chimes that are coded by tone to cue the driver to the direction of the impending collision, and presented to the driver via the vehicle's audio system (Mullins, 1996). Delco currently is selling a product marketed toward school buses to detect hazards when vehicles start from stop.

Another collision warning system made by VORAD is the Eaton VORAD EVT-200 collision warning system. It uses a high frequency doppler radar designed to give the driver advance warning of stopped or slow moving vehicles or vehicles in the driver’s blind spots. Upon sensing a potential hazard, a combination of lights and audible tones are emitted from the display unit to warn the driver. A blind spot sensor mounted on the side and a blind spot display unit mounted inside the side mirror alert the driver to potential blind spot hazards. The system also has Vehicle Information Management Systems (VIMS) and accident reconstruction features. Similar to conventional on-board computers, the VIMS system monitors driver times, time spent at various speeds, engine idle time, average speeds, and maximum speeds. It also measures average following time, average distance from other vehicles and the number of warnings given to the driver (Eaton, 1996).

In addition to radar systems, sonar based collision warning systems are currently available. One product, called "Blind-sight" is targeted at avoidance of lane-change collisions in the truck market. In addition, BMW offers a sonar based system to warn for minor parking collisions. It is not intended for operation at driving speed.

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