Precursor Systems Analyses of Automated Highway Systems

RESOURCE MATERIALS

AHS Institutional, societal, and Cost Benefit Analysis

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FOREWORD

This report was a product of the Federal Highway Administration's Automated Highway System (AHS) Precursor Systems Analyses (PSA) studies. The AHS Program is part of the larger Department of Transportation (DOT) Intelligent Transportation Systems (ITS) Program and is a multi-year, multi-phase effort to develop the next major upgrade of our nation's vehicle-highway system.

The PSA studies were part of an initial Analysis Phase of the AHS Program and were initiated to identify the high level issues and risks associated with automated highway systems. Fifteen interdisciplinary contractor teams were selected to conduct these studies. The studies were structured around the following 16 activity areas:

> (A) Urban and Rural AHS Comparison, (B) Automated Check-In, (C) Automated Check-Out, (D) Lateral and Longitudinal Control Analysis, (E) Malfunction Management and Analysis, (F) Commercial and Transit AHS Analysis, (G) Comparable Systems Analysis, (H) AHS Roadway Deployment Analysis, (I) Impact of AHS on Surrounding Non-AHS Roadways, (J) AHS Entry/Exit Implementation, (K) AHS Roadway Operational Analysis, (L) Vehicle Operational Analysis, (M) Alternative Propulsion Systems Impact, (N) AHS Safety Issues, (O) Institutional and Societal Aspects, and (P) Preliminary Cost/Benefit Factors Analysis.

To provide diverse perspectives, each of these 16 activity areas was studied by at least three of the contractor teams. Also, two of the contractor teams studied all 16 activity areas to provide a synergistic approach to their analyses. The combination of the individual activity studies and additional study topics resulted in a total of 69 studies. Individual reports, such as this one, have been prepared for each of these studies. In addition, each of the eight contractor teams that studied more than one activity area produced a report that summarized all their findings.

Lyle Saxton
Director, Office of Safety and Traffic Operations Research and Development

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16. Abstract
The program described by this eight-volume report, a resource materials document type, identified the issues and risks associated with the potential design, development, and operation of an Automated Highway System (AHS), a highway system that utilizes limited access roadways and provides "hands off" driving. The AHS effort was conducted by a team formed and directed by the Calspan Advanced Technology Center. Primary Team members included Calspan, Parsons Brinckerhoff, Dunn Engineering Associates, and Princeton University. Supporting members of the team were BMW, New York State Thruway Authority, New York State Department of Transportation, Massachusetts Department of Transportation, the New Jersey Department of Transportation, Boston Research, Vitro Corporation, and Michael P. Walsh of Walsh Associates.

Calspan provided overall management and integration of the program and had lead responsibility for 5 of the 17 tasks. Parsons Brinckerhoff provided transportation planning and engineering expertise and had lead responsibility for 5 tasks. Dunn Engineering provided traffic engineering expertise and had lead responsibility on 2 tasks. Princeton supported the areas of transportation planning and automated control.

The 17 task reports (A through P plus Representative Systems Configurations) are organized into 8 volumes. This volume describes AHS Institutional, Societal, and Cost Benefit Analysis. Institutional and Societal Issues (Task O) was supervised by Alan Lubliner of Parsons Brinckerhoff and supported by Yuval Cohen and Joseph Sodan, also of Parsons. Preliminary Costs/Benefit Factors Analysis (Task P) was supervised by Yuval Cohen of Parsons Brinckerhoff and supported by Tracy Nixon and Richard Naish, also of Parsons.

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VOLUME VIII — AHS INSTITUTIONAL, SOCIETAL, AND COST BENEFIT ANALYSIS

CHAPTER 1: INSTITUTIONAL AND SOCIETAL ISSUES (TASK O)

Section **Page**

List of Tables

VOLUME VIII — AHS INSTITUTIONAL, SOCIETAL, AND COST BENEFIT ANALYSIS

CHAPTER 1: INSTITUTIONAL AND SOCIETAL ISSUES (TASK O)

1.0 EXECUTIVE SUMMARY

1.1 OBJECTIVE AND APPROACH

The objective of this task has been to document the panoply of institutional and societal issues and risks -- the so-called "non-technical" issues -- that confront the effort to deploy Automated Highway Systems (AHS). [*Note: One of the recurrent recommendations during the course of the Institutional and Societal Issues Precursor System Analyses (PSA) has been that AHS be renamed, perhaps to Automated Transportation Systems. In recent months, IVHS America has begun to use the term Automated Vehicle Operations (AVO). With misgivings about perpetuating the term, but for consistency with the official title of the PSA effort and the other volumes of this Final Report, AHS is used in this chapter.*]

The methodology involved a multi-stage process beginning (and continuing throughout the effort) with a review of all available literature regarding the subject of automated vehicles and highways and regarding Intelligent Transportation Systems (ITS), formerly called Intelligent Vehicle Highway Systems (IVHS). The initial research lead to a categorization of AHS-specific issues and risks that was later modified to conform with commonly accepted categories being used by the ITS community. Additional institutional and societal issues identified in the course of the more technologically-based tasks and arising from discussions within the PSA effort were added over time. As anticipated at the outset of our effort, the findings of Task G regarding comparable systems were particularly valuable.

Issues were defined and redefined as work continued throughout the year on related ITS issues. Another important aspect of this task was to examine which institutional issues arise in connection with the different Representative System Configurations (RSCs). It became apparent early on in this effort that institutional and societal issues vary enormously depending on which RSC is deployed.

The confluence of some early conclusions regarding technological, societal and funding issues resulted in the finding in early March 1994 that AHS deployments ought to be phased-in, beginning with those RSCs that are less infrastructure intensive and less central command and control dependent.

Following the Interim Results Workshop in April 1994, we identified certain key issues that called for more in-depth analysis and that were not yet being examined in such depth by others involved in the PSA effort. The subsequent research in these areas -- air quality, political structure (in certain geographic areas), land use, and social equity -- is a particular highlight of this Final Report.

1.2 KEY FINDINGS

(1) Perhaps, the most important finding of this task is that there are ***likely to be no insurmountable institutional and societal barriers -- show stoppers -- to the evolutionary***

deployment of AHS. This does not mean that surmounting some barriers will necessarily be easy. There is much to do before AHS deployments -- beyond initial test sites -- is feasible.

This finding itself rests on two of the earliest conclusions of this research effort:

(2) ***Institutional and societal issues and risks vary enormously depending on the RSC to be deployed;***

and an important conclusion that seemed a bit daring when we first stated it early in the year, but which came be accepted with a surprising near-unanimity as of the conclusion of the April 1994 Interim Results Workshop, that

(3) Based on an analysis of the history of the introduction and acceptance of comparable, earlier technologies; the likely availability of funding, and the need to resolve some institutional and societal barriers incrementally as part of the process of deploying ITS technologies -- even before AHS -- ***AHS must develop evolutionarily from less infrastructure and outside-the-driver command and control technologies to more infrastructure dependent/greater outside command and control technologies***.

Additional findings include:

(4) Beyond confirming early (pre-PSA) predictions that AHS would be expected to provide air quality benefits -- based on the assumption that carbon monoxide would be reduced simply because vehicles would move more consistently at higher speeds --***it is likely that AHS will provide air quality benefits not only by reducing CO emissions, but also by reducing both the hydrocarbons and nitrogen oxides that create the more serious air quality problem of ground-level ozone***.

(5) ***Many institutional/societal issues that arise in connection with AHS are not unique to AHS, but rather, related to any plans to build roads today or in the future.*** The AHS effort cannot be expected to address, let alone resolve, all of these larger societal and historical issues. On the other hand, these issues can become barriers to the deployment of AHS. And to the extent that AHS may accentuate the effects of how some of these issues are perceived, for example, urban sprawl, the AHS effort must be aware of its place in this larger context of institutional and societal issues and be prepared to address such issues in its deployments.

(6) ***The awareness that AHS is likely to evolve evolutionarily from ITS technologies and that the ITS effort is addressing many of the same institutional and societal issues does not mean that all of these issues will be resolved through the ITS deployment process prior to the time when it is technologically feasible to deploy AHS.*** Nor can the AHS effort expect that even those institutional and societal issues that are "resolved" in the process of deploying ITS will necessarily simply "go away" for AHS. Moreover, there are institutional and societal issues that are likely to arise specifically with AHS, as opposed to ITS, technologies.

(7) ***If the AHS technology is not generally available at modest cost, there are important equity issues involved in reserving or constructing a lane for the use of relatively wealthy private vehicle owners***.

(8) The AHS effort must play "catch-up" with the long-term state and regional transportation planning already well underway in response to previous state and Federal mandates and the more recent 1990 amendments to the Clean Air Act and 1991 Intermodal Surface

Transportation Efficiency Act (ISTEA). ***Transportation plans for the next 20 years in congested areas in many cases are looking to rail projects to address many of the same transportation issues that an AHS might conceivably address***.

(9) Application of the technology to a mode of transportation that serves moderate-income commuters in an existing, heavily used corridor under the institutional jurisdiction of relatively few actors provides the kind of setting that could allow an early AHS success. AHS proponents must focus on both short-term and long-term opportunities by being aware that it is the institutional and societal milieu that determines if, when and where new technologies such as AHS will be deployed and being prepared to:

- ***Maximize the use or imminent improvement of existing facilities to demonstrate the benefits of AHS, even, or perhaps particularly, when the technology is used exclusively for non-personal vehicles, and that <u>such an early win opportunity may be represented by the desirability of automating the existing Lincoln Tunnel exclusive bus lane in New Jersey</u>***, and

- ***Support the development of non-AHS facilities where there may be a good opportunity for later conversion to automation***.

1.3 RECOMMENDATIONS FOR FUTURE RESEARCH

Recommendations for further research during the next, consortium phase of the AHS effort are described in section 4.0 of this chapter and summarized below:

(1) Tort and product liability -- further research into the most viable of the several potential approaches for addressing this issue as described in section 3.0 of this chapter.

(2) The extent to which AHS will induce demand for additional trips and for trips by low-occupancy vehicles that might otherwise be made by public transportation, and the extent to which AHS will encourage trips of greater distance -- increased VMT -- to take advantage of time savings.

(3) Further research into how the issues of public acceptance and education might guide how any initial test deployments are structured, how their expectations are defined, and how their results are interpreted and disseminated.

(4) The amount of revenue that might be raised with each type of funding source for AHS, the reliability and cyclical variability of revenues from each, and the political/institutional implications of each.

(5) Additional research into those potential applications of AHS technology that would be of particular interest to previously-identified potential stakeholder groups, and particular research into how AHS might be used to improve local control of traffic and improve community livability.

2.0 INTRODUCTION

2.1 PURPOSE

Some experiences to the contrary, we continue to live in a 20th century world in which it is assumed that there is a technological solution to many problems and that that technological solution will be found given the attention, time and funding needed to do so. That given, institutional and societal issues are sometimes recognized as the only intractable barriers to technological innovation and problem solving.

In examining the institutional and societal issues and risks associated with AHS, it has begun to become apparent that such non-technological barriers, too, can be overcome by sufficient attention (priority), time, and, frequently, funding. However, the will to do so -- unlike the built-in scientific/engineering motivation/ethos to solve problems simply because they are there -- is often not present among the actors in the institutional/societal milieu, where one party's solution is frequently perceived as another's problem.

The PSA effort has recognized this by specifically incorporating the examination of institutional and societal issues and risks at the same level of attention, at the same time, and in coordination with the examination of AHS technological issues and risks.

2.2 METHODOLOGY AND APPROACH

We, in particular, were requested to be comprehensive in its identification of institutional and societal issues and risks and approached the subject initially from several perspectives.

First, we identified those institutional and societal issues and risks that are likely to arise with AHS because they have been seen to arise with other similar technologies, and especially with the closely-related immediately predecessor ITS technology. We then sifted through these perceived institutional and societal issues to determine if and how they would affect AHS. Eight categories (plus additional sub-categories) of institutional/societal issues were identified early in this process:

- Regulation
- Government Reorganization
- Legal
- Economic and Other Institutional
- Funding Alternatives
- Public/Private Cooperation and Motivation
- Environmental
- Societal
  - Public Acceptance and Education
  - Marketing and Marketing of Related Products
  - Public Health and Welfare
  - Impact on Local Economy, Economically Disadvantaged, Inner City

An initial finding was that many-to-most of the institutional/societal issues identified as associated with ITS also are associated with AHS, but sometimes to greater or lesser degrees. Because of this close relationship with ITS [AHS being considered one end of the spectrum of ITS technologies -- advanced vehicle control systems (AVCS) or AVO] and due to the desirability of facilitating communication with all the actors already involved in the institutional and societal aspects of ITS, the list of institutional/societal issues was reorganized for the remainder of this study by categories that have achieved a common currency within the ITS discussions and studies to date:

Intergovernmental
Legal
Environmental
User Acceptance
Societal
Funding Alternatives

In this categorization, private sector participation has been included within the funding alternatives and intergovernmental categories, regulation within legal, and larger economic issues generally within societal. While some Issues overlap categories and some categories overlap each other, such a categorical breakdown does help to organize the multitude of institutional and societal issues somewhat.

Second, we began to identify those AHS-specific institutional and societal issues and risks that arise directly in addressing the various technological components of AHS.

Next, we applied the unique characteristics of the each of the Representative System Configurations (RSCs) to the consideration of institutional and societal issues and risks. Another initial finding was that institutional/societal issues often vary enormously by RSC. Through this exercise it became increasingly clear that the issues of AHS funding and AHS costs and benefits (the latter examined in detail in Task P of the PSA work, Chapter 2 of this volume), are more specifically questions of who benefits and who pays -- something that varies widely by RSC, and that makes it evident that there are really several AHS technologies and that the answer to the question of who benefits and who pays differs for each.

Thus, the cost of the technology required for RSCs 1 and 2 (smart vehicle, very little infrastructure investment) is likely to be paid for directly by the user (purchased with or to be installed in his/her vehicle, or leased with/without the vehicle) and the assessment of benefit will be a market decision for each individual. Since that cost, at least initially, may be high, the number of users may be limited initially to the more wealthy and those inclined to invest in new technology when it is first introduced (no matter whether the technology is VCRs, CDs, cellular phones, or cruise control). The benefits of AHS would be somewhat limited by the necessity to operate in mixed traffic with non-AHS vehicles. And these limited benefits would be experienced by the few who paid for the system.

There would likely be relatively little governmental investment/cost and government-related issues would be rather limited; there would be little need for public-private partnerships for funding, and some of the issues associated with such partnerships would not arise; and with little government involvement, the legal issues of intellectual property and privacy (beyond what would already have already arisen with ITS) would be moot. Product liability would be similar to that for any current new vehicle-related product, and there would be relatively little change in the current tort liability situation. With relatively few users and little change in infrastructure, there would be few environmental impacts -- or benefits. Public acceptance and marketing would be the major issues; presumably the private sector would not proceed with development and marketing if the potential user population were too small.

Conversely, with RSCs 5-7 and, especially, 9-13, governmental changes, if not major governmental costs/funding, would be more far-reaching, along with the issues associated with such governmental involvement: regulation, public-private partnerships, antitrust, intellectual property, licensing, public education, effects on local economy and land use. With greater command and control in the infrastructure, the nature, and not just the degree, of tort liability may change. However, with greater command and control in the infrastructure, the cost to individual vehicle operators/owners may decline (presumably the greater costs of infrastructure improvements also can be amortized over the longer life of the infrastructure, particularly relative to that of an individual vehicle) -- and the number of users increase. The benefits of AHS then would be more widespread along with the costs.

At this point it was possible to draw some initial conclusions about the institutional and societal issues that had been identified. In addition to the aforementioned categorical breakdown, these issues were seen as falling into several "types" depending on when and how (or if) they should be addressed through the AHS development/deployment process:

(1) Many of the more "difficult" issues are already being addressed, at least in part, by those involved with developing ITS, particularly through ITS America. For those issues, it is probably advisable for AHS to "wait and watch" as these issues are either resolved or not and what the effect is on the deployment of ITS. Then, after there is some opportunity to see at least initial effects, to determine what additional steps must be taken on these issues to implement AHS.

(2) For other issues, it is possible and somewhat less difficult to begin now to understand the alternatives and to set the framework for resolution -- most likely through the next AHS development step: the work of the consortium that will design the first AHS deployment.

(3) Still other issues are dependent on the RSC selected. If the initial RSC deployment selected does not trigger these issues, they need not be addressed -- at least in the near term (see below). Similarly, some issues may simply "go away" over time.

(4) Finally, some issues are simply too large for AHS development/ deployment to address. Although these issues arise and/or are affected by AHS development/deployment, they may be the same issues that have arisen with previous technologies (or policy decisions) and may represent some fundamental policy decision points (or schisms) in our society unlikely to be resolved in connection with any one technology and particularly not one which falls within a continuum of previous transportation systems development such as AHS.

Implications that can be drawn regarding the third type of issue above -- the fact that some issues do not arise with certain RSCs and some RSCs, therefore, have fewer "barriers" to implementation -- dovetails with the aforementioned initial conclusion and recommendation drawn from an investigation of certain categories of institutional and societal issues, particularly public education and acceptance and funding, as well as technological development issues. That is, a) because experience with introduction of previous technologies indicates that it is desirable, when possible, to introduce an evolution in technological innovation over time so that consumers/the market/the public can begin to visualize and understand the use of the technology and its benefits, b) because there is unlikely to be sufficient funding at the outset to build RSCs requiring major infrastructure improvements, and c) AHS is most likely to develop technologically as an extension of ITS technology that is largely privately-funded and smart vehicle-based, it is not only a probable scenario, but also desirable that AHS deployments be phased-in -- starting with more smart vehicle/less infrastructure-intensive RSCs and progressing to more centralized command and control and infrastructure-intensive RSCs.

Having presented these findings to the Interim Results Workshop in April 1994, we proceeded to identify certain key issues that required more in-depth analysis, that were not yet being examined in such depth among the other PSA contractors' work, and to which we could make a particular contribution. These were identified as:

- Air Quality
- Political Structure (in geographic areas not specifically being examined by other PSA contractors)
- Land Use
- Social Equity

Our team of nationally-experienced air quality experts augmented by the tailpipe emissions expertise of international specialist Michael Walsh took responsibility for further research regarding the air quality issue. Michael Walsh's paper on Technological Developments Which Should Lower Emissions from Vehicles on Automated Highway Systems is included as appendix A of this volume.

Meanwhile, a team from Princeton University's Woodrow Wilson School of Public and International Affairs proceeded with an examination of the latter three issues with specific application to three diverse geographic areas and potential facilities: the portion of the Long Island Expressway in New York that has been studied in depth as a potential deployment site (as reported in Volume III, Chapter 2), the exclusive bus lane leading to the Lincoln Tunnel from New Jersey together with its feeder roads, and the Nogales-Tucson-Phoenix corridor in Arizona. The Princeton paper, Automated Highway Systems: Institutional Issues, is included as appendix B of this volume.

Finally, as a result of our research, the work of other PSA contractors, and the concurrent continuing work to address ITS-related issues, some of the issues identified in the earlier part of the past year's effort -- or at least aspects or subsets of these issues -- have actually begun to be resolved by the end of this PSA contract year. That is, the issue was raised, research was undertaken, and as a result of analysis, it may now be concluded that the subject is no longer an issue to be resolved by the next phase of the AHS process or thereafter. This is the case with some of the legal issues, such as antitrust, and some aspects of the air quality issue. All issues initially inventoried are, nevertheless, included in section 3.2 below; if an issue has been resolved or partially resolved, the reasons for that conclusion are described in that section.

3.0 TECHNICAL DISCUSSION

3.1 OVERVIEW OF RESULTS

3.1.1 Intergovernmental/Private Sector Participation

AHS-related intergovernmental and private sector participation issues include those issues related to who should own, operate and/or regulate the owners/operators of AHS. Most of these issues are triggered by a decision to advance to a higher level of investment in infrastructure for AHS (RSCs 3-13, especially RSCs 12 and 13). The current mechanism for highway funding and ownership, which is centered on state DOTs may be inadequate for a system that may be in large part privately-financed and require a level of technological sophistication among personnel that is difficult to retain in government. Experience with financing and operating private toll roads in some states has offered some lessons for AHS, but the experience is not exactly transferable. Moreover, the legislative and policy environment for transportation infrastructure investments is changing, with ISTEA assigning responsibilities for Transportation Control Measures (TCMs) to Metropolitan Planning Organizations (MPOs). Issues also include "cultural barriers" to creating new agencies/organizations -- both from the perspective of existing agencies and from that of the general public.

For a more thorough discussion of public-private partnerships as a funding mechanism see section.3.7.

3.1.2 Legal

No other institutional and societal issue area has received greater attention in the development of ITS than legal and regulatory issues. This is a natural outgrowth of the largely private sector involvement in ITS and the particularly litigious environment in this country.

The four most significant legal issues identified for ITS -- tort and product liability, antitrust, privacy and intellectual property -- also are relevant to AHS. Thanks to the attention of a number of corporate as well as some government legal experts, these issues have already been examined in depth and further examination continues through the ITS America process and individual corporate decisions. While that process will continue concurrently with the AHS initial system design, and may not be "completed" prior to early decisions on AHS, it is unlikely that a separate AHS-related in-depth examination of antitrust, privacy and intellectual property would yield any additional benefits beyond those likely to be forthcoming from the ITS process -- and it is likely that these issues will be addressed, and either resolved (in the case of antitrust really already have been resolved) or not, by ITS before AHS is deployed.

For example, in the case of the privacy issue, American consumers have expressed a willingness (or acquiescence) to sacrifice at great deal of personal privacy for personal convenience and public protection in recent years. However, there is a growing resistance movement in favor of privacy protection. ITS America has drafted a set of privacy principles to guide the control of data collection, type of data collected and its use in connection with ITS deployment. Whether these principles will suffice for the public acceptance of ITS, amidst the contrasting trends noted, remains to be seen. However, while the issue is directly applicable to AHS deployment, it is unlikely that AHS adds any new or different aspects to the consideration of this issue.

On the other hand, the issue of liability may be of greater importance and impact with higher levels of ITS deployment (AVCS/AVO and AHS). Indeed, with RSCs 5-7 and 9-13, the migration of control functions away from the vehicle owner/operator may alter fundamental relationships upon which the existing body of tort liability law related to vehicle use has been developed. Liability could shift to infrastructure and equipment owners/operators/suppliers even as the total cost to society is reduced as a result of safety improvement. Again, potential approaches to this issue are being considered through the ITS process, but this will become more important to AHS, most likely at more advanced stages of deployment, and potential approaches will need to be resolved by that time.

3.1.3 Environmental

There are several levels at which "environmental" issues can be considered. At the "highest" or most generic level, are issues involving societal investment trade-offs among individual vehicle-based technology improvements, other transportation/mobility improvements, and economic and land use development goals, as well as investment decisions and funding limitations that are not otherwise related to these considerations. Some of these issues are being approached through focus groups organized by other PSA contractors. At the other end of the spectrum are issues related to the environmental aspects of weather and natural occurrences (e.g. rock slides) and the effects on AHS operations and maintenance. These issues are being addressed through other tasks.

In between are a category of environmental "impact" issues typical of those examined for any transportation or non-transportation policy decision or physical transportation or non-transportation improvement/development. Inasmuch as members of our team have a particular expertise and extensive experience in environmental "impact" analysis for Federal, state and local projects and actions, we have examined this category of environmental issues in this task.

The overall guiding principles for a "Federal action" are defined by the National Environmental Policy Act (NEPA) and subject to the Regulations for Implementing NEPA (40 CFR 1500-1 508), FHWA Environmental Impact and Related Procedures (23 CFR 771), guidance provided in FHWA Technical Advisory T 6640.8A (Guidance for Preparing and Processing Environmental and Section 4(f) Documents), and other Federal environmental statutes and orders including the requirements of those in table 1-1.

Table 1-1. Relevant Environmental Statutes and Orders

7 USC 4201 et seq., Farmland Protection Act of 1981	42 USC 4371 et seq., Environmental Quality Improve-ments Act of 1970
16 USC 461 et seq., Archaeological and Historic Preservation Act	42 USC 4601 et seq., Noise Control Act of 1972
16 USC 470f, Sections 106, 110(d) and 110(f) of the National Historic Preservation Act of 1966	42 USC 9601 et seq., Comprehensive Environmental Response, Compensation, and Liability Act of 1980
16 USC 662, Section 2 of the Fish and Wildlife Coordination Act	42 USC, 7401 et seq., Clean Air Act of 1990
16 USC 1452, 1456, Sections 303 and 307 of the Coastal Zone Management Act of 1972	43 USC, Coastal Barriers Resources Act of 1982
16 USC 1271 et seq., Wild and Scenic Rivers Act	Executive Order 11514, Protection and Enhancement of Environmental Quality, as amended by Executive Order 11991
16 USC 1536, Section 7 of the Endangered Species Act of 1973	
33 USC 1251 et seq., Clean Water Act of 1977	Executive Order 11593, Protection and Enhancement of the Cultural Environment
33 USC 1241 et seq., Resource Conservation and Recovery Act	Executive Order 11988, Floodplain Management
42 USC, 300(f) et seq., Safe Drinking Water Act	Executive Order 11990, Protection of Wetlands

Depending on the precise location, extent, construction requirements, and overall degree of complexity and controversy of the prototype AHS, varying degrees of documentation as identified by NEPA and the other listed Federal requirements could be required. However, of the above, there are only a few generic environmental impact issues directly related to AHS deployment as opposed to any other Federal action. They are: air quality, fuel use/conservation and noise; in addition, although site specific, RSC considerations to date indicate that there are likely to be visual impacts with any RSC involving changes to infrastructure (RSCs 3-13).

AHS-related air quality issues are of particular importance because of the mandatory nature and strict standards of the Clean Air Act as amended. While it was assumed -- even prior to the PSA studies -- that automated highway systems would reduce air pollution, that assumption was based on the concept that consistent, higher speeds would reduce carbon monoxide. However, the issue of air pollution is not one of CO alone. Indeed, as CO pollution is reduced, primarily through improved tailpipe emissions technology, and CO standards achieved in former "non-attainment" areas, concern has shifted to the far more difficult problem of ground-level ozone, created by an increase of hydrocarbons and nitrogen oxides. The effect of AHS on all three major pollutants has been examined as part of our research for this task.

3.1.4 User Acceptance

In the course of initial research on institutional/societal issues, it became apparent that the issues that come most immediately to mind in considering this category are those related to public acceptance and education. Early examination of comparable systems through the research undertaken for both Task G and this task indicates that there are many lessons to be learned about public acceptance and marketing of new technologies.

Among them is the aforementioned desirability of incremental development, and the need for long-term commitment and persistence. The history of automobile travel itself is one of incremental technological development; automated highway systems are part of the continuum of that history. The development/marketing of the typewriter illustrates the importance of long-term commitment and persistence; the absence of such long-term commitment may be a disincentive to AHS development (see Societal issues below).

In addition, benefits should be visible as well as quantified; quantified, even documented, benefits are desirable, but may be less persuasive than what the public/consumer can see for himself/herself. The technology must be user friendly; it must be reliable, and it must be priced in a range attractive to consumers. The perception of safety may be an important public acceptance/marketing tool for a new vehicle-related technology; indeed, the perception of safety with AHS may be particularly attractive to some drivers, particularly the elderly, who may be intimidated by current freeway driving factors.

Perhaps most importantly, as shown in the development and marketing of the typewriter, automobile travel itself, and more recently the Interstate Highway System, AHS must meet perceived needs or desires.

3.1.5 Societal

Other non-funding institutional/societal issues and risks run the gamut from concerns about the American economy in general (its competitiveness, technology employment retention/expansion, opportunities for defense industry conversion, balance-of-trade, effect on/from competitive modes) to concerns about the local economies that may be affected by the location of AHS facilities and particularly entrance/exit locations. The latter also is related to issues of land use, the impact on the inner city, and related social equity issues of AHS and other transportation investments. There is also an issue of concern regarding the potential effects on health, if any, of magnetic fields, particularly with an electrical propulsion systems for AHS vehicles (RSC 13).

3.1.6 Funding and Financial Analysis

The challenge is to develop, deploy and maintain a system that is uniform, compatible, decentralized and multi-faceted in an environment shaped by numerous public jurisdictions and private sector interests. Embodying the concept of public-private partnerships on a national basis will be an essential way of enabling all concerned parties to participate together in the deployment of AHS. There will be a multitude of mechanisms for public-private partnerships that are possible and feasible.

The public sector is theoretically able to install and maintain an AHS system by using a combination of Federal Aid funds, other Federal demonstration moneys, state highway funds, state general funds and local government funds. But the current capacity of the public sector to fund an extensive system that will use a considerable percentage of existing Federal, state and local budgets has to be questioned.

Alternatively, there are other funding mechanisms such as tax increment financing, transportation development districts, local option taxes, right-of-way donations, the awarding of concessions to deliver roadways (also known as the franchise approach or the public-private partnership model). Each approach has its pitfalls and limitations, as well as its advantages. Given the size and complexity of the AHS program undertaking, there will in all probability not be one single method for financing the system, but rather a preferred combination of methods that may work.

The 1990 National Transportation Policy and ISTEA encouraged States to develop new cost-sharing partnerships with the private sector, and provided state and local governments with many new options to fund transportation. It encouraged the sorts of approaches now being tried successfully in several states whereby franchise agreements have been entered into between states and the private sector to finance, develop, build and operate new roads or improve existing highways. ISTEA also permits States, for the first time since the turn of the 20th Century, to use tolls as a supplement to conventional fuel and vehicle taxes on much of the Federal-Aid system.

The private sector can bring considerable technological expertise and efficiency advantages as a direct result of its role in other high technology programs. The private sector is much better able to take advantage of efficiencies in production and distribution. And as long as the private sector is efficiently regulated, without excess burdens imposed by government bureaucracy, the public interest can be protected and assured. Additionally, the private sector may be better able to take political heat from concerned parties when it comes time to market tolls or increases in toll rates, or indeed when inter-jurisdictional co-operation between public agencies is needed.

The private sector can participate in AHS system delivery by designing, installing and operating a system in a specified corridor. The right to develop and install such a system could be granted across several political jurisdictions or boundaries. There could be numerous public agencies involved in monitoring, regulating or otherwise overseeing the private operation. They could see to it that design, construction, and particularly maintenance standards are being met or complied with. Electronic toll collection and road pricing systems could be used to charge for the use of the privately supplied AHS system. Toll revenues collected could directly retire the debt incurred by the private sector. Profit sharing or cost sharing allocation formulas can be developed to spread the benefits and costs of implementation.

Private toll road facilities, operated under concessions awarded by state highway agencies, could provide the basis for the operations of such AHS systems. At the end of the concession period, ownership of the roadway would revert back to the relevant public agency. Alternatively, for the purpose of avoiding tort liability, the public highway agency could maintain ownership of the roadway at all times, with the private concessionaire responsible under the terms of a franchise agreement for maintenance, repair, and overall operations.

While the applicability of public-private partnerships in the highway transportation sector has been demonstrated effectively elsewhere in developed and developing countries, in the US during its early history, and more recently through the construction of several private toll roads (primarily the privately owned and operated Dulles-Leesburg Toll Road Extension in Virginia, and the privately financed SR-91 Express Lanes in Orange County, California), there are some issues and risks with this form of delivery. Public sector contracting and procurement traditions, customs and regulations make it difficult for private sector interests to incur the considerable risks of project development, principally the environmental permitting process, completely at its own risk with little or no reward until revenue operation. Private firms are less able and willing to deal with delays in start up, with environmental challenges or construction schedule changes in scope and cost.

3.2 INTERGOVERNMENTAL/PRIVATE SECTOR PARTICIPATION

Although identified early in the ITS, including AVCS/AHS, process as one of the major categories of issues in deployment, it is actually quite difficult to distinguish issues herein from the legal/regulatory and funding alternative issues discussed later in this volume. After several efforts at shuffling issues to distinguish their more distinctive characteristics, five intergovernmental issues have been defined in this category. They are: 1) coordinating multiple jurisdictions, 2) multi-jurisdictional regulations with conflicting/overlapping requirements, 3) the capability and desirability of State DOT development of AHS, 4) guideway ownership, and 5) private sector participation issues beyond those specifically related to funding alternatives (the latter of which are described in section 3.7). As described below, it is also clear that these issues overlap considerably with each other.

3.2.1 Coordinating Multiple Jurisdictions

As described in appendix B, the decision to reserve lanes or construct an AHS can involve state and local transportation departments; state and local land use planning agencies; existing toll road, tunnel, or bridge authorities; environmental regulatory bodies, and economic development agencies. Funding decisions can involve governors and mayors, state legislatures and city councils, as well as metropolitan planning organizations (MPOs). These agencies/individuals have disparate views and different interests. The political nature of intergovernmental processes being what they are, the cost of approval for an AHS project may be augmented by additional projects built to secure the necessary consensus.

If the AHS is to be entirely within the jurisdiction of one state, or one multi-state agency, the implementation process will be somewhat easier than in other multi-state urban areas. If regional cooperation is required and no mechanism is in place for coordination, the process is likely to be very difficult. One of the most crucial aspects of this issue is gaining a better understanding of the relative management and financial strengths and weaknesses of the various potential participants in a multijurisdictional arrangement [Horan/Gifford, 1993]. The US Department of Transportation's IVHS Institutional and Legal Issues Program is seeking to identify key elements in coordinating complex, systems-level program efforts across jurisdictional, organizational, and agency boundaries through case studies and ITS operational tests [IVHS America National Program Plan, Draft May 1994].

There are few good recent examples of the establishment of multi-jurisdictional regional transportation agencies with real power. TRANSCOM in the New York City metropolitan area is a successful example of multi-jurisdictional cooperation on traffic management and information issues, and is becoming increasingly involved in the deployment of ITS technologies. However, its governance mechanism requires unanimous consent for action, and that degree of agreement may be too cumbersome for construction, operation, and maintenance of an AHS. (TRANSCOM might be a reasonable model for an agency that operates a command and control facility.)

The Lincoln Tunnel exclusive bus lane examined as a candidate for automation in appendix B offers a case study of intergovernmental complexity -- and it is relatively simple compared to many locations where AHS may be desirable: The Port Authority of New York and New Jersey controls both the tunnel and the Port Authority Bus Terminal in Manhattan to which the bus lane is linked; the governors of both states retain veto power over its decisions. The Port has served as a mechanism for regional infrastructure construction for almost 75 years. An independent authority, with a board appointed by the Governor of New Jersey, runs the New Jersey Turnpike, and the road which links the tunnel and the turnpike is under the jurisdiction of the New Jersey Department of Transportation. (The Commissioner of Transportation, also a gubernatorial appointee, is a member of the boards of all the major transportation agencies in New Jersey, including the Turnpike Authority and NJ Transit which operates most of the buses that use the tunnel.)

The New Jersey state legislature, through its transportation and appropriation committees, takes an active role in road construction decisions and in the past has had an adversarial relationship with the Turnpike Authority and the Port Authority. The North Jersey Transportation Planning Authority's jurisdiction includes the counties near to New York City, but it functions more like a legislative committee than a regional planning agency, and any required expenditure of Federal funds will be subject to the balancing of interests that has become routine in its decisions.

Any tolling to pay for automation of the bus lane that results in higher bus fares would be volatile, but alternatives to tolling also raise difficult political/intergovernmental issues. It is possible that the State of New Jersey would provide the required revenue to construct an AHS at the Lincoln Tunnel, but officials would face substantial political difficulties in doing so and would probably look to the independent authorities for funds. The Port Authority already operates the PATH commuter train at a substantial annual loss, and can be expected to resist expenditures of any size for an AHS that is not tolled or which requires cross-subsidies by other Port Authority facilities. Without a balancing act that provided an expenditure of equal value on a project of direct benefit to New York state residents, the Port Authority funding might be vetoed by the Governor of New York.

The Turnpike Authority could automate the appropriate part of its roadway; if sufficient additional toll revenue were not expected, however, its board too might resist such an expenditure. And there may be bond restrictions that limit the Authority's ability to pay for AHS improvements on the linking road. Nevertheless, with considerable political effort by the Governor of New Jersey -- for which there is precedent -- Authority financing for an AHS at the Lincoln Tunnel is possible, the determining factor being competing alternative demands for funds.

3.2.2 Multi-Jurisdictional Regulations and Requirements

AHS projects by their nature are likely to include regional applications that involve more than one political jurisdiction. Conflicting and/or overlapping requirements among jurisdictions can retard the AHS deployment process.

Several non-AHS regional management efforts are underway that may provide role models for the AHS deployment program. ISTEA could be amended to allow interstate compact authority to be used to conform conflicting and overlapping requirements for regional implementations.

Again the Lincoln Tunnel automated exclusive bus lane example illustrates this issue: The State of New Jersey is developing its plan of compliance (SIP) under the Federal Clean

Air Act, the state DOT is developing its construction master plan, the Northern Jersey Planning Authority is developing its congestion management plan under ISTEA, and it is not at all clear how an AHS would conform to any of them. (The New Jersey Land Use and Development Plan places a priority on economic development and infrastructure development in the inner cities, and is specifically designed to limit residential and business decentralization; automation of the Lincoln Tunnel bus lane access may be acceptable because of its likely minor land use implications (see section 3.6.2).

3.2.3 Responsibility for AHS Development

There are several sub-issues here. Among them is the current division of responsibilities between State DOTs and MPOs, the latter of which are responsible under ISTEA for Congestion Management planning. Although State DOTs have been the key building blocks responsible for development of the national highway system to date, questions have been raised as to their ability to handle the complexities of AHS deployments. At the same time, there is institutional (and electorate) resistance to creating new organizations.

3.2.4 Guideway Ownership (And Operation)

Ownership alternatives include the Federal government (DOT/FHWA), states (state DOTs), other public entities (e.g., the Port Authority of New York and New Jersey), and special purpose authorities (public/private or not, e.g., toll road administrations). Recurrent local budget and staff shortfalls and limited local technical expertise may influence the choice in some areas. Another such consideration is the difficulty of retaining the highly-skilled personnel who will be necessary for the long-term operation of AHS within the public sector; even after they have been trained and gained experience at public expense, they may be lost to higher paying private sector jobs.

Operational issues are discussed in the Task K chapter (AHS Roadway Operation Analysis) of volume 3 of this report. Education and training needs are already beginning to be addressed, at least for ITS technologies, by detailed proposals for new curricula [Jovanis, 1993, and Smith/Hoel, 1994].

Ownership of existing rights-of-way is certainly the logical starting point for resolution of this issue in any one area. Title to all or part of the right-of-way could be transferred by a current local owner to another entity to facilitate AHS development.

The owning jurisdiction could operate and maintain the AHS facility -- current normal highway functions such as clearance of debris, patching, etc., as well as AHS-specific maintenance of electronics, check-in/out, overall system monitoring (see Task K: AHS Roadway Operation Analysis in Volume 3 of this report). Therefore, system operation, rather than ownership *per se*, may drive this issue.

Greater levels of outside-the-driver command and control and/or an electrified guideway increase the difficulty of finding a qualified, competent and interested system operator. AHS equipment manufacturers may be one source of operators.

Ownership of the initial fleet of test vehicles is a related sub-issue.

3.2.5 Private Sector Participation Issues

Private sector participation issues, in addition to those specifically related to funding, include: a) the credibility/acceptability of non-governmental ownership/operation, b) the level of private sector access to/ownership interest in public assets, c) the definition of public-private partnerships for AHS and the methods by which they should be implemented, and d) prohibitive regulations that inhibit private participation (in addition to those multi-jurisdictional ones discussed above in section 3.2.1).

The encouragement of public-private partnerships within AHS development and deployment has been a goal from the outset, no doubt anticipating a reluctance to rely entirely on government financing, but also acknowledging the advantages of the private sector in technological innovation and service maintenance. Public expectations from quasi-governmental and private service providers are higher, but the public has demonstrated a willingness (or at least an acquiescence) to paying more for this higher level of service. Issues involve the appropriate role of the government and quasi-government agencies and the private sector at different stages of AHS development, deployment, operations and maintenance, and the ability to "hand off" from one to the other between stages.

An understanding of viable models for private sector involvement is needed; one approach might be the granting of franchises such as those used for cable television and cellular technologies [Horan/Gifford, 1993]. Again, the limited experience with private toll road construction and operation, as well as with other recent technological innovations (e.g. cellular phone technology) has highlighted some of the current regulatory and "understanding" gaps in the ability of the private sector and government to form partnerships and work together. Current case studies of partnering options and operational tests of early ITS deployments will aid in understanding obstacles to partnership development and coordination, the key elements of successful partnerships, and available conflicts resolution measures [IVHS America National Program Plan, Draft May 1994].

3.2.5.1 Credibility/Acceptability of Non-Governmental Ownership/Operatio

Public expectations from and willingness to pay for private or quasi-governmental services may be higher than from government agencies. The example is cited of public expectations regarding snow removal on the tolled, quasi-governmental New Jersey Turnpike vs. other New Jersey state highway facilities. What is the ability/desirability of government-supported AHS development to hand-off operations and maintenance to private or quasi-government agencies?

3.2.5.2 Level of Private Sector Access To/Ownership in Public Assets

To accomplish unprecedented levels of cooperation and coordination may require a not heretofore available level of private sector access to, and perhaps ownership interest in, public assets. California's recent, painstaking development process for four new toll roads to be constructed -- and to an extent owned -- by the private sector may offer role models for AHS deployments.

3.2.5.3 Definition of Public-Private Partnerships for AHS

Methods by which public-private partnerships should be encouraged to develop AHS are largely unprecedented, with the possible exception of the California toll road examples noted above. The applicability (or unsuitability) of existing procurement rules creates an atmosphere of uncertainty that is not conducive to private sector participation.

3.2.5.4 Prohibitive Regulations

The problem is at least two-fold: 1) direct prohibitions against private participation in the development of public facilities in some areas, and 2) unintended side effects of regulations adopted for other purposes, but which nevertheless have a chilling effect on private sector participation. The latter issue arises particularly with new technology. One example cited by a state highway department was the inability of the department to allow the Cellular One company equal access to public rights-of-way as other companies that are considered "utilities" under laws adopted long before anyone conceived of cellular telephones.

3.2.5.5 Project Uncertainties

Uncertainties and delays in AHS development and fear of changes and vagaries in the government's commitment -- witness experience with the SST and Superconducting Super Collider (SSC) -- increase the cost of development and put initial investments at risk, discouraging vendors from participating.

Early planning should take into account the need to retain the interest of private sector vendors, and minimize the costs of interested manufacturers due to delay.

3.3 Legal

Four primary legal issues were identified with both ITS and AHS: tort and product liability, privacy (also, clearly, a societal issue), intellectual property, and antitrust. There are a number of other regulatory issues, as well, primarily related to procurement (in addition to those issues with a direct bearing on public-private partnering, as discussed in section 3.2).

3.3.1 Tort and Product Liability

The most significant problem for AHS is that migration of control functions away from the vehicle operator may alter fundamental relationships upon which liability laws have been developed (which heretofore have placed fundamental liability upon the driver). Greater liability could shift to the infrastructure and equipment suppliers -- even as the total cost to society may be reduced.

Other liability issues associated with AHS (as identified in DOT, June 1994) are: a) the increase in vehicle and roadway complexity, b) the increased component reliability that will be required, and c) the possibility of severe damage caused by collisions of vehicles traveling at higher speeds and reduced spacing between vehicles.

The impacts of this issue are that: 1) such liability is a deterrent to private sector design and manufacture, and reduces competition, and 2) cost exposure to expensive lawsuits reduces the incentive to be a market leader and increases prices. Syverud cites several interviewees who indicated that decisions regarding whether to pursue development of AVCS technology had been delayed or adversely affected by product liability concerns.

Changes to state/Federal liability law could limit -- or share more widely -- potential damages and pain and suffering awards from malfunction or misuse. Some efforts at tort reform are already underway unrelated to ITS or AHS. For example, a new Federal law, the General Aviation Revitalization Act, limits the ability of lawyers to sue small aircraft industry manufacturers for product liability, and an increasing number of states have passed legislation that places some limits on product liability [Bryant, 1994].

There are a variety of possible approaches to resolving this issue:

- **Government assumption of liability or liability above a certain threshold**. There are several precedents for this approach, including those for international air carriers, the commercial space industry, the nuclear power industry, and environmental cleanups. Under Public Law 85-804 NASA indemnified contractors for the shuttle based on a finding that the program represented an extrahazardous risk for which insurance could not be obtained at reasonable rates. EPA indemnified contractors for liability risks resulting from involvement in environmental cleanups [IVHS America Legal Issues Committee Procurement Task Force]. Indemnification in such cases requires a strong legislative consensus in favor of the technology and against excessive tort liability, which may be difficult to attain for automotive products, especially when the Federal government is financially constrained by the deficit [Syverud, 1993].

- **Other modifications of liability laws**, such as a uniform statute of limitations, capping of damages and the modification of joint and several liability clauses

- **Assurance of reasonably-priced insurance**.

- **Risk pooling** (coverage purchased as part of fees for service or produce). Risk retention pools are provided for in 15 U.S.C. 3901-03.

- **Conditioning the receipt of service/products on an agreement to submit claims to arbitration** (or other alternative dispute resolution).

- **Regulation stipulating compliance triggers liability limitation** (compliance with safety standards or with required warnings of known hazards).

- **Extension of sovereign immunity to government contractors or suppliers if they comply with government specifications/ regulations**. The courts have not resolved whether the ***Boyle*** doctrine [Boyle v. United Technologies Corp., 487 US 500, 108 S. Ct. 2510 (1988)] that insulates contractors that comply with government specifications in producing the product that is the subject of litigation, applies to non-military contractors. The government could determine whether it will advocate that this doctrine be applies to AHS.

Another approach, at least for demonstration projects, is that taken by California in creating a supplemental health insurance program for injuries related to some PATH projects, and then crafting agreements wherein participants in demonstration projects voluntarily assume the risk of any injuries that result from the project and limit their compensation to that provided by the health insurance program. Health insurance covers significantly fewer items of damage than tort liability and excludes pain and suffering and emotional distress, thus, significantly lowering liability exposure [Syverud, 1993]. Hopefully demonstration AHS projects can produce sufficient data to document system safety and assuage some liability concerns [Syverud, 1993].

Researchers have noted in the past year that private sector interest in ITS design and manufacture remains high, and such liability issues -- at least as relates to Federal law -- have not been seen to be a deterrent (at least to some ITS technologies) to date. Also, there remains the concern that liability laws serve the purpose of motivating the development and deployment of safe products/technology. Therefore, it is not likely that intervention to address this issue will be undertaken in the early stages of ITS development.

3.3.2 Privacy

Safeguards and guidelines on the control and use of data that may be gathered by and for AHS are important for the public acceptance and support of AHS (and ITS before it). Careful consideration must be given to the circumstances under which travelers or vehicles need to be identified, how identifying information will be stored and used, who will have access to the information, and which secondary uses of the information will be permitted [National IVHS Program Plan Draft, May 1994].

The problem relates to both "historical information" (where someone has been) and surveillance issues concerning "real-time" and "future-time" information (where someone is and will be going). Surveillance issues raise significant Fourth Amendment concerns.

On the other hand, limits on use of data may limit opportunities for beneficial use, such as better public planning, as well as system financing (marketing of data is one way to defray some costs of a system).

Also, local law, e.g. Minnesota Government Data Practices Act, may *require* a state to provide any data collected to the general public, although most state statutes modeled after the Federal Freedom of Information Act include an exemption providing protection against disclosure of certain information that could be considered an invasion of privacy.

At the same time, the Federal Privacy Act of 1974 regulates the collection, maintenance, use and dissemination of personal information, and several states have adopted similar acts, some states imposing similar restrictions regarding some types of data on the private sector (DOT, June 1994).

Several possible approaches to resolving this issue have been discussed, perhaps the major forum for which has been the IVHS America Legal Issues Committee (LIC). For example, the use of private contractors to collect data may help limit access of other parties to some data.

Marty Abrams, Director of Privacy and Consumer Policy at TRW and Chairman of the LIC Privacy Task Group, has described the ambivalent feelings of Americans regarding privacy as falling into three general categories. At one end are privacy absolutists, and at the other end are people who basically don't care what information others may gather about them. In between are "privacy pragmatists", the middle 50%±, who depending on the specific situation may join with the privacy absolutists to oppose further erosion of their privacy or with those who don't care. This large middle group generally is willing to surrender some aspects of their privacy if they understand and support the purpose for which the information is to be used, and if they are assured that the information that is collected for such a purpose is not used for another purpose or mis-used. (This, however, can vary among individual circumstances at any one time.) To allay fears of this middle group and gain support for ITS -- and by extension AHS -- the LIC has drafted a set of Information Privacy Principles:

(1) IVHS information systems should center on the traveler's interests.

(2) IVHS information systems should be built and maintained in a manner visible to travelers.

(3) IVHS information systems should have an appropriate role in enhancing travelers' safety and security interests, but absent consent or an appropriate court order, information identifying individuals should be safeguarded from law enforcement.

(4) IVHS information systems should be secure.

(5) IVHS information systems should comply with state and Federal laws governing privacy and information use.

(6) IVHS information systems should only collect information that is needed to fulfill IVHS purposes.

(7) IVHS information systems, coupled with appropriate privacy protection, may be used for non-IVHS applications.

(8) Federal and state freedom of information obligations require disclosure of information from government maintained databases. That disclosure should balance the traveler's interest in privacy and the public's right to know.

(9) These principles are dynamic.

"AHS" can be substituted for IVHS in all of the above principles, as the use of data that will automatically be part of the check-in, check-out and "real-time" processes of AHS will continue to raise the same privacy concerns. If the successful promulgation of these principles through the ITS process helps to allay fears prior to widespread deployment of AHS, the AHS program may find a greatly reduced privacy issue. As noted by Regan, 1994, the failure to take into account this issue can impede the introduction of new products; negative consumer response to Lotus MarketPlace, containing buying preference details on households and individual consumers, resulted in Lotus' decision not to issue the product.

It is in the interest of the AHS program to encourage the transportation community to start by eliminating the use of loaded jargon, such as "traffic *surveillance*."

Private sector concerns about disclosure or transfer of intellectual property can impede AHS development. Indeed, intellectual property issues already have stalled or constrained IVHS projects [Syverud, 1993].

When Federal funding is involved, there is precedent for granting the non-Federal party the rights to inventions developed in performance of an agreement as long as the Federal government retains a nonexclusive, nontransferable right to use the invention. (The non-Federal party generally may copyright material, e.g., computer software, developed under a Federal funding agreement as long as the Federal agency reserves a royalty-free license to use or authorize others to use for a Federal government purpose.)

The private sector has expressed the belief that government has insisted upon receiving more intellectual property rights without paying the full value of such rights and thus has reduced the contractor's ability to offset its development costs through sales to other government and private sector buyers.

Existing procurement practices differentiate between intellectual property developed "at government expense" and that developed "entirely with private funds". Some in the private sector believe that government procurement practices do not adequately address situations wherein pre-existing (private) technology will be further developed through government contracts, although the Standard Patent Rights Clause applies only to inventions that are "conceived" or "first actually reduced to practice" under a Federal contract.

The policy purpose underlying Federal law (as summarized in DOT, June 1994) is to:

- Promote the use of inventions arising from Federally- supported work
- Ensure that the inventions are used in a manner to promote competition and enterprise
- Promote the commercialization of domestic inventions
- Ensure that the government obtains sufficient rights to meet the government's needs and to protect the public against nonuse or unreasonable use of inventions

The Federal government also retains "march-in rights" with respect to any invention title to which is retained by the recipient of a Federal funding agreement that require the owner to grant a license to any responsible applicant with reasonable terms under certain public policy conditions, including:

- The owner's failure to achieve practical application of the invention
- The necessity of the action to alleviate health or safety needs
- The necessity of the action to meet specified requirements for public use
- The failure of the owner, or licensee, to manufacture the patented item in the United States

And Chapter 18 of Title 35 of US Code allows the government to obtain title to inventions or direct that it be vested in other entities in "exceptional circumstances" when restriction or elimination of the right to retain title to an invention "will better promote the policy and objectives of this chapter."

From the private sector viewpoint, the need is to define uniform specific policy regarding what property rights government wishes to retain for itself (from the private manufacturer/developer's viewpoint -- although not necessarily the taxpayer's --limited to those necessary for government purposes), publicize methods for seeking waivers, and be willing to negotiate before a contract is awarded. Government might obtain the protection it needs by entering into intellectual property agreements that mandate that a contractor who has a monopoly on a technology required for AHS implementation must license the technology to others -- at commercial rates, after the contractor/developer recoups its development costs and a reasonable profit.

Additional aspects of this issue include specific state/local law, such as the Minnesota Government Data Practices Act, that may require the state to provide data prepared by contractors to the general public. Thus, there may be justification for promulgating Federal uniform regulations. On the other hand, according to Stern, *et al.*, 1993, a contractor in

Minnesota can retain title to intellectual property developed in part under state contracts by negotiating a royalty arrangement, license agreement or comparable arrangement whereby the state receives fair compensation for its contributions toward the creation of such rights.

The AHS development procedure, wherein the next step in the process is intended to be undertaken by a consortium of private companies, perhaps with state, local, quasi-public agencies and universities, may further complicate the division of intellectual property rights. FHWA's Request for Applications for a consortium to manage this next design phase included the standard patent rights clause contained in 37 CFR 401.14, as modified. Thus, the AHS program may begin to address this issue, before the rest of the ITS community, possibly as early as the selection of and contract negotiation process with the consortium.

3.3.4 Antitrust

Although raised earlier in the ITS/AHS process, this may be more a problem of perception than an issue. The National Cooperative Research Act of 1984 limits antitrust liability for research and development; the statute's coverage was extended in 1993. Although this law may not cover standards-setting, judicial standards for antitrust determinations still must be based on the "rule of reason."

A change in antitrust enforcement policies by the Department of Justice that would discourage joint ventures and teaming arrangements in competitive markets would encumber timely deployment and create competitive disadvantages vis-à-vis European and Asian development and deployment of AHS. There is concern about whether or not the Department of Justice will become more aggressive in pursuing enforcement in non-traditional areas [Adler, *IVHS Legal Issues*, Vol. 2, No. 2 (Spring 1994), pp. 11-15].

Again, as with the intellectual property issue, the AHS development process may precede any further action by the ITS community to resolve this issue (to the extent it exists). DOT, June 1994 notes that DOT is "evaluating any legal issues, including antitrust concerns,...connected with the Automated Highway System Program....Specific antitrust concerns will be addressed as they are identified."

3.3.5 Other Legal/Regulatory Issues

3.3.5.1 Cost accounting, Cost certification, Auditing requirements

While not unique to AHS, complex requirements increase the ultimate costs to taxpayers while reducing the pool of effective competitors to supply AHS.

Potential resolution includes:

- Minimizing applications of such requirements for AHS
- Training
- Centralizing decision-making in the Federal government as to required information for certainty/consistency
- Increasing the uniformity of applicable accounting rules

For business privacy reasons, some companies find it necessary to maintain a legally separate subsidiary for government contracts, so as not to expose all of the company's books to Federal audit (IVHS America Legal Issues Committee meeting, November 1993]. Some of these companies may then find it difficult to respond to some government procurements because the best people in the firm to work on the project are not necessarily allocated to the separate subsidiary [Syverud, 1993]. As noted by Syverud, this issue and some other perceived legal/regulatory "constraints" are frequently "simply the painful learning curve experienced by private companies who are dealing, for the first time, with established regulatory methods for highways and automobiles." That does not make them any less real for these companies, but it suggests that of the several possible means of resolution listed above, the most important may be information dissemination through seminars, easily understandable written explanations, and training (see Inexperience with High Technology Procurements below).

3.3.5.2 Inexperience with High Technology Procurements

Delays and missteps could result in less effective competition for production of AHS products. Obscure government contracting law, e.g., Walsh-Healey Act, Service Contract Act, make it difficult for inexperienced would-be contractors [IVHS America Legal Issues Committee Procurement Task Force]. Would be private sector participants may be accustomed to procedures with Federal agencies such as the Department of Defense, but not with state and FHWA procurement practices [Syverud, 1993]. Resolution could be through training.

3.3.5.3 Organizational Conflict of Interest Limitations

Conflict of Interest (COI) limitations at all levels of government may limit the extent to which companies can be both the designer and builder of AHS-related systems. ITS is facing the same issue, and there is no consensus about the threat vs. benefits of COI rules. However, again because of the AHS timetable, this issue may not be resolved through the ITS process in time to address concerns that arise in connection with AHS.

The application of these rules should be evaluated for their suitability to high performance procurements [IVHS America National Program Plan, Draft May 1994].

3.4 ENVIRONMENTAL

3.4.1 Air Quality (and Fuel Use/Conservation)

The primary vehicle-related environmental issue is air quality. The 1990 Clean Air Act amendments reflect continued concern for reducing vehicle-related air pollution -- basically prohibiting the implementation of transportation programs that contribute to additional pollution in non-attainment areas. ISTEA further emphasizes the need for the planning of any transportation facilities/improvements to take into account these air quality concerns. The issue of energy/fuel conservation is linked with air quality issues: see subsections on "Acceleration/Deceleration", "Power Supply" and "Vehicle Miles of Travel" below.

The major pollutants emitted from motor vehicles are carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx). CO is of concern primarily as a localized pollutant, with elevated levels often found along heavily traveled roadways and near congested intersections. Both HC and NOx are of concern as regional pollutants because they interact in the atmosphere in the presence of sunlight to form ozone (O3). Ozone is becoming the focus of vehicle-related pollution concerns because of its deleterious health effects and the number of "non-attainment" areas around the country which exceed ozone standards -- and because CO is effectively being reduced by past, current and planned tailpipe technology improvements in response to the Clean Air Act and state (lead by California) mandates.

[There is currently no EPA-approved methodology for estimating the effects of alternative roadway systems on particulate emissions from the tailpipes of mobile sources. The current procedures only allow for a direct relationship between particulate emissions and VMT. See subsections on Power Supply and VMT at the end of this section.]

Because the range of ITS technologies is so broad, it has been easy to deflect air quality concerns to date by pointing to specific ITS technology areas (e.g. emissions detection, demand management and congestion pricing applications, improvements specifically to/for transit vehicles) through which air quality improvements can be anticipated and noting that there is no one ITS technology or package of technologies being proposed at this time. (A statement that since transportation programs are the responsibility of individual communities and regions, areas with air quality problems will necessarily promote ITS strategies that lead to reductions in emissions really avoids the issue.) AHS, however, is a more specific subset of technologies, to which it is possible to attribute air quality effects at least somewhat more directly.

Many of these effects were identified in Soden/Kogan, 1994 earlier in this study; the relationships between emissions and potential effects of AHS were based on the authors' experience using the Environmental Protection Agency's (EPA) latest emission factor algorithm, MOBILE5a, under a variety of conditions. Subsequently, Michael P. Walsh has provided an in-depth report on the current and planned extent of tailpipe emissions technologies and their relationship to AHS, included as appendix A of this volume.

Numerous factors affect emissions from motor vehicles, including vehicular thermal states (a warmed up engine emits substantially fewer pollutants than one that has just started), inspection and maintenance requirements, vehicle age, etc. Factors of particular relevance to the operating characteristics of vehicles affected by implementation of AHS include vehicular speed and driving patterns, that is, whether the vehicles are cruising at constant speed or going through cycles of deceleration, idling, and acceleration.

3.4.1.1 Incident Reduction

Any system that decreases the amount of time that vehicles are queued or traveling at slow speeds because of an incident should result in lower emissions. A reduction in idling time due to fewer incidents, and fewer stop-and-go movements in congested conditions (see Acceleration/Deceleration below), results in a direct reduction in idling emissions --**a seven-fold reduction in CO and HC** as measured by MOBILE5a.

In addition, CO emissions are very high for vehicles traveling at very low speeds (i.e. below 10 mph), as frequently occurs near incidents.

3.4.1.2 Acceleration/Deceleration

A vehicle traveling at a constant speed of 35 mph should have fewer emissions than the same vehicle traveling at a peak speed of 50 mph (see Increased Speed below) with numerous stops and starts. Any system that reduces the number of acceleration/deceleration cycles during the course of a trip should reduce vehicular emissions.

Moreover, it is the potential of prolonged steady speeds with AHS that is its primary attribute in improving air quality when compared with existing roadway travel. It is not currently possible to model the specific emissions outputs for any volume over any specific roadway geometry because current emissions models are based on a standardized driving cycle with its existing "transient" speeds (originally developed to duplicate the speed and time profile of a typical Los Angeles area highway trip in the 1960s). Nevertheless, an examination of current and planned tailpipe emissions technology improvements indicates that AHS can have a significantly beneficial air quality impact.

Current emission control technology includes closed loop, single bed three-way catalysts; fuel injection, usually multipoint fuel injection, and no secondary air. Manufacturers are likely to use improved catalyst formulations with higher noble metal loadings, sequential multipoint fuel injection, and direct-fire ignition systems in order to meet the latest Clean Air Act standards. Improvements to catalyst formulations when taken together with reductions in gasoline contaminants such as sulfur and lead (reformulated gasoline will also be responsible for some of the emission reduction), and reduction in oil additive-based contaminants such as phosphorous, will result in reductions in catalyst deterioration -- the principal cause of emissions deterioration in well-maintained vehicles. Sequential multipoint fuel injection and direct-fire ignition systems allow more careful control of air/fuel ratio and spark timing.

While these current and emerging technologies should reduce emissions under all operating conditions, they are ideally suited to careful, precise control of emissions and fuel consumption under a standardized condition or series of conditions. At steady speed conditions, especially, the vehicle's computer can easily be programmed to achieve the optimal combination of air/fuel mixture, spark timing, exhaust gas recirculation flow rate, etc. to minimize emissions. Airplane engines are currently adjustable to take advantage of such conditions in flight.

In addition, without the complications of accelerations and decelerations, the chemistry and physical environment of the catalyst can also be optimized to both maximize conversion efficiency of all three major pollutants -- CO, HC, and NOx -- as well as minimize deterioration over time.

The level of tailpipe emissions is a function of a) the engine-out emissions, and b) the conversion efficiency of the catalyst -- both of which are highly dependent on the proper functioning of the fuel and ignition systems. The trend toward fuel injection has been growing because of their inherently better fuel control. Under stead speed conditions expected with AHS, fuel-injection equipped vehicles should be able to achieve precise air/fuel control.

Precise injection timing may help reduce hydrocarbon emissions under steady-state conditions; an effective way to use *sequential fuel injection* is to optimize injection timing to occur while the intake valve is open. This can be accomplished by using aerated fuel injectors to eliminate the need to rely on evaporation and thereby allow direct injection of significantly less fuel into the combustion chamber. This technology will enable lower emissions and lower fuel consumption, especially under AHS conditions.

Improvements to the fuel control and ignition systems, such as increasing the ability to maintain a stoichiometric air/fuel ratio under all operating conditions and minimizing the occurrence of spark plug misfire, will result in better catalyst conversion efficiency and less opportunity for failure. As a result, under AHS conditions, catalyst conversion efficiencies could approach 100%.

3.4.1.3 Increased Vehicular Speeds

Increasing vehicle speeds for vehicles already traveling faster than 25 mph would have the effect of reducing both CO and HC emissions. However, current EPA models, based on the standardized driving cycle, indicate slight increases in NOx emissions at higher speeds (due to higher engine operating temperatures). A slight increase in NOx does not necessarily mean that the critical ozone levels would increase; the formulation of O3 in the atmosphere results from a complex set of chemical reactions, and it is possible that a large decrease in HC emissions would more than off-set a small increase in NOx emissions. Moreover, among the nation's non-attainment areas, there are those in which NOx is not one of the key precursors to ozone formation; in such areas, the projected reduction in hydrocarbons with AHS should improve air quality in any event.

However, a closer examination of the state of developing emissions technologies indicates that even in the rest of the non-attainment areas, NOx increases may not be expected with AHS. For one thing, the rhodium levels of many current vehicles are sufficient to enable achievement and maintenance of a 0.2 g/mi NOx standard in use, even without the application of advanced fuel controls and even under current transient speed conditions. Improved control of the air/fuel ratio at stoichiometric can also improve NOx emissions. But more importantly for AHS, technologies already available make it possible to lower emissions of CO, HC, and NOx at constant cruise conditions ranging between 50 and 70 mph to levels which should approach 0.0 grams per mile.

3.4.1.4 Vehicle Inspection Systems

An AHS system that includes inspection of vehicular emissions as a prerequisite for entering the system may restrict the system to vehicles that are either in good operating condition or are newer vehicles. This might reduce overall vehicular emissions because the vehicles traveling on the AHS would probably travel longer distances, and it would be beneficial to encourage the use of cleaner vehicles for longer trips. Moreover, a disproportionately high percentage of current emissions are produced by a small percentage of gross-polluting vehicles, or "super-emitters", including not only older models with less advanced emissions controls but also drivers with aggressive or high-speed driving patterns [Horan, ed., Workshop Proceedings, March 1993]. The existence of AHS, with its inherent, desirable advantages for drivers, should act as an incentive to reduce the number of super-emitters (both due to vehicle condition and driving pattern) among the nation's vehicle fleet as a whole. Moreover, emissions testing at AHS check-in (or at pre-qualifying licensing stations) may well result in quick correction of excessive emissions from vehicles that simply need a tune-up [IVHS America National Program Plan, Draft May 1994].

3.4.1.5 In-Car Air Quality Levels

Although vehicles may be bunched closer together while traveling at higher speeds on an AHS, and thereby result in higher in-vehicle air pollutant levels, this is offset by the fact that vehicles in corridors where AHS might be deployed are probably bunched even closer together while traveling at very low speeds under normal peak period driving conditions on non-AHS roadways and emitting, in general, higher pollutant levels.

3.4.1.6 Power Supply

Alternative propulsion for AHS has been examined in the Alternative Propulsion task in Volume VI. For the purposes of this air quality analysis, we have examined comparable technology -- that is, the internal combustion engine -- with and without AHS. The pollution reduction benefits of alternative fuels or alternative power sources are assumed to apply generally in proportion to AHS and non-AHS facilities.

However, it is worth noting here the benefits of vehicular propulsion power from a centralized location. Such a system could reduce emissions because centralized systems could be professionally maintained and have very effective pollution control equipment. Another benefit of a central power supply is that emissions could be released to the atmosphere from elevated stacks as opposed to near ground level, allowing for better atmospheric dispersion. A more complex issue pertains to the efficiency of a centralized power generating facility (with power losses through transmission lines) as compared with fueling motor vehicles through a network of gasoline stations (and the trucking network necessary to supply fuel to the gasoline stations). Finally, particulate control equipment at a centralized power station could be very efficient.

3.4.1.7 Vehicle Miles of Travel

The previously discussed reductions in vehicular emissions associated with AHS may be offset by an increase in emissions resulting from an increase in the region's vehicle miles of travel (VMT). This is because motorists might travel additional miles in order to use this system if it would reduce travel time. Travel time savings, indeed, might lead to more dispersed land use development and longer average trips. An efficient AHS might induce vehicular trips that might not otherwise be made -- or that otherwise might be made via public transportation (the Princeton research indicates that AHS is competitive with rail in certain corridors). On the other hand, AHS could be a tool for Transportation Demand Management (TDM) and a platform to support the integration of various policy instruments, including growth management, congestion pricing and the performance of public transit vehicles.

3.4.2 Noise

The relationship of noise to higher, more steady speeds depends on the distance from the roadway; the effects within 200 feet and beyond 200 feet are inverse. For the greater number of those affected beyond 200 feet, higher speeds mean higher noise levels.

This is an issue in urban areas, and it may be an issue in some sensitive rural areas. Increases in speed with AHS are only possible with RSCs involving infrastructure changes, at least exclusive lanes.

Noise impacts are location specific and are mitigatable. However, the most common form of roadway noise mitigation, noise barrier walls, are sometimes perceived as creating other problems: adverse visual impacts, community disruption.

3.4.3 Visual Impacts

Some schemes for RSCs involving higher levels of infrastructure improvements (I-3, and sometimes I-2) anticipate extensive use of flying access/egress ramps for entry-exit to the AHS. The visual impact of such improvements could be perceived as significant in many urban and suburban areas, as well as some scenic rural areas.

It may be important to recognize this issue early in the AHS development process by directing system designers to minimize the amount of "concrete" used in retrofitting existing facilities for AHS and finding creative solutions for merge/entry-exit and emergency vehicle and maintenance access that minimize the amount of space and concrete required. [As highway engineers have encountered sensitive visual areas in the past, they have had to seek more flexible, rather than the usual standards. With one of the advantages of AHS being the ability to move vehicles safely in a smaller space (both longitudinally and latitudinally), it may be incumbent on AHS designers to think beyond rigid, past Interstate highway standards (and, perhaps, think more of monorail or downtown people mover-type visual standards). Ironically, it may be easier to design separate AHS facilities (I-3, RSCs 8-13) so as to minimize visual impacts.

3.5 USER ACCEPTANCE

3.5.1 Public Acceptance and Education: Costs/Benefits

The issue here has been defined primarily from research into other previous comparable technologies. The lessons learned from the experience of introducing such new technologies in the past is that their benefits must be both convincingly quantified and visible.

One consumer benefit of AHS, driver comfort with a reduced need for manual intervention, will increase at higher Infrastructure levels (see the Comparable Systems Analysis of air traffic control in Volume 2 of this report).

AHS equipment must be priced in a range attractive to consumers (see comparable systems analysis of typewriters and automobile travel in general).

On the other hand, initial consumer investment in one technology may limit future technological changes. Consumers will seek to amortize their initial investments before buying something new, and manufacturers will turn to serving a proven market before aggressively pushing new products.

See also Task P: Preliminary Costs/Benefit Factors Analysis, Chapter 2 of this volume.

3.5.2 Public Acceptance and Education: Complexity

AHS-related equipment must be easy to use -- particularly while driving -- and to maintain. Use must be **less** complicated than programming a VCR (inability to program a VCR has no safety implications). The on-vehicle (driver-compartment) equipment operations issue may be addressed at the ITS level before becoming an issue for AHS.

3.5.3 Marketing

AHS must meet perceived needs or desires (see comparable systems analysis of typewriters, automobile travel, and the Interstate Highway System, among others).

Incremental development may be essential (witness the development of the automobile travel market itself), not only for consumer marketing but also for "selling" the benefits of AHS to potential state/local system developers/owners.

In this regard, the automation of the exclusive bus lane access to the Lincoln Tunnel, as described in appendix B, may be a candidate for an early demonstration of the benefits of AHS. The bus lane extends from and includes a portion of the New Jersey Turnpike and another access roadway plus a connecting roadway between these facilities and the tunnel. The connecting road ramps down to the toll plaza from the Palisade above. Traffic on the ramp in both directions currently has to deal with the hill, the curves, and the sun, and often moves slowly with substantial headway between vehicles. Nevertheless, the existing contraflow bus lane is the largest commuter line into New York City from the west, carrying 65,000 people a day.

With the reconstruction of both the lane and the Port Authority Bus Terminal in Manhattan needed to accommodate the new, wider buses required to serve the disabled, there would be an additional capacity for 450 more buses -- an additional 20,000 people. But these additional buses and the existing traffic still must cope with the ramp down to the toll plaza which inhibits the ability to maximize such a capacity increase. In such a corridor, it is difficult to envision a politically acceptable way to dedicate an existing lane for the faster movement of relatively privileged private vehicle drivers, and, in any case, it is not practical to move more private vehicles at higher speed into the congested streets of Manhattan. But an AHS for buses probably would be favorably received; an automated guidance system would increase safety, especially with the wider buses, and improve traffic flow -- and the dedicated lane already exists.

Field experience is necessary with new technologies to gain at least some understanding of the demand function and how it can be calibrated against price [Horan/Gifford, 1993]. Services that do not have a natural market, but do provide a public service, may have to be provided by government [Horan/Gifford, 1993].

Technical shortcomings or perceived shortcomings would inhibit initial marketability. It is important that early deployments establish its reliability. The impression that reliability is questionable would set back marketability materially.

US proponents can begin marketing efforts now by publicizing existing European guided bus technology, such as the M.A.N., Breda, and Volvo systems, and the Mercedes-Benz Channel tunnel system when it comes on line.

Design of entry-exit ramps (see 3.4.3 Visual Impacts) may be important to overcoming NIMBY opposition. Location of entry/exit ramps is directly related to market penetration.

One special target market may be elderly and disabled individuals. By the year 2020, 17% of the US population will be age 65 or older, and of these, more than half will be 75 or older. AHS may make safe vehicle operation possible for those whose advancing age or physical disabilities reduce driving abilities and interfere with safe and convenient use of public transportation [IVHS America National Program Plan, Draft May 1994].

It also will be important for AHS to consider all potential markets, including the less obvious (see comparable systems analysis of typewriters and automobile travel, among others).

Product (equipment) visual appearance (design) may be important to marketing success.

Above all, a long-term marketing commitment and persistence may be required.

3.5.4 Marketing AHS Products

A marketing/technical coordination function, similar to that employed for nearly all new computer products, may be appropriate in early stages of AHS development/deployment -- to interface among vehicle and potential equipment manufacturers, potential users, and AHS system owners/operators to assure technical compatibility and demand/need, and to reduce risk and perceived risk.

3.6 SOCIETAL

The environmental impacts of a program or project under US law also include their economic and social effects, including "community cohesion and the availability of public facilities and services; adverse employment effects...and disruption of desirable community and regional growth" (Title 23 of the US Code, Section 109(h)).

3.6.1 Social Equity

Social equity Impacts of AHS will vary by RSC and urban/suburban/rural deployment decisions and/or phasing. How the system is funded (see Task P: Preliminary Costs/Benefit Factors Analysis in this volume) is closely related to the issue of equity. To the extent that an AHS RSC is supported by an infrastructure paid for by public funds, the benefits and costs of that system must be equitably distributed throughout society [IVHS America National Program Plan, Draft May 1994].

As noted in appendix B, user fees could be set on a social cost basis, wherein each user is charged the full social cost of his/her use of the system, and there would be credits for the value of reduced congestion in the non-automated lanes and for reduced emissions. In the Lincoln Tunnel exclusive bus lane example, minimal charges to buses using the automated lane would reflect social cost considerations; in that case, the social benefits of getting drivers out of cars and into buses might be substantial enough to warrant full public subsidy. In the more likely common AHS scenario user fees would be set on a politically practical, case-by-case basis, but even such arrangements can be effective to the extent they build in some characteristics of social cost pricing.

Tolling of any kind, of course, means that only those who can afford the tolls would be able to use the AHS. Where new lanes can be financed and constructed in a non-traditional way, the equity issues may be manageable. Dedicating or replacing an existing lane would establish a priority for the relatively wealthy. This may only be acceptable if the benefits to those still on the non-automated highway/lanes (e.g., reduced congestion) were sufficient and appreciated.

Economic, environmental and equity considerations could more easily justify the dedication of existing lanes to buses. If the automated lane(s) were restricted to trucks, some of the equity issues would remain, but the people on the non-automated lanes would probably appreciate the benefit of reduced stress more.

3.6.2 Impacts on Land Use/Inner City/Local Economies

While not unique to AHS, AHS effects on land use could be as profound, if not more so, as those caused by the Interstate system and should be considered (perhaps as "goals" or "guidelines") in a development program for AHS (see comparable systems analysis of automobile travel and air traffic control).

As described by the Princeton researchers in appendix B, by reducing the time cost of travel, an AHS has the potential to significantly alter the current land use pattern. By reducing travel time per a given distance, AHS will reduce the demand for spatial proximity; in general, such changes tend to decentralize the locations of both residences and businesses.

In the short run, travel on an improved link of a network will reduce congestion and allow trips at more efficient speeds. In the long run, however, this advantage will dissipate, as more travelers choose the improved link, development occurs along that link, and locational changes induce longer and/or more frequent trips on the link. Reducing commuting times, for example, increases the incentive to live farther away from work and encourages the spatial segregation of home and work. Likewise, reductions in travel time or cost reduce the incentives for businesses to locate near input sources or markets, and may encourage them to seek lower-cost land on the fringes of urban areas.

Such effects, if substantial, are likely to adversely affect central cities and older, inner-ring suburbs, reducing their job and tax bases. To the extent that these areas are the residential locations for substantial numbers of the nation's more disadvantaged citizens, such land use changes are likely to be regressive in their impacts. In addition, the expansion of the suburban fringe is likely to have adverse environmental impacts on the undeveloped land outside the urbanized area. Of course, the magnitude of these effects depends on the degree of change in travel costs, but even a small change in the relative valuation of places can cause noticeable shifts in land use patterns.

On the other hand, the automation of bus access to the Lincoln Tunnel, one of the case studies examined by the Princeton researchers in appendix B, is likely to have relatively minor land use implications. There may be a shift in land-use patterns within the suburbs, with bus accessible locations gaining in value and density. Bus accessible suburbs in New Jersey would be expected to prosper modestly at the expense of Manhattan, New York suburbs, and other locations where automated bus service is unavailable. On the other hand, to the extent that tunnel congestion is a serious detriment to business operations and growth in Manhattan, automation of the exclusive bus lane could help the city to retain businesses and jobs that would otherwise be tempted to relocate to New Jersey.

Development principles for AHS might be drafted to include the principle that AHS and state, regional, and community land use planning work in harmony to support desirable development in sustainable locations served by other parts of the public infrastructure (public transportation, water, sewers, etc.), and aid in the retention of open space and prime agricultural land.

Geographically limited in their effect, but immediate land use and local economic effects will be realized by the choice of ramp locations for AHS, and also the resulting effects on other non-AHS ramps.

3.6.3 Public Health and Welfare: Magnetic Fields

As described in Volume VI of this report, the type and level of alternative propulsion methods that might be explored for use with AHS would not produce magnetic fields that might be considered a health risk. Nevertheless, there appears to be a growing public consciousness and fear of magnetic fields, so the perception of an issue will remain for an AHS that involves outside-the-vehicle electrical propulsion.

3.7 FUNDING AND FINANCIAL ANALYSIS

3.7.1 Introduction and General Principles

The challenge is to develop, deploy and maintain a system that is uniform, compatible, decentralized and multi-faceted in an environment shaped by numerous public jurisdictions and private sector interests. Similar to the strategy involved in developing an IVHS system nationwide, an organization such as an AHS America would probably have to be formed to deal with the numerous complex issues of policy and politics. Embodying the concept of public-private partnerships on a national basis will be an essential way of enabling all concerned parties to participate together in the deployment of the AHS system. There will be, of course, a multitude of mechanisms of public-private partnerships that are possible, feasible or even preferable. Many models or iterations may indeed contradict the cultural tradition of a strong separation of the public and private sectors. But as part of an overall strategic plan of action, public-private co-operation in delivery of systems and services will be essential.

The ITS community has approached the delivery of such systems in the United States by viewing the public sector as being responsible for the infrastructure components of the system, while the private sector will contract to supply whatever the public sector cannot provide. This approach will need to be carefully evaluated in the context of AHS. Certainly, the public sector is theoretically able to install and maintain an AHS system by using a combination of Federal Aid funds, other Federal demonstration moneys, state highway funds, state general funds and local government funds. The first order of business is to estimate the capital cost of installing a comprehensive AHS system on the nation's freeways and major urban arterials, and make sure that the costs include all of the system components, traffic surveillance and control costs, the costs of detection equipment, new signaling, freeway controls such as ramp metering and variable message signs, and so on.

But the current capacity of the public sector to fund an extensive system that will use a considerable percentage of existing Federal, state and local budgets has to be questioned. Implementing a nationwide AHS system involves not simply a large one-time capital cost. It requires years of research and development, early implementation and deployment activities. It will then entail years of ongoing maintenance, operations and periodic capital upgrading. There is no question that traditional public sector mechanisms cannot fund the full range of such activities alone. There is some question as to even whether they should. Alternatively, there are other funding mechanisms such as tax increment financing, transportation development districts, local option taxes, right-of-way donations, the awarding of concessions to deliver roadways (also known as the franchise approach or the public-private partnership model). Each approach has its pitfalls and limitations, as well as its advantages. Each approach has been applied to a variety of circumstances, often in concert with one another. Given the size and complexity of the AHS program undertaking, there will in all probability not be one single method for financing the system, but rather a preferred combination of methods that may work.

But clearly, as with ITS, the AHS program will have to marry both the traditional public sector and the private sector in a partnership that may rival in size and complexity the Interstate Highway program. And this will be consistent with the 1990 National Transportation Policy and ISTEA. Both policy developments and recent thinking recognize that the private sector can offer significant contributions to the provision of new highway capacity or the upgrading of existing facilities by increasing the pool of available financial, technical, entrepreneurial and operational resources. The ISTEA encouraged States to develop new cost-sharing partnerships with the private sector, and provided state and local governments with many new options to fund transportation. It encouraged the sorts of approaches now being tried successfully in several states whereby franchise agreements have been entered into between states and the private sector to finance, develop, build and operate new roads or improve existing highways. ISTEA also permits States, for the first time since the turn of the 20th Century, to use tolls as a supplement to conventional fuel and vehicle taxes on much of the Federal-Aid system. Thus, the policy environment and the need for additional capital to augment limited public resources has made public-private partnerships an attractive option for highway delivery.

Under such an approach, and following a competitive procurement phase whereby qualified private sector interests are solicited to propose on transportation projects conforming to applicable Federal, state and local laws, the relevant public sector agency grants an exclusive franchise to the winning firm, consortium of firms or group of private interests. The franchise authorizes the consortium to use the highway right of way, develop the system, be responsible for operations and maintenance, and, if necessary, collect tolls and raise revenues for the purpose of recovering its investment. Presumably, the right to use the right of way is conditional and limited to a specified time period, and will no doubt be subject to regulatory control and/or oversight to prevent monopoly power abuses or an abrogation of the responsibilities of the consortium.. Theoretically, the use of the right of way can be made available to anyone who is qualified and applies for such a right. Under the franchise approach, users may have to be charge for access to the system, with the risks of deployment and operation borne by the private operator seeking to develop the market for AHS services.

The public-private approach to infrastructure delivery is certainly not without precedent. It is the model of choice in many developing countries that do not have a viable government-funded transportation sector to speak of. It has been the model for many toll roads in France, Spain and Italy, where private operating companies are responsible for delivering high quality service on their toll facilities. Britain, Canada and Australia are embarking on such initiatives. In the United States, most if not all of the earliest roads built in the republic were privately owned and operated. In the modern era, private franchises have been awarded to consortia seeking to design, build and operate toll highways in Virginia and California. Washington state, Minnesota, Arizona, Georgia, Texas, Colorado and Florida all have privatization statues and have initiated public-private programs to enlist private capital in search of returns.

There will be numerous examples, models and motivations for public-private partnerships in AHS systems delivery. In such a framework, the private sector can bring about considerable technological expertise and efficiency advantages as a direct result of its role in other high technology programs. The private sector is much better able to take advantage of efficiencies in production and distribution. And as long as the private sector is efficiently regulated, without excess burdens imposed by government bureaucrats, the public interest can be protected and assured. Additionally, the private sector may be better able to take political heat from concerned parties when it comes time to market tolls or increases in toll rates, or indeed when inter-jurisdictional co-operation between public agencies is needed.

The private sector can participate in AHS system delivery by designing, installing and operating a system in a specified corridor. The right to develop and install such a system could be granted across several political jurisdictions or boundaries. There could be numerous public agencies involved in monitoring, regulating or otherwise overseeing the private operation. They could see to it that design, construction, and particularly maintenance standards are being met or complied with. Electronic toll collection and road pricing systems could be used to charge for the use of the privately supplied AHS system. Electronic toll and traffic management systems have been in use in densely traveled corridors throughout the US with success. Heavy Vehicle Electronic License Plate (HELP) technologies with single transponders can serve individual corridors. Toll revenues collected could be combined with and would directly retire the debt incurred by the private sector. Profit sharing or cost sharing allocation formulas can be developed to spread the benefits and costs of implementation.

The private sector can also participate by being directly responsible for traffic surveillance, traffic information systems, collection and dissemination of data and analysis. Privately funded and publicly regulated, these systems could use advanced sensors and communications equipment, combining ITS functions to reduce operating costs and maximize marketability and user acceptance. Private sector distribution and marketing skills will be brought to bear to educate potential users and train system operators. Private funding could be responsible for route guidance systems, which would benefit from reduced costs if public funding is available in addition.

Private toll road facilities, operated under concessions awarded by state highway agencies, could provide the basis for the operations of such AHS systems. And since the financial viability of the private toll facilities are completely dependent on the ability of the operators to assure their users that the quality of service on such roadways is high, private operators will be motivated to maintain their roadways and operate them at a high level of service. At the end of the concession period, ownership of the roadway would revert back to the relevant public agency. Alternatively, for the purpose of avoiding tort liability, the public highway agency could maintain ownership of the roadway at all times, with the private concessionaire responsible under the terms of a franchise agreement for maintenance, repair, and overall operations.

While the applicability of public-private partnerships in the highway transportation sector has been demonstrated effectively elsewhere in developed and developing countries, in the US during its early history, and more recently through the construction of several private toll roads (primarily the privately owned and operated Dulles-Leesburg Toll Road Extension in Virginia, and the privately financed SR-91 Express Lanes in Orange County, California), there are some issues and risks with this form of delivery. Public sector contracting and procurement traditions, customs and regulations make it difficult for private sector interests to incur the considerable risks of project development, principally the environmental permitting process, completely at its own risk with little or no reward until revenue operation. Private money is costly, limited and conditional. Private firms are less able and willing to deal with delays in start up, with environmental challenges or construction schedule changes in scope and cost.

Stringent regulatory control over the ability of private consortia to recover their investment through periodic toll increases may discourage private equity interest altogether. Concern over the monopoly power abuse of captive road users may lead to regulatory agencies limiting the rate of return on investment to levels that are not competitive with alternative investments that are not subject to such a substantial risk profile. The private sector may be concerned regarding standards on technology or systems, so that an initial investment in a particular AHS component technology may not pay off if an alternate is indeed chosen by the public regulatory body or by local political interests in general. There are risks in choosing a particular manufacturer of a system component too early on.

The legal liability risks of initial project development can be substantial. The most significant liability concern arises during the operations of the AHS roadway. Protection of a private firm's investment position by limiting public sector improvements to alternate non-AHS roadways may be required, and may prove politically unpopular. Public credit support, outright subsidy, or general participation in the cost of deployment of systems may prove difficult to achieve. Indeed, there could be existing state laws or limitations on using state credit support to privately sponsored essential-facility type projects. The public sector would be facing increased financial risk if subsidies and/or guarantees are offered to assist the private operators overcome the early hurdles in financing projects that require a considerable ramp up of traffic demand (and resultant toll revenues) to remain viable.

Most often, the private sector may have to deal with a multi-layered public sector, with approval processes spread over many jurisdictions. The opportunities to delay a project through the approval process, appropriations or the regulatory process may be far too numerous for the comfort of potential private sector electronics manufacturers. Recent private sector proposers of public-private transportation projects have found that there is no statute of limitations on the environmental clearance process. This means that barring the cost hurdle, there is no means of stopping a challenge to a completed environmental review even after revenue operations have commenced on a new highway project. Simply the fear of incurring costs associated with fighting such a challenge, however good the chances are of a win, are enough to lower the acceptable tolerance level of private proposers.

Finally, the multinational and multiplant automobile industry needs to co-ordinate its efforts and priorities, not an inconsiderable task. Indeed, even the co-operation of vehicle manufacturers may be a difficult proposition, particularly where manufacturers own subsidiary components suppliers and have a vested interest in promoting their own technology or vendor.

3.7.2 Lessons Learned from the Opportunities for the Private Sector in Deploying and Operating ITS Programs

A definite advantage to public-private partnership approaches to AHS deployment is that lessons can be drawn from the initial European and Japanese efforts to implement IVHS using such approaches. European efforts include the Dedicated Road Infrastructures for Vehicle Safety in Europe (DRIVE) program, and the Program for European Traffic with Highest Efficiency and Unprecedented Safety (PROMETHEUS), as well as the British Autoguide and Trafficmaster programs. The Japanese programs include the Road Automobile Communication System (RACS), Advanced Mobile Traffic Information and Communication System (AMTICS) and the Vehicle Information and Communication System (VICS).

Such programs involved the private sector in the earliest stages of project development, including concept definition and general idea forming, preliminary field trials and initial demonstrations. Private sector efficiencies in designs, system architecture and marketing know-how were exploited to maximum advantage. Private suppliers could respond to requests to provide specific supplies or services, or a combination of broad tasks. Firms were reimbursed for up to half of their research and development costs subject to negotiated rates. The programs often allowed private firms to retain their intellectual property rights. The programs also afforded private firms extensive opportunities to market their products in several countries, often with the support and encouragement of host nation ministries of transport. Several tax advantages were afforded non-reimbursed research and development costs incurred by private firms. With the Japanese programs, a large number of private sector firms worked together to develop standardized system components.

Based upon this and other experience with ITS and Advanced Traveler Information Systems (ATIS), several possible scenarios can emerge as implementation strategies. Under the public financing scenario, the public sector could assume the responsibility for overall research and development, testing, demonstration, design and deployment. Federal, state and local highway and traffic authorities would be involved, monitoring traffic for the purpose of traffic control and management, and disseminating traffic information to the public and perhaps to private subscribers. Electronic components would be the responsibility of private suppliers. Under the public-private scenario, the deployment of the AHS system would be a joint responsibility of the public and private sectors. Exclusive franchises of concession would be awarded to qualified private firms who would operate under regulated conditions. A variant of this approach would be a publicly owned system financed and deployed by government, who would specify performance characteristics and standards. Private contractors would then be offered the opportunity to bid for specific system components, or for combinations of tasks. Under a purely private scenario, right of way is procured entirely via private means, and the private firm is granted exclusive use of the roadway infrastructure as well as command and control operations. This last scenario is highly unlikely given public contracting and procurement regulations, public use laws, regulatory risk and, perhaps most importantly, legal liability issues.

To borrow some approaches from the European and Japanese IVHS programs, and from the early history of the work carried out in the US, a successful AHS program should:

(1) Start by forming a large industry trade group that includes stakeholders at the public policy level and private industry consortia interested in various activities, ranging from developing and installing system components to operating AHS corridors under franchise;

(2) Use non-traditional public and private sector funding of early research and deployment efforts, with a view of retaining intellectual property rights by pioneering private firms;

(3) Solicit innovative design, construction and operational advise from the private sector in numerous areas of interest;

(4) Provide a basis of understanding by framing initial research and development efforts;

(5) Move to rapidly establish codes of practice to address liability concerns;

(6) Consider public-private approaches to franchising operations. This could include both exclusive franchises (just as in the cable franchise awarded by state or local governments) or the non-exclusive franchise (an example being the cellular telephone system).

Whatever the ultimate structure is for funding an AHS system, it is clear that there will be important roles for a champion at the government agency level, overseeing the early program development, ensuring that performance goals are established and objectives met. The public sector can also substantially reduce costs by making roadways available for development of the AHS system. Right of way can be donated or leased. Dedicated roadway authorities can also administer tolls and other revenue raising measures such as dedicated taxes or assessments. It is the blending of mechanisms such as public sector involvement, tolls, private vendor financing and other private funding, that will fund the AHS system. No single source of funding will work. Rather, a combination of sources will be effective, and this will be the challenge of a public champion. Without this source of persuasion, it will be difficult to marshal inter-jurisdictional co-operation and ensure that the program will work.

3.7.3 Tolling Issues

A fundamental economic issue with any of the public-private approaches listed above concerns the willingness and the ability of potential users to pay user or access charges to gain access to an advanced highway system such as AHS. Clearly, if existing Federal, state and local budgets are not sufficient, will users be faced with access charges that are potentially unaffordable? Certainly, the cellular telephone market service faced a similar question when it was initially planned. Users are now more conditioned to paying access rates that were once deemed to be too excessive. Trafficmaster, a system financed entirely using private funds and costly venture capital, contains access charges that average around $25 a month. The issue is complex, of course. It will up to future researchers to investigate whether the total cost of accessing an AHS roadway (including the out-of-pocket costs of travel such as tolls, gasoline, etc.) as well as the cost of in-vehicle travel time will be less than the total costs of using general purpose roadways, since the time and convenience savings in using the AHS road may outweigh the toll rate or other user fee imposed on the marginal user.

Privately-supplied new roadway capacity will tend to incur higher tolls or access fees than similarly supplied public roadways, since private provision demands a return on its investment far more often than does a typical public authority. If toll rates are indeed viewed as too burdensome, or if there is public utility-type regulation of future toll levels rather than allowed rates of return (inhibiting a private operator from periodic increases in the access fee to protect his investment) private sector interests may even be dissuaded from proposing on such innovative projects. It is more than a coincidence that most of the recent examples of public-private initiatives in transportation (California, Arizona, and Washington state) have featured rate of return regulation rather than traditional public utility oversight and control. Indeed, it could be argued that the extent of competition for roadways is such that effective market power cannot be conferred easily on a private franchise holder of a roadway, with remarkably few exceptions. There is always competition for a tolled highway: namely, roads that are "free" or not priced at the point of use. With this element of operational risk, an issue that arises then is the appropriate or efficient form of economic regulation that is warranted.

The tolling issue is of course inane to the whole concept of value-for-money service brought about by the system. Value for money features include better scheduling of trips, more reliable commuting, more driver convenience when making trips, a better sense of safety on the road, a more advanced traffic information system, access to customized information tailored to specific types of road users or to specific roads or corridors, and even higher average speeds. The private sector is particularly able to gauge the reaction of the end user to such features and other niche market opportunities. Clearly, willingness to pay will also vary by location, type of trips, nature of users; there may even be seasonal or cyclical variations.

Another difficulty in forecasting willingness to pay is the obvious learning experience with any new system. That is, there will be numerous operational tests of AHS that will result in several applications offered by different industries. Firms will rise and fall based on the applications that are being implemented. All of this is an efficient process whereby a new industry is trying to determine the "best" package of applications for long-term operations. The prime example of this cyclical market-determining economic phasing lies with the trucking industry's experimentations with ITS. The trucking sector has gone through many iterations to come up with acceptable packages of services for trucking and fleet management. And this has been a tricky environment for gauging willingness to pay, despite the fact that the trucking industry is a true end user with an economic stake in such applications.

3.7.4 Evaluation of Specific Financing Sources

As the AHS stakeholder community examines its options for financing its programs, several reasonable alternatives loom and beckon. Clearly, the major source of funding will be Federal, state and local government resources, including either general obligation bonds or revenue bonds. But increasingly limited resources and continuing demands on infrastructure are leading to the development and utilization nationwide of a wide variety of new arrangements and procedures. This movement has changed the way we view highway transportation. Traditionally, highway transportation has been seen as a public service delivery for which the government taxed and provided the service for "free" to any and all users. Now, public demands for both new and maintaining existing highways have exceeded currently available resources, and in an atmosphere of competing public demands, the process of project selection and development becomes far less certain.

The current thinking at the national level, recently expounded upon at the Federal Highway Administration, is that highway transportation is also a service for which a reasonable fee can be charged: a toll for expedited transit. This change in view, from "freely" provided public service to user supported service, and the desire to further involve the private sector in this process, underlies all of the recent innovations in transportation policy and development nationwide. And, of course, this view is not new to the US The concept of linking direct use of highways to direct payment (and of aligning the costs and benefits of road use) has been the mainstay of classic economic theory. And more importantly, most if not all of the earliest roads developed in this country were toll roads, developed under a partnership between the public and the private sector.

Toll roads, whether developed publicly, jointly by public-private partnership, or by private means, are gaining acceptance as a means of achieving many goals. Toll roads could speed up project delivery, accelerate construction, be better maintained than their alternatives, and could free up otherwise scarce resources for other uses. Better maintenance translates directly into reduced vehicular operating costs, and this is particularly recognized by heavy goods vehicle operators. Toll roads are better patrolled and they are safe, recording fatality records that are less than one-third the national average. With some of the mechanisms now available under Federal law, toll revenues can be put to productive uses for an AHS transportation program.

A tolled AHS highway will be used, thus generating revenues to retire outstanding debt and defray ongoing expenses, if there is a willingness to pay its tolls, and this willingness arises out of a perception that the route will involve travel time savings, will allow higher average speeds, or will generally be associated with a higher quality of service than its alternatives. Direct revenues from the AHS tolls thus come only from the successful operation of the project. And this creates a powerful incentive for the AHS toll road operator, be it public, private, or jointly public-private, to assure that the higher quality of service is made available to potential and existing users.

Financing a start-up AHS roadway will require, however, a careful managing process. Today's lenders to toll road authorities (buyers of the authority's bonds) require a number of features to protect their investment. They will want to know (among other things): the project's cost; its environmental permitting and construction schedule; its potential for delay and overrun; its date certain delivery; all risks and pitfalls, particularly whether or not technological issues have been resolved elsewhere with operational AHS systems of the type considered for that corridor; the roadway's operational schedule and costs; an assessment of how willing potential users would be to pay for AHS services and features; and the terms of set or desired toll rate increases. In classic project finance, cash flow net of debt and ongoing expenses must always be positive, and the AHS project's ability to cover a multiple of debt and expense costs adhered to and monitored. With today's construction costs, right-of-way uncertainties and environmental challenges, given the special operational complexities posed by the introduction of a new technology such as AHS, and given the general reluctance to charge toll rates substantially higher than experienced on roadways elsewhere, it is more than likely that most new AHS roads will NOT be able to be self-financed.

The dependence on a single, projected revenue stream creates sufficient uncertainty with regards to construction, market and revenue risk that it is difficult to conceive of a completely non-recourse (i.e., fully self-financed) start-up facility. This is where access to other forms of credit are not only important, they are indispensable. Governments have, in the past, often supported toll roads by subsidizing them, or providing free or reduced-cost land, or even contributing some of their capital construction costs by outright cash, grants or loans. The market would seem ripe for start-up AHS roadways that have access to this or other forms of assistance from both the government and the private sector.

The recently enacted ISTEA legislation permits the commingling of Federal, state, toll-generated and private funds for the construction of new toll highways. Conceivably, a city can thus use general obligation bonds to partially fund right-of-way acquisition for a public-private tolled AHS road authority. The state department of transportation could maintain the system by utilizing state and/or local highway funds for this purpose. The road authority could issue revenue bonds to construct and operate the road. The state can lend money to the road authority, and this loan can be Federal-aid eligible, a reimbursable cost to the state in helping to finance the road. The state can thus use its remaining Federal allocation, all of which would otherwise have been dedicated to constructing the project, on other conventional highway projects (many of which are not suitable for tolling). Federal dollars could thus used as a "leverage" to build more transportation projects per dollar appropriated. The blending of credits, credit support mechanisms, the sharing of the risks of project development and of operational risk, are all trends in today's highway development.

Recent changes in the conditions at the marketplace, namely, the decline in tax-exempt borrowing rates, have rendered debt financing a cheaper alternative compared to before. There are strong advantages to the broad application of statewide loan revolving funds. And finally, the advent and successful implementation of electronic toll collection and advanced highway vehicle systems will have had important implications for operating AHS roadways once they are deployed. Electronic toll collection and traffic management systems render facilities more attractive to potential users and might reduce vehicular operating costs.

3.7.4.1 Recent Major Policy Developments Affecting AHS Roadway Toll Financing

In 1987, the Surface Transportation and Uniform Relocation Assistance Act included provisions for a toll road demonstration program under which Federal funds could be used to defray the costs of up to 35 percent of the construction or reconstruction of a toll highway, bridge or tunnel. This was the first time since the Federal Aid Highway Act of 1916 that Federal funds could be combined with toll funds on toll road projects, and is an important milestone. A total of nine projects were either initially proposed or later added under this program, in Pennsylvania, Florida, Texas, Delaware, Georgia, West Virginia, South Carolina, California and Colorado.

The pilot program has had mixed results. Progress has been stalled by environmental, political, legal and financial hurdles. To date none of the projects has proceeded into revenue operations, but two are in an advanced stage of development. The 6.5- mile Georgia 400 Parkway in Atlanta has just completed with its construction, and the San Joaquin Hills Transportation Corridor in California has recently commenced construction.

In 1990, a new national transportation policy was presented by the US Department of Transportation and endorsed by the President. The new policy recognized the constraints and challenges in providing financing for new highways and encouraged the concept of tolls. It also recommended relaxing the Federal constraints on toll facility developments. But the most important recent policy development that will no doubt affects future AHS toll road financing is, of course, the Intermodal Surface Transportation and Efficiency Act (ISTEA) of 1991, which extended the provisions of the 1987 demonstration program to all 50 states.

For the first time since the start of the Federal aid program (not counting the pilot program in 1987), states are allowed to use Federal funds in the form of loans or grants to create and finance public-private toll road entities. Such loans are "subordinate" or "junior" to other debt incurred by the facility, meaning that these loans get repaid only after any other loans are repaid, in the event of a default, except for loans made by the state or other public agency to that entity. The importance of a Federal loan appearing as junior, subordinated debt in a transportation project financing is that its presence signifies to private debt holders (holders of the "senior" debt issued) that they will get repaid first in the event of a default. This helps the marketability of the senior debt when it is placed in private capital markets. For example, the recently privately financed State Route 91 Express Lanes in Orange County, California, relied to a certain extent on a subordinated loan from the Orange County Transportation Authority. The junior loan signals a measure of confidence to the holders of the privately placed bonds that, despite the fact that the project relies on the security of projected cash flows resulting from collecting tolls during revenue operations, there is another credit bearing entity (in this case, the local government agency) that is foregoing its senior status in bond repayment so that the private bond holders would get repaid first in the event of a default.

ISTEA did not change the basic Federal-aid highway mechanism, since Federal aid is available to reimburse states for expenses they will make on eligible projects under Title 23 of the US Code. Rather, ISTEA expanded the types of expenses that are eligible for reimbursement (loans to a public or private toll entity are considered an eligible state expense), the types of projects that are eligible, and the identity of the facility owners. There is a five-year grace period on the repayment of loans to eligible entities (whether privately-owned, jointly public and private, or state-owned). All environmental permitting must be done before the loans are made available. Finally, an attractive provision is that these loans repaid to the state may continue to be recycled for other eligible transportation projects, thus establishing a state revolving fund for transportation.

Progress in implementing the flexibility provisions contained in ISTEA, i.e., the ability of states to mix Federal, toll-generated and private funds, has been slow. It is not a fully funded government program, authorizing many categories of activities but not appropriating the funds necessary to implement them. It is an optional, not a mandatory program, and many sections and provisions are arcane and confusing to those uninitiated with highway program legislation. And, various provisions are currently subject to a legislative-induced technical corrections process in Congress, all of which adds a certain element of uncertainty.

A full analysis of how and to what extent the many toll financing provisions contained in ISTEA will affect future AHS roadway financing is beyond the scope of this study. However, the implications of the new policy environment are important. Because ISTEA allows and encourages the commingling of Federal, state, private sector funds, and tolls where appropriate, the new law paves the way for significantly increased use of tolls and public-private partnerships as an AHS roadway development tool. There are new mechanisms for sharing the risks, responsibilities, as well as the rewards of project development with private sector interests such as AHS investors, construction firms, management and toll collection, and highway information technology companies. Under contracts, leases, and public-utility-type franchise agreements, such private entities may design, finance, build and operate new toll highway facilities, or participate in the repair or expansion of existing facilities.

The provisions for establishing public-private partnerships eligible for Federal-aid funding have important implications for possible AHS financing. To be eligible for Federal aid reimbursability, ISTEA requires that there be a contractual agreement negotiated between the state and the private entity proposing to develop the AHS facility. This agreement would include a description of the roles of the respective parties, would allocate responsibilities, and would contain details of the financial arrangements. ISTEA specifies only that the private developer/operator/sponsor is limited on his investment to a "reasonable return" on capital. But the agreement is critical--through it, the state exercises its responsibilities of complying with all applicable statutory requirements under Federal law, such as carrying out the environmental permitting and compliance process. All other terms of the contract are up to the state and the proposing parties. ISTEA does not specify any other eligibility requirements for the private partners.

3.7.4.2 How Public-Private Partnerships for Developing New AHS Roadways can be Structured

Public-private participation in developing new AHS roads could involve a public sponsor and a private partner willing and able to finance, build and operate (and possibly own outright) the road. There are several ways of doing this, and each potential project opportunity should be evaluated in a unique fashion. In general, every public-private partnership involves either the public agency sharing or the private sponsor solely responsible for the following project development activities:

a.Obtaining and supporting the financing for the project;

b.Directing and funding the planning, design, testing and construction activities;

c.Holding legal title to the system technology to be developed; and finally, d.Operating the system, collecting tolls, as well as distributing toll revenues.

Because privately operated AHS roadways would still be considered public use projects, the state or local government would regulate safety, policing, quality of service, toll rates and/or profits. State and local design standards, and other government procurement and fair wage practices may need to apply.

There are two basic types of public-private agreement. Under the "build-own-operate (BOO)" scenario, a private consortium agrees to finance, build, own, operate and collect toll revenues for access to the roadway for a limited period of time. This can happen if a private consortium agrees to buy an existing corridor from the government, and then expands or repairs it. For example, the Ambassador Bridge between the US and Canada is privately owned and operated. The Dulles-Leesburg Toll Road Extension planned for Loudoun County, Virginia, is another example of such a facility. Privately owned and operated, the new road is being financed through tolls and substantial private equity. All of the right-of-way is either donated or has been purchased in a piecemeal fashion by the project sponsor. All pre-construction development costs were paid by the owner.

The other basic type of public-private partnership arrangement involves a "build-operate-transfer (BOT)" or "build-transfer-operate (BTO)" scenario, differing only by the timing of the government's financial responsibility. Under either type of arrangement, a private consortium qualified by the government agency submits a competitive proposal and, if chosen, the consortium is allowed to proceed with negotiations that lead to the signing of a concession or franchise agreement. The concession agreement authorizes the private consortium to plan, design, finance, build, and operate an AHS roadway for a limited time period (usually 20 to 50 years). After this period, ownership of the facility is transferred to the sponsoring government free of charge (under the former or BOT scenario), or the transfer can occur right after the completion of construction (under the latter or BTO scenario). Under BTO, the private consortium leases the facility from the government, operates it, collects toll revenues sufficient to retire project debt and earn a "reasonable" return on investment, all after which ownership rights are passed back to the government. Technically, although the government usually "owns" the facility from the first day of operations, full financial responsibility remains with the private consortium.

The BTO scenario may be preferred to the BOT model when some form of government ownership of the facility is advantageous, and to ostensibly limit tort liability for the private consortia. Clearly, a government-owned project is covered under sovereign immunity laws for tort, and this will avoid exposing the private consortium to uninsurable risk during operations. The final important benefit of BTO is that, subject to certain conditions, it helps the private consortium avoid paying local property taxes on the facility (normal corporate income taxes, of course, still apply). The best examples of BTO projects in development are the four projects selected by the California Department of Transportation (CALTRANS) under the AB680 legislation. These will be reviewed in more detail below.

3.7.4.3 An Example of Enabling Legislation: AB680

Enacted in July 1989, California Assembly Bill No. 680 authorizes the state's Department of Transportation (CALTRANS) to enter into agreements with private entities to develop transportation facilities. The Act authorized up to four demonstration projects, at least one in the northern portion of state, one in the south. Ownership of each facility would be held by the state at all times, which is empowered to lease each facility to developers for up to 35 years. The private operators can set and collect tolls and retain toll revenues net of ongoing debt and expenses sufficient to produce a "reasonable return on investment." Toll revenues earned in excess of this amount must be used to retire project indebtedness or are to be returned to the state's highway fund. Projects developed conform with all applicable Federal, state and local standards and laws. The state may also use its eminent domain powers to acquire land, and may provide maintenance and policing services on a reimbursable basis. The state may lease to developers the development rights to the airspace on or adjacent to the highway facilities. Projects qualifying for the program have to supplement the existing non-tolled system of transportation.

Four projects were selected by CALTRANS in September 1990. Exclusive franchise agreements were signed for all four in December 1990. With one exception, all projects are currently in the process of obtaining environmental clearance. One project, the tolling of the median lanes of SR-91, has recently commenced construction.

While the initial record with the AB680 projects have been mixed, some useful lessons have been learned by both the project sponsor community (public and private) and by the public transportation sector itself. The better the project's inherent and underlying economics, the higher the degree of local public support, the easier the environmental process envisioned, the cheaper the right-of-way costs and the more able and committed is the private party, the more likely a project will succeed. And, significantly, the AB680 initiative would not have been launched without the presence of a single public sector champion, here in the form of Carl Williams at CALTRANS, who marshaled its progress, kept momentum going, met with interested parties as well as those who sought to derail the process, all while he was also briefing legislative officials and staff. Simply put, if there is no consensus built on such a program, it will not proceed beyond the planning stage.

3.7.5 Financing Options for AHS in General

There will be generally two major sources of funding for proposed AHS corridors:

1. Conventional financing sources, including Federal aid, special Federal demonstration funds or grants (such as the earmarked funds authorized but not appropriated under the ISTEA), state highway funds, tax-exempt bonds issued by the state (and backed up by either the full faith and credit of the state under a general obligation issue, or by user fees such as statewide sales taxes or tolls) and local or community highway funds. Given the reduced level of both Federal and state funds, and particularly given the significant amounts of capital required to deploy advanced system electronics, add travel lanes for several miles, deal with entry and exit accommodations, as well as ongoing maintenance and upkeep costs of the advanced roadway corridor, it is anticipated that additional sources of funding will be necessary. However, the major portion of the capital program costs will still have to be borne, in all likelihood, by conventional financing means.

2. So-called "innovative" or non-traditional financing sources, such as local option taxes (for example, dedicated motor fuel taxes), toll financing, special district assessments (for example, special districts supported by special assessments backed by tax-exempt bonds), impact or utility fees and public-private

partnerships can be used to complement traditional sources to finance the improvements.

The new paradigm of public-private partnerships in highway development, including joint development, private provision of toll facilities under franchise, road utility districts and traffic impact fees, is among the mechanisms that will be discussed in more detail below. Each of these approaches has been tried in various locations throughout the United States. Very rarely is one particular scheme implemented on its own. Rather, the usual case involves a commingling of several sources of funding, sometimes used in conjunction with traditional Federal/state aid.

3.7.5.1 Toll Financing

Toll financing can be publicly or privately administered or implemented, or it can be a combination of both. It involves collecting tolls and dedicating toll revenues to service bonds (debt) issued to pay for the construction and operation of a roadway. Recently constructed toll facilities (such as the E-470 Beltway in Denver, Colorado, and the Hardy Toll Road north of Houston, Texas) and facilities that are commencing construction (such as the San Joaquin Hills Transportation Corridor in Orange County, California) have required some degree of supplemental sources of funding to be financially viable (for example, donated right of way, dedicated developer fees, special district assessments, or public sector guarantees of toll revenues bonds). Many toll highways require long pay back periods.

The authority to develop toll highways is usually derived from state-enabling legislation. The state agency in question will then have the option of administering the tolls through a toll authority, and this alone may require some inter-jurisdictional co-operation, not an insignificant undertaking. Tolls can also be used effectively as traffic management devices, particularly with the possibility of affecting driver behavior during peak hours of use. Congestion pricing or time-of-day tolls are made even more possible with the technological advances afforded by electronic collection, but there remain the issues of enforcement, understandability, political acceptability, double taxation issues, or even the diversion of some traffic onto non-tolled, non-AHS routes or lanes, leading to traffic and safety concerns.

The evidence for toll financing historically is that it has been shown to work, and, because tolls link more closely highway usage to highway revenues, toll highways are often better maintained, have better incident management budgets, provide higher quality of service, have better landscaping, boast higher average speeds, and have better service establishments or rest areas than other highways.

The evidence against toll financing is often equally compelling. Toll revenues may not be sufficient, or may be subject to cyclical fluctuations. Toll rates necessary to finance a capital-intensive system such as AHS could be viewed by the more discretionary traveler as too excessive, leading to diversions or to discouraging some trips altogether, or by the more captive commuter as too burdensome. Toll rates that are more acceptable may not be adequate, from a revenue standpoint, to justify their implementation.

3.7.5.2 Local Option Taxes

These new taxes could be transportation user fees such as dedicated motor fuel taxes or special vehicle registration fees, the revenues from which could be used as a basis for a government agency issuing tax-exempt bonds, or they could be non-user taxes such as sales tax surcharges dedicated to finance AHS corridors. Local option taxes have been applied nationwide and require local legislative (county level) and/or electoral approval. In some cases, localities have enacted such taxes either through referendum or subject to county legislative approval. Tax surcharges are usually politically well received only when there is a perceived need on the part of the public for them. They also often incur substantial administrative and overhead costs.

Most of the counties in Florida have adopted a local option gas tax of up to seven cents, and this provides about one-half of county and one-third of municipal funds for highway improvements. Local option taxes pay for highway improvements in the state of Washington, in Orange County and Santa Clara County, California, throughout the state of Montana for all of its resort towns with populations less than 1,500, and elsewhere.

The concern with this form of financing is that local county-level sales taxes have been politically difficult to impose. For example, in the city of Phoenix, Arizona, the Maricopa Association of Government extended a half-penny increase in the county sales tax for two years. However, tax receipts have systematically declined since the beginning of the recent recession, leading to concerns regarding the adequacy of funding existing government programs (part of which included the local freeway network). While the fiscal solution may be to raise the tax rate while trying to achieve cost savings on the program improvements, social and community opposition to a tax increase has been perceived to be substantial. Therefore, portions of the freeway system may not even be built. The lesson from this particular local option tax as a funding source for AHS is that government agencies attempting to levy a surcharge on or raise a tax rate have discovered what a difficult political proposition those attempts entail.

3.7.5.3 Special District Assessments

Special district assessments are targeted taxes used solely to finance transportation facilities that provide specific local benefits. Owners of property who will benefit from the AHS corridor are assessed a charge to help defray portions of the costs of the system. The districts are specially delineated and supported by the assessment and backed by tax-exempt bonds to generate funds. There are hundreds of special service districts set up to enable localities to fund road projects.

Tax increment financing (TIF) is a form of dedicated property tax surcharge that is assessed only on new growth. The revenues resulting from the assessment are thus subject to the increase in the value of the land, and this may not even take place, rendering the revenue stream inadequate. Tax increment bonds with recourse to this source only, therefore, are not as secure as full faith and credit bonds.

Special assessment districts themselves are usually associated with relatively low administrative costs (except for the cost of issuing bonds) and are often reliable sources of funding. They have been implemented in many localities throughout the US, particularly in California. Pleasanton, California, has 19 separate special assessment districts, most of which finance a variety of highway improvements. The Route 28 Corridor in Loudoun and Fairfax Counties, Virginia, has been formed as a special district, with revenues dedicated to financing highway improvements (a two-lane highway to six-lanes with three interchanges). A special levy on commercial and industrial properties within the district provided 80 percent of the cost.

The issues associated with levying such district charges are delineation of the district boundaries, with disagreements between local town or village jurisdictions, the political problem of raising general property taxes, the adequacy of the revenues, the nature of the assessment itself (is the tax levied on a one-time basis, or is it one of a series of charges over some time period at intervals established by the enabling legislation?) and the degree of co-operation needed between the various agencies involved (the locality, the agency administering the highway improvement program, different forms of local government, the private developers and landowners, etc.).

3.7.5.4 Impact and Utility Fees

Impact and utility fees could be one of the institutionalized means of levying charges to offset a portion of the public cost of AHS roadways. They are usually one time fees that certain municipalities or other subdivisions can assess upon private developers. Assessed through the power derived from zoning and other enabling legislation, they are mandatory charges levied uniformly on new development, and can thus act as a way of controlling growth. Impact fees have to be structured carefully so that they do not inhibit growth, but rather so that growth is controlled.

Examples of impact fees are widespread. The Town of Hudson, New Hampshire, allocates developer contributions to fund highway improvements in three corridors. The Counties of Broward and Palm Beach in Florida levy traffic impact fees (typical fees in the latter were $1,650 per detached single family dwelling unit and $2.95 per square foot for a 50,000 square foot retail development) for the purpose of funding transportation plans. The City of Orlando, Florida, collects traffic impact fees, and these are based upon the expected number of daily vehicle trips per unit of development. Office space is levied a $2 per square foot charge.

3.7.5.5 Right of Way Donations

Developers of new or proposed property can often donate right-of-way to offset all or part of the local portion of a project's cost. Whether this is done in return for zoning variations for properties held by the developer elsewhere, or done because it is a good form of land banking to ensure that the land will be available when it is needed, it provides a reliable mechanism for funding portions of an AHS roadway's costs.

Examples of right-of-way donations abound. In Columbus, Ohio, a developer donated land and completed a new interchange at his own cost. Developer contributions were used in the Village of Tarrytown in Westchester County, New York, to widen Route 119 by up to four lanes. With the distinct possibility that smart roadways can be used as common carriers for several fee-paying activities (sharing the right-of-way with utilities, fiber optics companies, telecommunications companies, etc.), this source of funding can be considered quite substantial. Of course, there are restrictions on the use of right-of-way, and limitations on commercial applications of the real estate itself, but this is a viable source for future consideration.

3.7.5.6 Public-Private Partnerships

Public-private agreements can take on many forms, ranging from developer contributions of right-of-way, to private entities building and operating AHS roadways or portions of smart corridors, to outright private ownership of the roadway itself (selling off the public roadway to a private operator). The private entity usually recovers its investment by being allowed to impose charges and collect the resultant revenues. There are some obvious benefits to this type of mechanism.

Involving private capital in public AHS corridor development may mean that services can be performed faster, more efficiently, that the public cost of carrying out the program is reduced, or that additional public projects can be performed elsewhere for the same public dollar. Private involvement may bring the benefits of streamlined or innovative design to project development, all for the purpose of reducing overall cost. There are also problems with public-private partnerships. Despite the overwhelming experience with streamlined design-build approaches, private sector assumption of the risks of project development (particularly the up-front environmental permitting and approval process) has been subject to great uncertainty and risk, and has resulted in a great deal of unrealistic expectations on all sides. This has led to project delays, over-runs and a renewed mis-trust between otherwise amicable parties. Private sector funds are costly (carrying higher taxable capital cost requirements), and sources are less patient and less able to deal with administrative or program delay than the public sector. Very often, highway projects are not adequately profitable on a toll basis to be able to entice private sector interest.

4.0 CONCLUSIONS/KEY FINDINGS

A summary of the potential funding sources for an AHS is shown in table 1-2.

4.1 SUMMARY OF ISSUES

Table 1-3 presents an overall summary of the issues, concerns, risks, and conclusions forsections 3.2 through 3.6. Table 1-4 presents issues related to public/private ownership.

Table 1-2. AHS Characteristics of Poential Funding Sources

Revenue Source	Volatility	Reliability	Political Acceptability	One-Time vs. Periodic Payments	Private vs. Public Source	Revenue Potential
Tolls	Medium	High	Mixed	Periodic	Private	High (if demand is high)
Concessions	Low	High	High	Periodic	Private	High (if demand is high)
Real Estate Development						
Assessments	High	Low	Possible	Periodic	Public	High (if demand is high)
Impact Fees	High	Low	Possible	One-Time	Public	Low
Zoning Allowances	High	High	High	One-Time	Public	Low
Joint Development	High	High	High	One-Time	Private	High
Sale of Development Rights	Low	High	High	Either	Private	High
Lease of R.O.W. Access	Low	High	High	Periodic	Private	High
Sale of R.O.W. Rights	Low	Low	High	Either	Private	High
Dedicated Tax Revenues						
Tax Increment Financing	High	Low	Low	Periodic	Public	Medium
Gas Tax	Medium	High	Low	Periodic	Public	High
Sales Tax	High	Low	Low	Periodic	Public	High
Fed/State/Local Funds	Low	High (if known)	High	Periodic	Public	High
Employee Head Tax/Income Tax	High	High	Low	Periodic	Public	High
Cost Reduction Measures						
Donated R.O.W.	Low	High	High	One-Time	Private	High
Vendor Financing	Low	High	High	One-Time	Private	High

Table 1-3. Summary of Issues, Concerns, Risks, and Conclusions

Issue No.	Item Type	Description	Conclusions/Findings/Risks	RSC Impact	Task Impact	Section Ref.
1	Issue	Coordinating Multiple Jurisdictions: AHS deployment can involve multiple agencies; funding can involve multiple political bodies -- all with disparate views and interests	Fewer jurisdictions will mean fewer coordination problems for early deployments. Political nature of intergovernmental processes may mean additional costs for AHS projects. USDOT programs are identifying key elements in coordinating such complex programs through case studies and operational tests.	all RSCs	A, F, H, I, P	3.2.1
2	Issue	Multi-jurisdictional regulations and requirements: Conflicting or overlapping requirements can retard AHS deployment	Several non-AHS regional transportation management efforts are underway that may provide role models. ISTEA could be amended to allow interstate compact authority to conform conflicting, overlapping requirements for regional implementations	all RSCs	F	3.2.2
3	Issue	Responsiblity for AHS development: State DOTs have been key to development of national highway system to date. Are DOTs able to handle complexities of AHS deployments?	There is institutional and electorate resistance to creating new organizations. (Refer also to private sector participation issues.)	3-13	H, P	3.2.3
4	Issue	Guideway ownership/operation	Title to all/part of existing r-o-w could be transferred; owning jurisdiction could operate and maintain or contract out. Greater outside-vehicle command and control and electrified guideway increase difficulty of finding qualified, competent, interested operator. Local government budget, staff shortfalls and limited technical expertise may influence choice; loss of trained personnel to private sector is related concern (see Task K). Ownership of initial test vehicle fleet is related issue.	5-7, 9-11, and especially 12, 13	K, M	3.2.4

Table 1-3. Summary of Issues, Concerns, Risks, and Conclusions (continued)

Issue No.	Item Type	Description	Conclusions/Findings/Risks	RSC Impact	Task Impact	Section Ref.
5	Issue	Credibility/Acceptability of non-Governmental Ownership/ operation. What are public expectations? Are there different roles for different sectors at different stages? What is ability to "hand off" between sectors between stages?	Public expectations from private or quasi-governmental service providers are higher, but public has demonstrated willingness (or at least acquiescence) to paying more for higher level service. Understanding of viable models for private sector involvement is needed. Current case studies of partnering options and operational tests of early ITS deployments will aid in understanding obstacles to partnership development, coordination, key elements of successful partnerships, available conflict resolution measures.	3-13	H, K, P	3.2.5.1
6	Issue	Private sector access to/ownership in public assets	California's recent development process for new toll roads to be constructed -- and to an extent owned -- by private sector may offer role models	3-13	H, P	3.2.5.2
7	Issue	Definition of public-private partnerships for AHS	Methods by which public-private partnerships should be encouraged to develop AHS are unprecedented (possible exception: see above). Applicability/unsuitability of existing procurement rules is factor not conducive to private sector participation.	all RSCs	P	3.2.5.3
8	Issue	Prohibitive regulations: direct pro-hibitions against private sector participation in development of public facilities in some areas and un-intended side effects of regulations adopted for other purposes	Latter half of issue is recurrent problem with new technology. Direct prohibitions may be project-specific issue.	5-7, 9-13	P	3.2.5.4
9	Issue Conclusion	Project uncertainties and delays	Fear of changes and vagaries in government commitment to new programs/projects (e.g., SST, SSC) increase cost of development and put initial investments at risk, discouraging private sector participation. Early planning for AHS should take into account need to retain private sector interests and minimize delay-based costs.	all RSCs	P	3.2.5.5

Table 1-3. Summary of Issues, Concerns, Risks, and Conclusions (continued)

Issue No.	Item Type	Description	Conclusions/Findings/Risks	RSC Impact	Task Impact	Section Ref.
10	Issue Concern	Tort and product liability: migration of control away from vehicle operator may alter fundamentals underlying liability case law; greater liability could shift to infrastructure and equipment suppliers. Other liability issues associated with AHS are vehicle, roadway complexity, increased component reliability required. Such liability is deterrent to private sector participation (and reduces competition), cost exposure discourages market leadership and increases cost.	There is a considerable variety of possible approaches to resolving this issue through changes to state/federal law, creative regulatory approaches, insurance industry involvement, etc. Some efforts at tort reform are already underway (unrelated to ITS/AHS)	Increases at higher levels of command and control; greatest with 12, 13	P (related to B, C, D,E, H, J, K, N)	3.3.1
11	Issue	Privacy: safeguards on collection, use, control of data are important to public acceptance and support, and to addressing legal concerns	ITS Information Privacy Principles may help	all RSCs	P	3.3.2
12	Issue	Intellectual Property: private sector concerns can impede AHS development; federal government frequently retains broad rights; state/local laws also involved.	Contract negotiations, and flexibility in those negotiations may be key. Documenting successfully-negotiated clauses may help future negotiations, and allay private sector fears. AHS effort may address as early as selection, contract negotiation with consortium.	all RSCs	H, P	3.3.3
13	Issue Conclusion	Antitrust	Although raised early in ITS/AHS process, may be more a problem of perception than issue: federal law limits antitrust liability for research and development.	all RSCs	H, P	3.3.4
14	Issue	Cost accounting, cost certification, auditing requirements: complex requirements increase costs and reduce competitors	Potential resolution includes minimizing application of regs to AHS, training, centralizaing decision-making in federal govt. as to required information, increasing uniformity of applicable accounting rules -- of which most important may be information dissemination and training.	all RSCs	none	3.3.5.1

Table 1-3. Summary of Issues, Concerns, Risks, and Conclusions (continued)

Issue No.	Item Type	Description	Conclusions/Findings/Risks	RSC Impact	Task Impact	Section Ref.
15	Issue	Inexperience with high technology procurements could result in less effective competition for production of AHS products	Obscure government contracting laws make it difficult for inexperienced would-be vendors; private sector participants experienced with one federal agency (e.g., Defense) may not be familiar with FHWA and state procurements. Resolution could be through training.	3-13	H, P	3.3.5.2
16	Issue	Organizational Conflict of Interest limitations at all levels of government may limit participation by companies in both design and building of AHS	Applicability of these rules should be evaluated for their suitability to high performance procurements.	all RSCs	none	3.3.5.3
17	Issue Concern Conclusion	Air Quality (and fuel use/conservation): Clean Air Act basically prohibits transportation programs that contribute to pollution in non-attainment areas. ISTEA emphasizes planning to take into account air quality concerns. Relationships between emissions and potential effects of AHS are several.	AHS is likely to have a beneficial effect on three major pollutants: CO, HC, NOx. Effect of AHS on VMT, and induced demand, remain unresolved.	all RSCs	A, H, I, L, M	3.4.1
18	Issue	Noise	Noise impacts are location-specific & mitigatable, although common form of roadway mitigation sometimes perceived as creating other problems.	3-13	A, H	3.4.2
19	Issue	Visual impacts of extensively modified infrastructure may be adverse	Recognition of issue should lead to direction of system designers to minimize visual impacts. Ironically, it may be easier to design visually acceptable separate AHS facilities than retrofitted roadways.	3-13	A, H	3.4.3
20	Issue	Public acceptance and education: the individual's costs/benefits.	Lessons learned from previous, comparable technologies is that benefits must be convincingly quantified and visible. Initial consumer investment may limit future technological changes.	all RSCs	H, P	3.5.1

Table 1-3. Summary of Issues, Concerns, Risks, and Conclusions (continued)

Issue No.	Item Type	Description	Conclusions/Findings/Risks	RSC Impact	Task Impact	Section Ref.
21	Issue	Public acceptance and education: complexity	AHS-related equipment must be easy to use -- particularly while driving -- and to maintain. On-vehicle driver-compartment equipment operations issue may be addressed at ITS level first.	all RSCs, but issue may decrease in im-portance with greater outside-the-vehicle command and control	H	3.5.2
22	Issue Concern	Marketing	AHS must meet perceived needs or desires. Incremental development may be essential. Field experience is neccesary to gain understanding of demand function, and subsequently price. Early deployments must establish reliability. Publicizing existing European guided bus technology can be first step in marketing. Services that do not have a natural market, but do provide public service, may have to be provided by government. Design, location of entry-exist ramps will affect marketability, as will design of AHS equipment. One special market may be elderly, disabled. Long-term marketing commitment and persistence may be essential.	all RSCs	H	3.5.3
23	Issue	Marketing AHS products	A marketing/technical coordination function, similar to those common to computer industry, may be appropriate in AHS deployment to assure technical compatibility and reduce risk/perceived risk.	all RSCs	H	3.5.4

Table 1-3. Summary of Issues, Concerns, Risks, and Conclusions (continued)

Issue No.	Item Type	Description	Conclusions/Findings/Risks	RSC Impact	Task Impact	Section Ref.
24	Issue	Social equity	Varies by RSC and location. How the system is funded is closely related to equity issue.	3-13	H, P	3.6.1
25	Issue Concern	Impacts on land use, inner city, local economies	AHS effects on land use may be as profound, if not more so, than those caused by construction of Interstate system. Reducing time costs of travel will tend to decentralize locations of both residence and business. Reduced congestion may be temporal. Such effects, if substantial, are likely to adversely affect central cities and inner-ring suburbs, reducing their job and tax bases. Expansion of suburban fringe likely to have adverse environmental impacts. Development principles might be drafted to reflect desire to support land use planning goals, and support sustainable development, aid in the retention of open space. Site specific impacts will be result of ramp location decisions.	all RSCs to the extent that initial deploy-ment leads to greater levels of infra-structure deploy-ment	H, P	3.6.2
26	Issue	Magnetic fields	Task M (Vol. 6) indicates that type and level of alternative propulsion methods for AHS would not produce magnetic fields that might be considered a health risk. Perception issue may remain for an AHS that involves outside-the-vehicle electrical propulsion.	14	M, H	3.6.3

Table 1-4 Public-Private Ownership/Development Issues

Advantages
• Supplements limited public financing
• Can speed up construction schedule
• Can make construction more efficient (cheaper)
• May force a reliance on user charges for financing, which may be more equitable than public subsidies from general revenues
• Government can avoid construction cost risk and market risk
Potential Problems
• Differences in state legal and institutional frameworks would necessitate the development of varying public/private partnerships for each state. This could cause complications, including: - Difficulty in establishing uniform standards for AHS - Delays in constructing inter-state routes - Problems with varying maximum vehicle weights by state (as with current situation) - Complicated funding process, requiring increased oversight personnel or a long approval process
• Decreased local control/public input in: - Planning and implementation of AHS - Setting toll rates and schedules - Operations and maintenance of roadway - Setting vehicle size/weight restrictions
• Difficulty in assembling Right-Of-Way (private developers do not have power of condemnation)
• Potential political problems from Labor, which would be concerned about private labor hiring and compensation practices
• Liability issues could drive potential investors away
• Inability to use tax-exempt financing (bonds) could reduce benefit of using private investors - This problem could be eliminated through federal legislation
• Potential political problems resulting from use of private developers (disagreements over compensation, the setting of toll rates, any land grants made to the developer, conflicts in the planning or permitting process, etc.)
Toll-Related Issues
• Control of setting tolls
• Would private developers be allowed ownership of publicly-built routes with no nearby parallel routes - If so, political/legal problems would arise from potential users who wished to avoid tolls or to avoid the expense of equipping their vehicles for AHS
• Would private/public partnerships be arranged for whole regions, or one road segment at a time - If one segment at a time, then the heavily used routes or routes (described above) with no parallel non-AHS equivalents would be more attractive to private developers, leaving the remaining routes for the public sector to develop.
• Tolls, which would have to be very high to cover large cost of system, might discourage potential users, and decrease the overall social/economic benefits of system

4.2 KEY FINDINGS

(1) Perhaps, the most important finding of this task is that there are ***likely to be no insurmountable institutional and societal barriers -- show stoppers -- to the evolutionary deployment of AHS.*** This does not mean that surmounting some barriers will necessarily be easy. There is much to do before AHS deployments -- beyond initial test sites -- is feasible.

This finding itself rests on two of the earliest conclusions of this research effort:

(2) ***Institutional and societal issues and risks vary enormously depending on the RSC to be deployed;***

and an important conclusion that seemed a bit daring when we first stated it early in the year, but which came be accepted with a surprising near-unanimity as of the conclusion of the April 1994 Interim Results Workshop, that
(3) Based on an analysis of the history of the introduction and acceptance of comparable, earlier technologies; the likely availability of funding, and the need to resolve <u>some</u> institutional and societal barriers incrementally as part of the process of deploying ITS technologies -- even before AHS -- ***AHS must develop evolutionarily from less infrastructure and outside-the-driver command and control technologies to more infrastructure dependent/greater outside command and control technologies***.

Additional findings include:

(4) Beyond confirming early (pre-PSA) predictions that AHS would be expected to provide air quality benefits -- based on the assumption that carbon monoxide would be reduced simply because vehicles would move more consistently at higher speeds -- ***it is likely that AHS will provide air quality benefits not only by reducing CO emissions, but also by reducing <u>both</u> the hydrocarbons and nitrogen oxides that create the more serious air quality problem of ground-level ozone***.

(5) ***Many institutional/societal issues that arise in connection with AHS are not unique to AHS, but rather, related to any plans to build roads today or in the future.*** The AHS effort cannot be expected to address, let alone resolve, all of these larger societal and historical issues. On the other hand, these issues can become barriers to the deployment of AHS. And to the extent that AHS may accentuate the effects of how some of these issues are perceived, for example, urban sprawl, the AHS effort must be aware of its place in this larger context of institutional and societal issues and be prepared to address such issues in its deployments.

(6) ***The awareness that AHS is likely to evolve evolutionarily from ITS technologies and that the ITS effort is addressing many of the same institutional and societal issues does not mean that all of these issues will be resolved through the ITS deployment process prior to the time when it is technologically feasible to deploy AHS.*** Nor can the AHS effort expect that even those institutional and societal issues that are "resolved" in the process of deploying ITS will necessarily simply "go away" for AHS. Moreover, there are institutional and societal issues that are likely to arise specifically with AHS, as opposed to ITS, technologies.

(7) ***If the AHS technology is not generally available at modest cost, there are important equity issues involved in reserving or constructing a lane for the use of relatively wealthy private vehicle owners***.

(8) The AHS effort must play "catch-up" with the long-term state and regional transportation planning already well underway in response to previous state and Federal mandates and the more recent 1990 amendments to the Clean Air Act and 1991 Intermodal Surface Transportation Efficiency Act (ISTEA). ***Transportation plans for the next 20 years in congested areas in many cases are looking to rail projects to address many of the same transportation issues that an AHS might conceivably address***.

(9) Application of the technology to a mode of transportation that serves moderate-income commuters in an existing, heavily used corridor under the institutional jurisdiction of relatively few actors provides the kind of setting that could allow an early AHS success. AHS proponents must focus on both short-term and long-term opportunities by being aware that it is the institutional and societal milieu that determines if, when and where new technologies such as AHS will be deployed and being prepared to:

- ***Maximize the use or imminent improvement of existing facilities to demonstrate the benefits of AHS, even, or perhaps particularly, when the technology is used exclusively for non-personal vehicles, and that such an early win opportunity may be represented by the desirability of automating the existing Lincoln Tunnel exclusive bus lane in New Jersey***, and

- ***Support the development of non-AHS facilities where there may be a good opportunity for later conversion to automation***.

4.3 RECOMMENDATIONS FOR FURTHER RESEARCH

The following recommendations are derived primarily from the Technical Discussion of AHS issues and risks contained in section 3.0. The need for additional research during the next, consortium phase of the AHS process proceeds directly from the issue identification and definition during this PSA phase. Moreover, the PSA phase has seen the "weeding out" of issues, as they have been defined, addressed, or partially if not fully resolved during this phase -- either through the PSA effort itself or through the concurrent ITS effort. That leaves the most intractable issues, those not likely to be resolved through the ITS deployment process by the time it is technologically feasible to deploy AHS, those not yet being addressed because they do not arise with other ITS technologies, and special challenges to AHS deployment as the general categories of issues for which further research is appropriate.

(1) Liability is likely to remain a significant issue for AHS. Early conclusions of the ITS process regarding non-AHS technologies are that liability may not be as significant an issue as originally anticipated. However, these conclusions do not apply to AHS, in which the migration of control functions away from the vehicle owner/operator may alter fundamental relationships upon which the existing body of tort liability law related to vehicle use has been developed. The potential for large AHS product liability claims threatens the financial viability of AHS deployment. Several potential approaches toward addressing this issue are suggested in section 3.0 of this chapter. Further research into the most viable of these approaches for resolving this issue should be conducted during the consortium phase of the AHS process.

(2) The most serious and pressing of the environmental issues, which further research may help address if not resolve, are a) the extent to which AHS will

induce demand for additional trips and for trips by low-occupancy vehicles that might otherwise be made by public transportation, and b) the extent to which AHS will encourage trips of greater distance -- increased VMT -- to take advantage of time savings.

(3) Experience with the introduction of other technologies is that the issues of public education and acceptance must be addressed anew by each new technology. Further research into this issue during the consortium phase may help prepare for addressing these issues beyond the initial AHS deployment. Indeed, anticipation and preparation now should guide how any initial test deployments are structured, how their expectations are defined, and how their results are interpreted and disseminated.

(4) Each one of the potential sources of funding should be analyzed in more detail in the context of the next planning and preliminary design and implementation phase of the AHS program.. How much revenue can be raised with each type? Are the sources of revenue reliable? Are receipts subject to cyclical fluctuations? What administrative issues are involved? Can the mechanism be managed effectively? By what agency? Is the mechanism practical? Who oversees the collection of revenues? What are the tax implications of assessments in special districts for property owners? What changes in existing legislation are needed to implement some of these options, or what new legislation is required? How politically acceptable are some options?

(5) While the AHS and ITS efforts have done an admirable job of attempting to engage the broadest range of stakeholders in the conception of the technology as well as the definition and resolution of issues, AHS in particular has yet to define itself in such a way as to attract strong advocacy from stakeholder groups. Beyond additional research into those potential applications of AHS technology that would be of particular interest to previously-identified potential stakeholder groups, for example, public transit and commercial vehicle operations, as well as State DOTs and vehicle manufacturers, the AHS effort might address itself to the needs and concerns of potential stakeholders whose interests have not yet been identified. One research effort, for example, might focus on how AHS might be used to improve local control of traffic and improve community livability. Platooning of vehicles between signals, or detection and reduction of impaired drivers (through illness or substance-abuse), might be attractive aspects of such research from the viewpoint of local communities.

APPENDIX A: TECHNOLOGICAL DEVELOPMENTS WHICH SHOULD LOWER EMISSIONS FROM VEHICLES ON AUTOMATED HIGHWAY SYSTEMS

1.0 INTRODUCTION

Virtually all current vehicles utilize the following emission control technology:

- Closed loop, single bed three-way catalysts
- Fuel injection, usually multipoint fuel injection
- No secondary air

In order to meet the 1990 Clean Air Act Federal standards, and to remain competitive with regard to performance, manufacturers are likely to utilize:

- Improved catalyst formulations with higher noble metal loadings
- Sequential multipoint fuel injection
- Direct-fire ignition systems

The latter two technologies allow more careful control of air-fuel ratio and spark timing, relative to current technology. Improvements to catalyst formulations coupled with reduction in gasoline contaminants such as sulfur and lead, and reduction in oil additive-based contaminants such as phosphorous will lead to reductions in catalyst deterioration, the principal cause of emissions deterioration of well-maintained cars. In addition, advanced electronic controls and On Board Diagnostics (OBD) should reduce production line variability and assist in improving in-use durability.

Starting in 1994, this year, California has proposed four separate standards for Transitional Low Emissions Vehicles (TLEVs), Low Emissions Vehicles (LEVs), Ultra Low Emissions Vehicles (ULEVs), and Zero Emissions Vehicles (ZEVs)[1]. Manufacturers may certify portions of their fleet to any one of those standards to meet a combined HC standard that decreases from 0.25 g/mi in 1994 to 0.062 g/mi in 2003.

California has also mandated a minimum sales requirement for ZEVs so that sales for each manufacturer are 2 percent of its fleet in 1998, increasing to 10 percent by 2003. These regulations apply to all cars and light-duty trucks. Medium-duty trucks (defined by California as

[1] In the short term, these are expected to be electric cars.

6000 to 8500 lb GVW) have different numerical emissions standards but a similar requirement that is phased in starting in 1998. No ZEVs are required in this segment.

It should be noted that future vehicles will be certified on reformulated gasoline with a lower RVP than current certification fuel (Indolene). Hence some of the emission reduction is associated with the fuel, which we have assumed will contain 2% oxygen and have an RVP of 7.8 psi.

While these current and emerging technologies should reduce emissions under all operating conditions, they are ideally suited to careful, precise control of emissions and fuel consumption under virtually any standardized condition or distinct series of conditions. At steady speed conditions, especially, the vehicle's computer can easily be programmed to achieve the optimal combination of air fuel mixture, spark timing, exhaust gas recirculation flow rate, etc to minimize engine out emissions. Further, without he complications of accelerations and decelerations, the chemistry and physical environment of the catalyst can also be optimized to both maximize conversion efficiency of all three pollutants, CO, HC and NOx, as well as minimize deterioration over time.

2.0 TECHNOLOGY OVERVIEW

The level of tailpipe emissions from modern vehicles is primarily a function of the engine-out emissions and the overall conversion efficiency of the catalyst, both of which are highly dependent on proper function of the fuel and ignition systems. A fairly comprehensive system has evolved. There are many technological improvements, which are currently becoming widespread or are on the horizon, that make more stringent control of emissions feasible.

First is the trend toward increased use of fuel injection. Fuel injection has several distinct advantages over carburetion as a fuel control system -- more precise control of fuel metering, better compatibility with digital electronics, better fuel economy, and better cold-start function. Fuel metering precision is important in maintaining a stoichiometric air/fuel ratio for efficient three-way catalyst operation. Efficient catalyst operation, in turn, can reduce the need for dual-bed catalysts, air injection, and exhaust gas recirculation (EGR). Better driveability from fuel injection has been a motivating force for the trend to convert engines from carburetion to fuel injection. In fact, it has been projected that the percentage of new California light-duty vehicles with fuel-injection will reach 95% by the early 1990's, with 70% being multi-point. Because of the inherently better fuel control provided by fuel-injection systems, this trend is highly consistent with more stringent emissions standards. Under steady speeds expected with AHS, they should be able to provide precise air - fuel (A/F) control.

Fuel injection's compatibility with onboard electronic controls enhances fuel metering precision, and also gives manufacturers the ability to integrate fuel control and emissions control systems into an overall engine management system. This permits early detection and diagnosis of malfunctions, automatic compensation for altitude, and to some degree, adjustments for normal wear. Carburetor choke valves, long considered a target for maladjustment and tampering, are replaced by more reliable cold-start enrichment systems in fuel-injected vehicles.

Closed-loop feedback systems are critical to maintain good fuel control, although when they fail emissions can increase significantly. In fact, the California Air Resources Board (CARB) in-use surveillance data show that failure of components in the closed-loop system frequently has been associated with high emissions. The CARB's new requirement for onboard diagnostics which will also apply in the other 49 states after 1996 will enable the system to alert the driver when something is wrong with the emission control system and will help the mechanic to identify the malfunctioning component.

Second, improvements to the fuel control and ignition systems, such as increasing the ability to maintain a stoichiometric air/fuel ratio under all operating conditions and minimizing the occurrence of spark plug misfire, will result in better overall catalyst conversion efficiency and less opportunity for catastrophic failure. These improvements, therefore, have a twofold effect: 1) limiting the extra engine-out emissions that would be generated by malfunctions, and 2) helping to keep the catalyst in good working condition. As a result, under AHS conditions, catalyst conversion efficiencies could approach 100%.

Third, a trend that bodes well for catalyst deterioration rates (and therefore in-use emissions) is EPA's lead phaseout, which reduced the lead content of leaded gasoline by about 90% (to 0.1 g/gal) beginning in January 1986. The new Clean Air Act will actually lead to a complete ban on lead in gasoline in a few years. The phaseout will also reduce the small lead content of unleaded gasoline (since these amounts are due to contact with leaded gasoline facilities), which will reduce gradual low-level catalyst poisoning. Both catalyst and 0_2 sensor durability will benefit from these lower gasoline lead contents.

Finally, there are alternative catalyst configurations that could and likely will be used in the future to meet lower emission standards. It is likely that dual-bed catalysts will be phased out over time, but a warm-up catalyst (preceding the three way catalyst [TWC]) could be used for cold-start hydrocarbon control. To avert thermal damage and lower the catalyst deterioration rate, this small catalyst could be bypassed at all times other than during cold-start. Warm-up air injection could also be used with a single-bed TWC for cold-start hydrocarbon control. As hydrocarbon standards are lowered, heated catalysts will likely become a more important element of the pollution control system of many cars.

3.0 OTHER VARIABLES

Engine-out emissions are highly dependent on the conditions in the combustion chamber. Over the past few years, combustion chamber geometry and turbulence levels have been optimized in an effort to minimize emissions and maximize fuel economy. Fast-burn combustion, which is being used more and more, involves changes to chamber geometry, turbulence, and the location of the spark plug. It allows greater use of EGR for NO_x control without hurting efficiency, making simultaneous control of hydrocarbons and NO_x easier.

Ignition misfire is often due to fouled or faulty spark plugs, deteriorated spark plug wires, or other ignition component malfunctions. Greater durability of the ignition system, especially spark plugs, limits misfires and resulting thermal damage to catalysts. New ignition systems currently under development (and being used experimentally by SAAB and Nissan) may virtually eliminate misfires and the need for high-voltage spark plug wires.

Evolutionary improvements to engines will also aid in meeting the 1994 Federal standards. These improvements will include tuned inlet manifolds designed to reduce cylinder-to-cylinder variability, revised pistons to reduce crevice volume and oil consumption, and the incorporation of 'fast-burn' combustion chambers. A number of engines in production today already feature such improvements.

4.0 TECHNOLOGIES EMERGING TO MEET CALIFORNIA'S LOW EMISSIONS VEHICLE (LEV) STANDARDS

There is inevitable uncertainty associated with predicting the specific technology which manufacturers will apply to future vehicles in order to comply with the mandates of the LEV program. Historical evidence demonstrates that strong regulatory requirements create a favorable environment for technological breakthroughs. For example, in the 5-year period following the adoption of the 1970 Clean Air Act Amendments, unleaded fuel use, catalytic converter technology, and electronic control mechanisms quickly became the norm. It is likely that compliance with the LEV emission standards will result in the development of new technology.

Transitional low emission vehicles must meet a standard of 0.125 NMHC/3.4 CO/0.4 NO_x grams per mile. The California Air Resources Board projected in 1990 that for small or medium displacement engines, only heated fuel preparation systems and/or close-coupled catalyst completed systems will be required to meet TLEV standards. Many current gasoline engine families have certified to TLEV standards with calibration changes and evolutionary changes to hardware. The calibration changes required to met TLEV standards will include spark retard during warm-up, and more careful control of air-fuel ratio after cold-start and (possibly) electronic control strategies to precisely control individual cylinder air-fuel ratio.

Low emission vehicles must meet a standard of 0.075 g/mi for HC/3.4 g/mi for CO/0.2 g/mi for NO_x. Based on the most recent data, it is clear that the pace of technological progress has exceeded expectations and that the low-emission vehicle standards will require less advanced technology than previously expected. Just a few years ago, to produce LEVs, manufacturers were expected to utilize advanced fuel control strategies, greater catalytic loading for better NOx control for some models, and electrically heated catalysts (EHCs). In the Spring of 1992, however, Ford submitted to CARB a certification application containing data which strongly indicated that LEV levels can be achieved without using EHCs. In addition to these certification materials, CARB became aware of other significant advances being made by the automotive industry to reduce emission levels. Since the rate of progress has exceeded original expectations, CARB has revised its assessment of the technologies needed in each low-emission vehicle category.

The California Air Resources Board recently reviewed the status of implementation of the low-emission vehicle program. In summary, for TLEVs, it continues to project that only modest fuel control and catalyst improvements will be necessary. For LEVs, small to medium-displacement engines should be able to achieve the standards with fuel control improvements and improved conventional catalysts; larger, 8-cylinder engines may still require the use of post-start heated EHCs or other similarly effective technologies. For ULEVs, in addition to fuel control improvements and greater catalyst loading, CARB expects that post-start heated EHCs will be sufficient for most vehicles, although pre-start heated units may be needed for some applications.

Advanced Engine Modifications To Achieve Low In Use Levels

Dual Oxygen Sensors

Toyota has been using dual oxygen sensor systems since 1988. It makes good engineering sense that dual oxygen sensors will help maintain low emission levels in-use. As oxygen sensors age, their warm up response slows considerably, and the air-fuel ratio at which the sensor switches from low to high voltage (and vice versa) can shift significantly from stoichiometric, thereby increasing emissions. Because the second sensor is placed downstream of the catalyst, it operates in a relatively low temperature environment and is better protected from poisons. It therefore can be used to compensate for slow response and to adjust for changes in the switch point of the front sensor. In this way, a dual oxygen sensor system helps maintain good fuel control, and consequently good emissions control, as vehicles age.

4.1 SEQUENTIAL FUEL CONTROL

Precise injection timing may be helpful in minimizing hydrocarbon emissions under steady-state conditions. An effective way to use sequential fuel injection is to optimize injection timing to occur while the intake valve is open. This can be accomplished by using aerated fuel injectors to eliminate the need to rely on evaporation, thereby allowing direct injection of significantly less fuel into the combustion chamber. This technology will enable lower emissions and lower fuel consumption under AHS conditions, especially.

4.2 AERATED FUEL INJECTORS

Toyota's aerated fuel injection system already demonstrates emission benefits over the full range of steady-state conditions; efforts are under way to improve performance under transient and cold conditions as well. Use of aerated fuel injectors ensures good atomization during cold starts and therefore permits injection directly into the combustion chamber when the intake valve is open. This strategy reduces the amount of excess fuel needed to avoid driveability problems due to wall wetting, thereby minimizing emission increases and fuel economy degradation. This is especially important during transient engine operation (e.g. during rapid accelerations) when excess fuel is normally added to prevent engine stumbles and sags.

4.3 ADAPTIVE FUEL CONTROL

CARB believes that while adaptive control of steady-state engine operating conditions has been used for some time by industry, only a few manufacturers have been successful in developing adaptive strategies for **transient** operating conditions. In fact, to the knowledge of the CARB staff, the first application of this technology is on a few 1992 Toyota models, and it is aware of only one other major manufacturer that is planning to employ adaptive transient fuel control in the near future.

4.4 INDIVIDUAL CYLINDER TORQUE CONTROL

CARB staff discussions with numerous manufacturers indicate that measurement of cylinder torque is being examined as a means for controlling the entire fueling strategy of their engines, enabling them to reduce the dependence on oxygen sensors for primary fuel altogether. This same technique is being used by the automotive industry for misfire detection as part of the CARB's On-Board Diagnostic II (OBD II) misfire detection requirements. It may not be necessary to monitor all engine operating conditions to determine the level of fuel compensation needed over the full range of engine operating conditions if a particular injector is under- or over-fueling (e.g., due to a partially restricted or leaking injector). In CARB's view, torque changes become more pronounced as load increases. Under more moderate load conditions and more representative vehicle driving modes, as opposed to idle conditions, torque fluctuation should be readily detectable well within a one air-fuel ratio variation.

4.5 HEATED FUEL INJECTORS AND HEATED FUEL PREPARATION SYSTEMS

Fuel heating strategies have been used on production vehicles for some time now. Mercedes Benz has utilized an intake manifold heater on the 2.3L engines in its 190 series since 1991. As with aerated fuel injectors, improved fuel vaporization allows the use of leaner air-fuel mixtures during cold engine operation, thereby providing an even greater HC and CO emission reduction.

4.6 AIR INJECTION

To the extent that air-fuel enrichment is needed during cold engine operation to provide acceptable driveability, air injection can be utilized to provide the additional air needed to fully oxidize the excess HC and CO emissions in the catalytic converter. The need for air injection can be lessened by incorporating aerated fuel injectors, sequential fuel injection, and adaptive transient fuel compensation, either singly or in combination, to reduce the level of cold engine operating enrichment needed to achieve acceptable driveability. Air injection is a highly effective means of reducing NMOG and CO emissions, but may not be needed to meet the relatively less stringent Tier I or TLEV emission levels. In fact, none of the 1993 TLEVs certified by the CARB utilize air injection. However, air pumps have been an important element in achieving reduced NMOG and CO emissions on the CARB's EHC-equipped vehicles and would also be very effective in achieving LEV emission levels for vehicles without EHCs.

4.7 HEATED OXYGEN SENSORS

Heated oxygen sensors, a technology commonly used on many of today's vehicles, will also help reduce emissions. Heating oxygen sensors is important because as oxygen sensors age, they require higher operating temperatures to maintain adequate responsiveness to changes in air-fuel ratio, particularly during cold start operation. Slow response sensors can prolong the time required to switch from open-loop to closed-loop operation or provide poor fuel control during the initial closed-loop operating period thereby resulting in increased emissions. Oxygen sensor deterioration of this nature is most likely to occur after about 50,000 miles of driving. The deterioration can be masked, however, by electrically heating the sensor to operating temperature, thereby reducing the time needed to initiate closed-loop operation and minimizing emission increases due to improper air-fuel ratios caused by slow oxygen sensor response rates.

4.7.1 Additional Rhodium Loading for NOx Control

The rhodium levels of many current vehicles are sufficient to enable achievement and maintenance of a 0.2 g/mi NOx standard in-use. CARB in-use compliance records reveal that several 1989 models were able to achieve 0.2 g/mi NOx levels in-use (even without the application of advanced fuel controls). The emission results of these vehicles are listed in table A1 below.

Table A1. In-Use Compliance Test Results (g/mi) from Some 1989 Production Vehicles.

Results shown are the average of 10 tests; mileage on the test vehicles ranged from 31,000 to 49,000 miles.

Manufacturer	Engine Family	NMHC	CO	Nox
Volvo	KVV2.3V5FE8X	0.21	2.43	0.19
Ford	FKM2.2V5FXC4	0.23	4.88	0.14
Mitsubishi	KMT2.OV5FC18	0.22	2.19	0.20
Applicable Standards		0.39	7.0	0.4

Some manufacturers may need to add rhodium to match the levels used by these better performing vehicles. Adding rhodium to the catalyst is only one option for achieving low NOx emissions. Improved control of the air/fuel ratio at stoichiometric can also improve NOx emissions. Another option was proposed in the July, 1992, issue of Automotive Engineering magazine, which concluded that less expensive palladium could be a viable replacement for some of the rhodium in catalytic converters. For these reasons, the CARB considers increased rhodium loading to be an effective strategy for reducing NOx emissions and for maintaining NOx standards in-use.

Ultra-low emission vehicles must meet a standard of 0.04 g/mi for HC/1.7 g/mi for CO/0.2 g/mi for NO_x. At the very low emission levels of 0.040 HC (NMOG), it appears today that it will be necessary to have some form of additional exhaust aftertreatment. Several types of aftertreatment are being investigated, including:

close-coupled start catalysts
exhaust port catalysts
electrically heated catalysts
hydrocarbon molecular sieves

The electrically heated catalyst (EHC) has received the most attention, and has demonstrated the potential to meet ULEV standards even in large, heavy cars. The CARB, EPA, and a catalyst manufacturer (CAMET) have collaborated in extensive testing of these types of catalysts. To support its rulemaking to establish reactivity adjustment factors for Phase 2 gasoline-fueled low-emission vehicles, the CARB staff recently tested several late model vehicles which were retrofitted with EHCs. The warmed-up emissions performance of these vehicles, shown in table A2, are considered representative of the emission levels CARB expects to see from low-emission vehicles.

TableA2. Per-Bag Emission Results (g/mi) for Late-Model Year Vehicles Equipped with EHCs by the CARB

Vehicles operated on 1989 industry average gasoline.

Vehicle/Test		Bag 1	Bag 2	Bag 3	FTP Composite
1992 Lexus	NMHC	0.204	0.000	0.000	0.041
LS400	CO	1.766	0.078	0.079	0.429
	NOx	0.313	0.131	0.248	0.201
1988 Chev.	NMHC	0.230	0.003	0.019	0.054
Corsica	CO	1.692	0.142	0.794	0.643
	NOx	0.284	0.125	0.366	0.224
1990 Toyota	NMHC	0.192	0.000	0.009	0.042
Celica	CO	2.003	0.076	0.194	0.508
	NOx	0.666	0.154	0.084	0.241
1991 VW Jetta	NMHC	0.125	0.002	0.023	0.034
	CO	2.645	0.852	1.470	1.392
	NOx	0.357	0.038	0.184	0.144

Its most recent data using CAMET's latest EHC on a Buick are summarized in table A3. Ideally, the EHCs should be close-mounted to the main catalyst and contained in the same housing to minimize heat loss; results using this configuration are much lower, as shown in table A4. These results on a Honda Accord using an EHC developed by Corning, Inc. show NMHC emissions of 0.022 g/mi for 25 seconds of pre-heat while using only 14.8 watt-hours of electrical energy. For 25 seconds of post-heat, NMHC emissions were 0.046 g/mi with an energy requirement of 14.8 watt-hours. The test results also indicate that heating time, electrical energy demand, and emissions should decrease even further if a 24-volt energy source is used.

Table A3. EHC Energy Requirements of Recent CARB Tests

Test Date	Vehicle	Test Number	Watt-Hours	NMHC
7/10/92	Buick	28-10	33.9	.027
7/14/92	Buick	28-11	37.2	.025
7/16/92	Buick	28-13	38.0	.032
7/24/92	Buick	28-15	28.8	.027
7/29/92	Buick	28-16	33.8	.044
7/31/92	Buick	28-17	41.7	.022

Note: The July 1922 CARB test data involved various EHC heating and air injection strategies which contributed to the variability in the results.

Table A4. Corning EHC Test Results (6/8/92)

Description	Vehicle	Energy(W-hr)	NMHC
12 V Battery, 25 s Pre-Ht	Honda Accord	14.8	0.022
24 V Battery, 5 s Pre-Ht	Honda Accord	12.0	0.019
24 V Battery, 25 s Post-Ht	Honda Accord	11.6	0.027
12 V Battery, 25 s Post-Ht	Honda Accord	14.8	0.046

4.7.2 Other Strategies

While the CARB has identified several technologies to achieve the low-emission vehicle standards, it emphasizes that the regulations contain sufficient flexibility to accommodate nearly any strategy that can be used to reduce emissions.

One very viable strategy for achieving LEV and ULEV emission levels is the use of bypass start catalysts. In such a system, a small, quick light-off catalyst is mounted close to the exhaust manifold upstream of the main catalyst. During cold-starts, exhaust emissions are routed to the start catalyst, thus bypassing the main catalyst. Since the start catalyst is rapidly heated to light-off temperature, it treats the exhaust gases almost immediately. The exhaust gases are routed back to the main catalyst once it has reached a sufficient operating temperature.

Some of the other options being explored by the automotive industry include direct injection two-stroke engines, hydrocarbon vapor traps, exhaust gas ignition, and hybrid electric vehicles.

EPA has completed its initial evaluation of the direct injection two stroke engine with very promising results. One vehicle, a Ford Fiesta, had average composite FTP emission levels for all testing conducted at EPA of 0.05 g/mile non methane hydrocarbons, 0.2 g/mile

CO, and 0.2 g/mile NOx. In addition, average combined fuel economy was 50.2 MPG. The vehicle is equipped with a single close coupled oxidation catalyst. The CO levels and fuel economy values especially stand out relative to other clean, efficient production vehicles tested by EPA.

The hydrocarbon trap or molecular sieve is a zeolite-type material that can adsorb hydrocarbons at low temperatures, and then release them when heated to higher temperatures. It has been suggested that such materials can be used to adsorb cold-start HC prior to catalyst light-off, and then release the HC after the catalyst is operating at high efficiency. Such a material is more energy efficient than an EHC system, and is potentially cheaper as it may not require an electrical heating and control system. Unfortunately, zeolites are very temperature sensitive and little is known about their durability. In addition, research on these materials has been kept highly confidential and no data is publicly available to gauge their efficiency or durability.

The California Air Resources Board has projected that alternative fuel (CNG and methanol) vehicles will be able to meet the LEV standards with less additional technology than gasoline-fueled vehicles. In fact, the low vapor pressure of methanol requires more cold-start enrichment and presents greater difficulty in controlling cold-start related emissions. Cold-start related formaldehyde can also be an obstacle (as it has a higher reactivity index) in meeting the reactivity weighted HC standards. However, recent tests on M85 vehicles with an electrically heated catalyst have been encouraging, as aldehyde emissions on the FTP were less than 5 milligrams per mile. CARB staff also stated that recent tests on a M85 vehicle at low mileage showed the potential to meet even the ULEV standards with a start catalyst/main catalyst system without electrical heat.

5.0 CONCLUSIONS

Starting in 1975, when HC and CO standards were tightened as a result of the 1970 Clean Air Act Amendments, first generation oxidation catalysts were introduced on a vast majority of all new cars in the US. By 1981, when the NOx standard was tightened, the second generation systems, three way catalysts took over much of the market. As a result of the Clean Air Act Amendments of 1990 as well as the California decisions of 1989, the third generation systems, with greater durability have begun to be introduced since 1993. As a result of the California decisions of September 1990 (coupled with Section 177 of the Clean Air Act which allows other states to adopt the California program), a fourth generation will likely begin to be introduced by the mid to late 1990's, one based on either very rapid light off or even preheating.

Use of these advanced catalysts as well as improvements in engine technology, especially electronic control systems, as discussed above will lead to lower in use emissions from cars in the future. As the above discussion makes clear, however, it is generally easier and cheaper to control emissions under steady speeds than it is under transient conditions. Technologies already available make it possible to lower emissions of CO, HC and NOx at constant cruise conditions ranging between 50 and 70 MPH to levels which should approach zero grams per mile. Engine out emissions can be very low even without aftertreatment; further lowering those emissions with the use of highly efficient catalysts will lower them an order of magnitude more. While progress is being made in applying some of these advances to transient conditions, this is inherently more difficult because transient conditions typical of normal highway driving such as hard accelerations place other demands on the vehicle for rapidly changing and high power output. therefore one can always expect, so long as the prime powerplant will be the internal combustion engine, that emissions will be inherently lower with AHS than without.

APPENDIX B: AUTOMATED HIGHWAY SYSTEMS: INSTITUTIONAL ISSUES

I. INTRODUCTION

As part of Automated Highway Systems Precursor Systems Analysis, members of the faculty of the Woodrow Wilson School of Public and International Affairs at Princeton University conducted a review of several relevant institutional issues. The study included issues generally applicable to AHS implementation, and originally considered issues specific to two sites: the Lincoln Tunnel between New Jersey and New York, together with its feeder roads (particularly the New Jersey Turnpike); and' the Nogales-Tucson-Phoenix corridor in Arizona. After the initial period of background research was complete, the study was expanded to include the Long Island Expressway in Nassau County, New York; the discussion of this third site is therefore briefer than the others, but additional background information is available in the completed Roadway Deployment Analysis (Task H) for the Expressway.

At this early state of development of Automated Highway Systems, a number of questions remain unresolved. There are a large number of possible configurations for the highways; the costs and benefits of the system depend in part on the chosen configurations; the issues of social equity, political feasibility, and environmental impact depend in turn largely on the configuration, the costs and the benefits. Evaluating all the possible combinations of these factors for each of the sites would be extremely complicated and not of real help to policymakers. This is especially true in view of the fact that the data which has to be used in these evaluations are in some cases extremely fragmentary.

To provide a more useful analysis, we have focused our efforts in several ways. First we have concentrated on one type of vehicle at each site: buses at the Lincoln tunnel, private cars on the Long Island Expressway, and trucks between Phoenix and Tucson. In each case, there are good reasons why such a concentration is reasonable; taken together, discussion of the three sites should raise most of the issues that will arise in projects that provide for mixed or separate use,

Secondly we have dealt only with an AHS involving dedicated lanes. If the technology is entirely on the vehicle and the cost born by the owner at its installation, if it travels on existing highways and within the current mix of traffic, the institutional issues are too limited to be appropriately examined here. We have also differentiated only briefly between systems which have external technology on the road and those which use a command and control facility; again, the institutional issues are not affected much either way. Finally, although we discuss various alternatives, we focus most of our attention on the most likely institutional developments in each of the locations.

At the beginning, we should make clear what we mean by an AHS. We are concerned in this ~eport with a system in which vehicles will travel on dedicated lanes guided by technology both internal and external to the vehicle. We expect that the guidance system will be used both for entry and travel on the road, but not for leaving it. We understand that an AHS will have the capacity both for increased speed and increased capacity, and that therefore it is likely to be deployed in congested or heavily travelled corridors. And we assume that it will be safe.

II. GENERAL INSTITUTIONAL ISSUES

The general institutional issues fall into three basic categories: issues of cost and equity; issues of political structure; and issues of land use and environmental protection. ..

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A. ISSUES OF COST AND EQUITY

The costs of an AHS as described above are not clear, but some investment in dedicated lanes will likely be necessary. There are several possible ways an AHS could be financed. The Federal government could invest in it as it has in Interstate Highways or through some other mechanism; in that event a state match could, but need not be, required. States could provide the bulk of the financing from general or dedicated funds; again, some local match could be required. Existing authorities could be asked to pay for the road; they could raise the necessary revenue through new toils

or be required to meet the cost from existing revenues, with or without funding from general-government sources. New authorities could be formed to pay for it and charge tolls; special districts could be formed to finance it and use some form of tax-increment financing to meet the costs.

None of these choices is without difficulty. Federal financing would make the decision subject to the usual political process, which need not be elaborated here. State financing would in most cases make the decision subject to the limitations of a balanced budget. Any substantial state or local cost would mean that the outlay would have to compete with existing needs for freeways, highways, local roads, or other forms of mass transportation. It is always problematic to ask authorities to make expenditures without offsetting revenue; it is very hard for special districts to generate enough revenue to meet all the likely costs of an AHS. Any one of these methods could work in specific circumstances. In general, however, it is reasonable to expect that an AHS would be financed, very substantially, through tolls or other user fees.

These fees could be established on several bases. Among these are:

1. User fees are set to cover the cost of AHS construction and operation (average cost pricing):

Under this scenario, the full cost of AHS will be borne by users, who would most likely also be required to purchase and maintain on-board equipment to complement the public works investment. But the costs of construction of the system may bear little relation to the benefits that society will receive: for example, it is possible that construction costs will be significantly below social benefits, which include environmental gains and reduced congestion. The dedicated truck lane described in Section V is°a case in which such pricing might be an effective alternative.

2. User fees are set on a social cost basis:

In this scenario, each AHS user would be charged the full social cost of his/her use of the system. Calculating these charges would be cumbersome, and would involve charges to defray the construction and operating cost of the system, credits for the value of reduced congestion on the conventional lanes and for reduced emissions.

Such charges would presumably be distance sensitive. If implemented effectively, this scheme could closely approximate economic efficiency. The minimal charges to buses using the automated XBL described in Section II are an example of such a concept at work. In that case, the social benefits of getting drivers out of cars and into buses might be deemed substantial enough to warrant a full public subsidy.

3. User fees are set on a politically practical (case-by-case) basis:

This is the most likely of the scenarios, although not necessarily the most efficient. Since each site has unique political characteristics, each will develop its own funding and pricing scheme. These schemes will need to accommodate public acceptance of the technology, perceptions of equity, and existing politicel arrangements. Such arrangements will be most effective if they build in some of the characteristics of (2) by charging users based on the costs and benefits that their use imposes on the system and society. The more independent the relevant politicel institutions are, the more closely they will be able to approximate an efficient usage pattern. Within each of these broad categories exists a wide range of possible price systems, many of which are feasible for the first time with the computerized information gathering and provision that other components of IVHS will allow.

Tolling of any kind, as well any required initial investment in the technology, would mean that only those who could afford it would be able to use an AHS. Where new lanes can be financed and constructed in an acceptable way, the equity issues may be manageable. Dedicating or replacing an existing lane would be much more politically difficult; it would establish- a priority for the relatively wealthy. This may only be acceptable if the benefits to those still on the conventional highways (e.g., in reduced congestion) are sufficient and appreciated.

The equity issues would probably generate less conflict if the lanes were restricted to buses. In those cases, the economic, environmental, and equity considerations could much more easily justify dedicating an existing lane. If the lanes were restricted to trucks, some of the equity issues would remain, but the people on the conventional highway would probably appreciate it more.

B. ISSUES OF POLITICAL STRUCTURE

The decision to reserve lanes or construct a toll road can involve a great many agencies and individuals, including: state and local transportation departments; state and local land use planning agencies; existing toll road, tunnel or bridge authorities; environmental regulatory bodies; and economic development agencies. Funding decisions can involve governors and mayors, state legislatures and city councils, as well as cumbersome metropolitan planning organizations.

These agencies and individuals have disparate views and different interests. They will be asked to think well ahead of the usual political horizon, to comprehend difficult technological concepts, and to invest in a new technology that could change rapidly. Depending on the location of the road, these players may be asked to think regionally for the first time; if they do not, the cost of approval for an AHS project could greatly increase because of additional projects which may have to be built to secure the necessary consensus.

For an AHS to be implemented successfully, there has to be an agency or agencies in the area technically capable of evaluating its merits, planning for it, deciding to build it, financing its cost (or managing the financing), managing its construction, and operating it. If the road is entirely within the jurisdiction of one state, or one multi-state agency, this process can be accomplished more easily. If regional cooperation is required and no mechanism is in place, the process is likely to be very difficult.

There are few good recent examples of the establishment of multi-jurisdictional regional transportation agencies with real power. TRANSCOM, in the New York metropolitan region, is perhaps the most successful example of multi-jurisdictional cooperationon traffic management and information issues. Although it is becoming increasingly involved in the deployment of IVHS technology, its governance mechanism, in which all area transportation and safety agencies participate in major decisions, requires unanimous consent for action. That degree of agreement across several agencies may be much too cumbersome to construct, operate, and maintain an AHS. TRANSCOM may, however, be a reasonable model for an agency which operates a command and control facility.

C. ISSUES OF LAND USE AND ENVIRONMENTAL PROTECTION

Because of its potential impact on development, AHS construction for private automobiles is in most cases likely to be supported by the powerful development lobby, including real estate, legal, insurance, and other commercial interests. On the other side would be those who might be adversely affected by specific construction plans in their neighborhood, and, most probably, the environmental lobby.

A major purpose of an AHS is to move more people at faster speed through a heavily travelled corridor. From the point of view of the environmentalists, the best way to do this may be with a railroad or light transit. The prospect of more motor vehicle capacity is not one which is likely to appeal to them or to environmentally-engaged politicians, unless that improvement in capacity were in the form of HOV lanes or similar measures designed to reduce vehicle miles travelled.

By reducing the time cost of travel, an AHS has the potential to significantly alter the current land use pattern. The value and usage of a given location are largely determined by two factors: characteristics of the location itself and the accessibility of the location to other places to which people or products need to be transported. By reducing the time required to travel a given distance, an AHS will reduce the demand for spatial proximity. In general, such changes tend to decentralize the locations of both residences and businesses.

Improvements in road systems have two distinct types of effects on usage. In the short run, travel on the improved link of a network will reduce congestion and allow trips at more efficient (and less envir.,onmentally damaging) speeds. In the long run, however, this advantage will dissipate,' as more travellers choose the improved link, development occurs along the improved link, and locational changes induce longer and/or more frequent trips on the link. Thus "peak-hour traffic congestion rises to meet maximum capacity". Downs' law, as it has come to be known, induces a profound pessimism in transportation planners hoping to reduce travel times by improving roadway capacities. It is this pessimism that tempers the enthusiasm of environmentalists for AHS. Less short-run congestion may simply mean more travel and increased environmental damage in the long run.

Reducing commuting times, for example, increases the incentive to live far away from work and encourages both residential decentralization and the spatial segregation of work and home. Likewise, businesses depend on transportation to bring inputs (including labor) to the firm and outputs to market. Reductions in travel time or cost reduce the incentives for businesses to locate near input sources or markets, and may encourage them to seek low-cost land on the fringes of urban areas. Such effects, if substantial, are likely to adversely affect central cities and older, inner-ring suburbs, reducing their job and tax bases. To the extent that these areas are the residential locations for substantial numbers of the Nation's most disadvantaged citizens, most of whom will be unable to access jobs created in the suburbs, such land use changes will likely be regressive in their impacts. In addition, the expansion of the suburban fringe will be likely to have significant environmental impacts on the undeveloped land on the outskirts of urban areas. [1]

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[1] Transportation investments also can reduce firm costs by allowing them to move to locations with lower cost land. Landowners would presumably capture at least part of this benefit as the value of their land rises with increased accessibility. Such effects are quite complex, and beyond the scope of the analysis presented here.

Many of these effects have been experienced with the completion of the interstate highway ,system. That program dramatically reduced the cost of both inter-and intra urban travel, and induced firms and households to move apart. The result has been urban sprawl and the rise of "edge cities" near major interchanges. Similar effects might be expected with the adoption of an AHS. Of course, the overall magnitude of the effect depends on the size of the change in travel costs. Nonetheless, even small changes in the relative valuation of places can cause noticeable shifts in land use patterns.

III. THE LINCOLN TUNNEL-NEW JERSEY TURNPIKE COMPLEX

INTRODUCTION

The Lincoln Tunnel is one of three Hudson River vehicle crossings between Manhattan and New Jersey. It has three tubes with a total of six lanes, and terminates eastbound in midtown Manhattan, with direct access for buses to the city's main bus terminal. The Holland Tunnel, which has two lanes in each direction, terminates eastbound in lower Manhattan; the George Washington Bridge, with seven lanes in each direction, terminates eastbound seven miles north of the Lincoln Tunnel in upper Manhattan. All three crossing are tolled.

There are also three passenger railroad tunnels. Two of them serve a short distance interstate subway system (PATH) to and from lower and midtown Manhattan; the other tunnel serves longer distance New Jersey Transit commuter lines, as well as AMTRAK to and from m idtown Manhattan.

Approximately 58,000 eastbound vehicles a day use the Lincoln Tunnel. Of these 49,600 are cars, 5,100 are buses and 3,300 are trucks. Eastbound, the vehicles originate chiefly in northern and central New Jersey; Manhattan is their final destination in almost all cases. The eastbound buses almost all terminate at the bus terminal owned and operated, like the tunnel itself, by the Port Authority of New York and New Jersey.

With the exception of a short two lane stretch, there is a three lane highway in each direction between the New Jersey Turnpike and the tunnel ramp. The road near the Turnpike runs through meadowlands, then it moves below grade through a densely populated urban area on top of the Palisade. From there the three lane tunnel ramp descends to the toll plaza from the Palisade above. The traffic on the ramp in both directions, however, has to deal with the hill, the curves and the sun; it often moves slowly with substantial headway between vehicles. The eastbound, downhill, side is particularly slow.

During the morning rush, one of the three westbound lanes on the road and the ramp is converted to an eastbound express bus lane (XBL); the buses bypass the toll plaza and use an automated tolling system. This contraflow bus lane, in fact, may be considered the largest commuter line into New York from the west; it carries 65,000 people a day, much more than its nearest competitor, the Northeast corridor train line Although there is a monitoring system and a fleet of wreckers, the bus lane is subject to breakdown and delays.

In the afternoon rush hour, there is substantial congestion on the New York side at the entrance to the westbound tunnel, but the buses are directed through by traffic police; there is also an uneven traffic flow in the tunnel itself. However, the westbound lanes on the ramp and the New Jersey feed-out roads are much less congested in the afternoon than the eastbound lanes in the morning. For this reason, there is no westbound bus 'lane; there is mixed traffic going out of the city at all times.

The New Jersey Turnpike, a toll road, is the main North-South corridor road for the state and for traffic moving through the northeastern United States. In this part of the state, it has six lanes in each direction. Three northbound lanes use Turnpike Exit 16E and three southbound lanes use Exit 17 to gain access to I 495-State road 495, the access road to the tunnel. Approximately three quarters of the buses which use the XBL come from the Turnpike, about 60% of these come from the South and about 40% from the North. Because of its configuration, the ramp from Exit 17, which handles the southbound traffic, is the most congested at rush hour.

The other buses using the XBL enter from Route 3, which can also back up in the eastbound direction from the area of the New Jersey Sports Complex. At rush hour, these buses backtrack a little to join the bus lane through the "teardrop," the complex of road east of the Turnpike exits. At other times they come on the State Road 495 just east of the teardrop.

During the morning rush hours, from 7:00 a.m. to 10 a.m., the tunnel serves approximately 11,650 cars, 1,800 buses, and 850 trucks. All but about 240 of the buses enter through the XBL; the others use a local bus lane which enters directly onto the toll plaza from local streets. Traffic at the tunnel is increasing each year, but not to the extent of the increases which occurred during the economic boom of the 1980's (when traffic grew at about 3% a year). Currently, the Port Authority anticipates difficulty in safely adapting the XBL contraflow to the new, wider buses required to serve the disabled. With the reconstruction required to handle these buses, it should have capacity for an additional 450 buses during the morning rush, which means an additional 20,000 people.

A. ISSUES OF COST AND EQUITY

Constructing another tube for the Lincoln Tunnel for the purpose of an AHS lane would be logistically difficult and very expensive. The same is true for construction of an additional lane on the tunnel ramp portion of I 495 immediately west of the Tunnel and for the urbanized section of the road immediately west of the ramp. Additional lanes are more feasible in the meadowlands portion of I 495 and on the Turnpike, but the impact of such construction on these delicate wetlands could raise substantial environmental problems in addition to raising its cost. For our purposes, therefore, we will assume an AHS will use existing lanes, except perhaps in portions of the meadowlands.

In such an essential and Congested corridor, it is hard to conceive of a politically acceptable way to dedicate an existing lane for the faster movement of privileged private vehicle operators. It is probably not practical in any case to move private vehicles at higher speed or density through a tunnel that ends on the streets of Manhattan. A truck lane is also very unlikely; additional truck capacity would not greatly help the overall congestion west of Manhattan, and additional truck movement through Manhattan would only increase congestion there.

In view of these concerns about equity and practicality, in our view the most acceptable alternative would be to convert one existing lane to an AHS lane for buses. A possible choice would be one of the four eastbound lanes, creating two lanes for buses in the morning. A second eastbound bus lane was in fact studied and proposed by NJDOT in the early 1980's. The proposed rule which would have created the lane, however, was extremely controversial, especially among the developers in the meadowlands who believed it would have too big an adverse impact on the movement of general traffic. The proposal was withdrawn.

Recent attempts to relieve general traffic congestion and open an additional lane for bus traffic have proved impractical. Rerouting traffic is not a meaningful alternative because of congestion at the Holland Tunnel and the relatively inconvenient location of the George Washington Bridge. Congestion pricing is unlikely to be effective because the great majority of cars using the tunnel at rush hour are essential to the work of the driver or are otherwise subsidized; trucks do not use the tunnel during the peak unless they have no choice.

Alternative routes for an additional bus lane leading to the Lincoln Tunnel have been studied; most would use existing railroad rights of way and moderately used roads leading to the tunnel toll plaza. All have been shelved because of strong opposition by politically powerful local governments, yet increasing traffic on the XBL will require some remedy in the long run.

Given these political obstacles, the mostly likely candidate for an AHS bus lane would therefore be the conventional contraflow lane now used in the morning to move buses from the Turnpike to the tunnel. It would have to be usable by normal, mixed traffic in the middle of the day and at night. To work well, it would probably be essential to build an additional lane from exit 17 to the bus lane, as well along Route 3 as far as possible toward the Sports Complex. (Perhaps a dedicated bus lane could start even further back along the Turnpike in both directions as well). Finally, a guidance system on the tunnel lanes used for buses would also increase safety, especially with the wider buses, and improve traffic flow.

No doubt there would be some serious engineering problems in deploying this system, but an AHS at the Lincoln tunnel seems dependent on resolving them. If the demand existed, moving 20,000 additional bus passengers through the Lincoln Tunnel could be a substantial improvement in current commuting patterns. With the completion of the new NJ Transit rail connections at Kearny and Secaucus, however, there is a serious question about whether there will be sufficient additional demand; the market surveys show a likely shift of a portion of bus commuters to rail. Whether or not this occurs, protecting the future viability of the bus lane is essential. If additional traffic, frequent breakdowns, or an increase in the number of accidents make the bus lane an unattractive choice for a large number of commuters, the transportation network, even after the rail improvements, is unlikely to be able to handle the shift. An AHS bus lane has the potential to prevent this.

B. ISSUES OF POLITICAL STRUCTURE

The New Jersey-New York metropolitan area is, to say the least, politically complicated. Again, the Port Authority of New York and New Jersey controls both the

Tunnel and Bus Terminal. The Port Authority is governed by a Board of

Commissioners, half of whom are appointed by the Governor of New York and half by the Governor of New Jersey, with the advice and consent of their respective state legislatures. The Governors retain veto power over the minutes of the Board meetings, and therefore over its major decisions. The Port has served as a mechanism for regional infrastructure construction for almost 75 years.

An independent authority, with a board appointed by the Governor of New Jersey, runs the Turnpike. The road which joins the tunnel and the turnpike (state road 495) and U.S. Route 3 are under the jurisdiction of the N.J. Department of Transportation. The Commissioner of Transportation, an appointee of the Governor, is a member of the boards of all the major transportation agencies in New Jersey, including the Turnpike and NJ Transit.

The New Jersey State legislature, through its transportation and appropriation committees, takes an active role in road construction decisions and has in the past had an adversarial relationship with the Turnpike Authority and the Port Authority of New York and New Jersey. To the extent that state funds are needed for AHS development, they will be subject to the usual political maneuvering and legislative bargaining.

The North Jersey Transportation Planning Authority has a jurisdiction which includes the counties near to New York City. but it functions much more like a legislative committee than a regional planning agency; any required expenditure of federal funds will be subject to the balancing of interests which has become routine procedure in its decisions. The State and City of New York can also become involved if changes in Lincoln Tunnel traffic have any noticeable impact on the streets surrounding the bus terminal. Currently, commuter buses use the ramps, not the streets.

New Jersey Transit, a quasi-public corporation chaired by the State Commissioner of Transportation. operates most of the buses moving through the Lincoln Tunnel. It also subsidizes a number of the least profitable remaining bus lines, and purchases almost all the buses used by New Jersey companies. With one exception, all the private companies operate on narrow profit margins. These buses do not now pay rush hour tolls on the Turnpike, are modestly tolled on non-peak hours and pay tolls at the tunnels which have been frozen at low levels for a number of years. Raising bus fares on the public lines is politically difficult and often counterproductive; increased fares usually mean decreased ridership. The subsidized lines are close to extinction. And the profitable bus lines carry highly organized and articulate commuters. Any tolling which results in higher fares would be volatile, but alternatives to tolling would also raise a large number of difficult political issues.

Possibly the federal government would pay a large portion of the costs. If not, it is possible that the State of New Jersey would provide the required revenue to construct an AHS at the Lincoln Tunnel. As always, state officials would face substantial political difficulties in doing so, and at some point would probably look to the independent authorities to provide the funds. Authority financing may be the most likely solution, but it would not be easy.

The Port Authority of New York and New Jersey, which is in charge of the tunnel and the ramp, already operates the PATH commuter train system at an annual loss of several million dollars. It can be expected to resist expenditures of any size for an AHS which is not tolled, or which has a toll structure requiring cross subsidization by other Port Authority facilities. Although it may be possible for the authority to finance this AHS from its existing revenue sources, the board could be expected to challenge such an assumption. If the authority board could be convinced to deploy the system, it could probably do so only after it agreed to an equal expenditure which benefitted New York state residents as much as an AHS into the tunnel would benefit New Jersey commuters. Without such an agreement, the proposal would likely be vetoed by the Governor of New York.

The Turnpike Authority could decide at any time to automate a section of its mad. If sufficient additional toll revenue was not available, however, its board, too, could be expected to resist any expenditures on 1 495 or state road 495. (They have so far resisted constructing additional capacity even at exit 17.) Under current law, of course, no interstate highways can be tolled at all. Assuming the law was changed, state officials could be expected to resist tolling roads which were designated as interstates on the assumption that they would be free. There would certainly be local resistance to most such proposals in northern New Jersey.

Similarly, a change in the Turnpike law could be necessary for the board to spend money on state road 495; it may or may not be considered a turnpike access road under the current statute. There may in addition be bond restrictions against the board spending money in this way. Turnpike surplus funds could be used, if any are ever available after their current construction schedule, but such appropriations are subject to the legislative budget process. In any case, if the legislature has to appropriate the money, there is little gained by using the Turnpike Authority as a mechanism financing this project.

Nevertheless, with considerable political effort by the Governor of New Jersey, authority financing for an AHS at the Lincoln Tunnel is possible. In the absence of federal funds, it may be the only way. The final determining factor for the Governor in this matter is likely to be alternative uses of the funds available from these agencies.

Any AHS bus lane would have to compete with other proposed mass transit projects. Although the rail connections at Kearny and Secaucus are far along, there is a proposed West Shore Rail line under consideration which would serve commuters from Bergen County and the counties in New York immediately north of it, together the largest source of traffic into the city. Moreover, the Urban Core project, a joint effort among NJ Transit, the Port Authority, and the New York Mass Transportation Authority, is studying the entire rail network between New Jersey, New York City and Long Island. It is seeking to avoid the costly train turnarounds at Penn station, to rationalize the movement of freight, and to determine whether an additional rail tunnel under the Hudson is viable for both purposes. It is also likely to examine whether it makes sense to terminate all buses at some point in New Jersey and require a transfer to new rail lines, avoiding both the traffic and the management problems at the Port Authority bus terminal in Manhattan. This last item is a clear alternative to an AHS bus system.

C. ISSUES OF LAND USE AND ENVIRONMENTAL PROTECTION

The eastern portion of the Lincoln Tunnel-New Jersey Turnpike complex is located in a densely populated urban industrial area; the western portion consists chiefly of wetlands. The wetlands are environmentally sensitive and have already been seriously affected by industrial water pollution; because of this, there is some question as to whether any additional construction can take place on the relevant sections of the New Jersey Turnpike. The entire corridor has a major problem with air pollution, to which traffic congestion substantially contributes.

The environmental lobby in New Jersey is large, but fragmented. There is a small, but vocal planning community. The general public is periodically very concerned with environmental issues, although their concern has not had a consistent focus.

The state is developing its plan of compliance with the federal Clean Air Act, the state DOT is developing its construction master plan, the Northern Jersey Planing Authority is developing its congestion management plan, and it is not at all clear how an AHS will conform to any of them.

The New Jersey Land Use and Development Plan, in turn, places a priority on economic development and infrastructure investment in the inner cities, and is specifically designed to limit residential and business decentralization. Nevertheless, the automation of bus access to the Lincoln tunnel may be acceptable because it is likely to have relatively minor land use implications,

The majority of the effect will be felt by rush-hour bus riders into Manhattan. Depending on the size of the difference between fare increases and the full value of time savings experienced by riders, the program will reduce the full cost of commuting to the city for all users of the tunnel, but especially for bus riders.

If the system results in a net improvement in the welfare of bus riders (in the sense that the value of the reduction in travel time is not fully captured by fare increases) then simple theory would predict that it would encourage residential and business decentralization. But there are some complications in this story.

The most important of these is the fact that the majority of the net benefits are specific to bus riders. Recent evidence from Philadelphia suggests that there is a noticeable premium paid for suburban locations that are near commuter rail stations. Presumably; AHS will induce a similar effect in areas near the pick-up points for commuter buses. We might thus expect a shift in land-use patterns within the suburbs, with bus-accessible locations gaining at the expense of train-accessible, as buses become a more attractive mode. The land price effect will tend to increase densities (in addition to attracting some convenience-oriented businesses) in areas near bus stations. Land-owners in bus-accessible locations will benefit as the value of their assets rise with increased demand.

Conversely, if the new bus ridership is mainly drawn from former patrons of commuter rail, land near train stations will see reductions in value, but these losses will be smaller than the rises experienced by the winners. The great ease with which buses can change their routes will reduce the land value effects, since there is less certainty that the bus will be there next week than there is with rail.

Finally, removing buses from the regular roadway will reduce congestion for other drivers (at least in the very short' run) and enhance the attractiveness of suburban locations. Bus accessible suburbs in New Jersey will prosper modestly at the expense of Manhattan, New York suburbs, and other locations where automated bus service is unavailable.

Recent research has suggested that increased public transportation access by city residents to suburban job growth will reduce both the level and concentration of poverty in our nation's cities. The nature of congestion at the Lincoln Tunnel and the consequent automation of the eastbound XBL will not directly affect access to suburban jobs for the disadvantaged of New York City. If, however, tunnel congestion is a serious detriment to business operation in Manhattan, then XBL automation could help the city retain businesses (and jobs) that would otherwise be tempted to relocate to New Jersey.

The provision of a new high speed access corridor to Manhattan will tend to make a central city location more profitable for business. In the short run, businesses whose workers can commute by bus will benefit, possibly reducing their incentives to suburbanize. In the long run, businesses that benefit the most from efficient bus transportation may replace some of-the current firms. Convenience-oriented businesses in and around the Port Authority Bus Terminal will gain some advantage, as will owners of land there. Within the terminal, this is the Port Authority itself, outside the terminal the benefits will be spread to a variety of landlords.

IV. THE LONG ISLAND EXPRESSWAY

INTRODUCTION

The Long Island Expressway (LIE)is one of the most heavily traveled and congested roadways in the nation. It begins west of Riverhead in Sussex County, travels westward through progressively more developed suburbs in Sussex and then Nassau County, moves through the Borough of Queens in New York City, and terminates at a tunnel to Midtown Manhattan.

In most of Nassau County, the LIE is paralleled closely on its north by the Northern State Parkway and at somewhat greater distance in the other direction by the Southern State Parkway. None of these roads is tolled; each has three lanes in each direction; only the LIE carries trucks and buses as well as cars. Like the LIE, the other two roads are very heavily traveled and have serious congestion problems during the very long rush hours in the morning and the evening.

The Calspan team has studied AHS deployment along a fifteen mile stretch from exits 31 to 44 on the LIE, between the Cross Island Expressway on the west and the Seaford Oyster Bay Expressway on the east. Both these north-south roads are major arteries with mixed traffic. There are two principal AHS proposals under consideration for this stretch of the LIE; because of the technical difficulties in dealing with mixed traffic and the longer ramps and overpasses needed for trucks, both of the proposals apply only to cars.

One of the proposals would use a transition lane to provide direct access to an AHS lane from two general traffic lanes; the other would provide access to a separated AHS lane from the two general traffic lanes and from the service road which parallels the LIE. They are described (12 and 13 scenarios) and their advantages and disadvantages discussed in the Roadway Deployment Analysis, Task H. Both proposals involve eastbound and westbound traffic.

The two proposals are similar in several ways. In both cases five or six new entry points and five or six new exit points would be established on the LIE at some distance from the existing exits. Both would require taking away one currently existing general traffic lane and one additional lane now under discussion, to be constructed by the year 201 5. In both scenarios, cars exiting from the road would have to weave through general lanes of traffic and would need to deal with substantial backup problems as they move onto roads not part of an AHS. For both, traffic capacity is projected to be close to that of a four lane road in each direction by the year 2015.

The proposal which provides direct access to the AHS (12) has more traffic management problems in the existing and new lanes; the proposal with separated AHS lanes requires more new right of way at the new exits and entrances. The separated road proposal (13) seems the most likely to be deployed, and an analysis of it here would seem to be the most useful; it will therefore be our focus in this report.

A. ISSUES OF COST AND EQUITY

The right of way for one additional lane in each direction is available for almost all of the proposed length of the AHS, and currently HOV lanes are under consideration for this part of the LIE. The study area includes a small portion of Queens Borough, which is densely developed. To the east of the proposed AHS, in Suffolk County, there are HOV lanes from exits 49 to 57. Although further construction there would be difficult. the HOV lanes are possible candidates for conversion to an AHS, but they are not included in the Calspan study area. In Suffolk County, there is land available for development in the area of the LIE; construction here could be expected to have a much greater environmental and land use impacts than in Nassau County, which is almost completely developed, but the Suffolk County portion of the LIE is not included in the Caispan area. The site selected for the AHS therefore eliminates many, but not all, of the institutional issues which would arise if the section were extended in either direction.

Of course limiting the site in this way also considerably reduces its utility. This is a fifteen mile section of a much longer road. The average trip distance on this section of the road is seven miles. The principal benefit of an AHS on the proposed section of the road would be to reduce an average rush hour trip of perhaps twenty minutes to seven minutes. This would no doubt be attractive to a great many individual drivers if it were free. 'but its attractiveness could be considerably reduced if it were tolled. All the projections done so far for this project assume no tolls.

Even if it were free, and therefore attractive to many motorists who had the necessary technology in their vehicle, the year 2015 impact studies show that the general lanes on the LIE, which initially benefit from the AHS lane, begin to back up again fairly quickly because of the generally high level of east-west traffic on Long Island. The parallel roads follow a similar pattern, backing up again after an initial gain.

Ultimately the benefit is likely to be a reduction in local street traffic rather than faster movement on the highways. Finally, exiting the AHS lanes is likely to become a problem as usage increases, movement across the general traffic lanes becomes more difficult, and congestion begins to occur immediately off the highway where the AHS ends. If this occurs, the AHS lanes would eventually slow down as well.

Separated AHS lanes would be relatively expensive to build, requiring a substantial system of overpasses and ramps in addition to the purchase of right of ways for the exits and entrances. Tolls set to cover the cost would therefore be substantial and may discourage utilization; tolls set according to the motorist's willingness to pay will obviously depend on the perceived relative benefits of the system, which are problematical. It is difficult, however, to conceive of a scenario in which the road would not be tolled. Taking away one or two lanes of general traffic on the LIE would be hard enough without making the AHS lane free for the relatively wealthy who get to use it.

B. ISSUES OF POLITICAL STRUCTURE

Although the Long Island Expressway itself moves through two counties on Long Island and then through the City of New York, a fairly volatile combination of jurisdictions, restricting the AHS impact to Nassau County would simplify the institutional issues somewhat. The road is within the jurisdiction of the New York State Department of Transportation; on many issues there would be only one planning organization and one county government to deal with. Nevertheless, building an AHS in this area would be politically difficult.

The road is located in or near-a large number of towns in Nassau County. The citizenry in the area is well organized and very vocal. The planning organizations, including the MPO, are very active. Building the HOV lanes in the neighboring stretch of road was 'extremely contentious, as is the proposed rail link to the airports. Widening the service road in this area of Nassau County has on occasion proven impossible because of citizen opposition. Some of these contested projects were not nearly as intrusive as the construction of an AHS. A major controversy over an AHS is therefore likely, especially if the decision to build it becomes involved in a general debate over widening the LIE.

This stretch of the LIE moves through or close to several residential neighborhoods. The system of ramps and overpasses would be extensive and relatively high over the road; they would be visible from a large number of homes, and the vision probably won't be greatly appreciated. The new exits could cause additional congestion in several of these areas, which are not free from traffic problems even now. Citizen opposition to widening the road for any reason would therefore be likely; the configuration necessary for an AHS could greatly intensify the reaction.

Local politicians can be expected to join the protest. If the technology in the cars is not generally available, and the technology on the roads is relatively untried, the opposition arguments would be strengthened. In addition to the usual suggestion that the idea be tried on others, local politicians could then attack the elitist nature of the system, as well as its safety and utility. In addition, as in other cases, the argument for the AHS will also have to contend with alternative possible uses for the considerable funds which would have to invested in the AHS. !n Nassau County, one of the alternatives would include conventional widening of the LIE and/or one of the parallel roads.

An improvement in service on the Long Island Rail Road is a possible alternative or additional course of action to reduce congestion in Nassau County. The railroad now serves an enormous number of people from this area who commute all the way into the CBD every day. It is in the process of studying schedule changes and improved connections to move people within Long Island.

C. ISSUES OF LAND USE AND ENVIRONMENTAL PROTECTION

Long Island has long since given up its popular image as a suburb of New York City. The Census Bureau has recognized this change by designating Nassau and Suffolk counties a Metropolitan Statistical Area (albeit one without a central city). This designation reflects that fact that Nassau County in particular has become a major employment center in its own right. Thus, automation of a major corridor through the mixed employment and residential development in Nassau can be expected to have complex land use effects, many of which depend in important ways on the scenario adopted.

Nassau

Since roadway congestion is a major problem in the corridor, it is reasonable to expect that an AHS application to the LIE will, by reducing congestion in the short run, induce further development in the affected areas. Currently, the average commute in Nassau County is 31.5 minutes (Census 1990). If the average commuter takes the LIE for the average amount of rush hour time (21 minutes), then approximately 2/3 of the daily commuting time is spent on the LIE. Reducing this 21 minutes to, say, 7 minutes would cut the average commute by 14 minutes. Commuter and business response to such a reduction are likely to include relocation. Locations accessible to the AHS will become increasingly attractive, bidding up their value and increasing the intensity of land use. The land use effect of effective automation on the LIE would thus be twofold: it would induce overall decentralization and concentrate land use near the AHS.

Congestion reductions on alternate roads, by making them more attractive, will reinforce the decentralization induced along the LIE. But access to the LIE AHS will continue to be more valuable than access to alternate, conventional, east-west routes. As origins and destinations cluster around the automated corridor, congestion can be expected to increase. Effective tolling of the system could help to mitigate these effects, but unless the perceived benefit of the AHS is entirely eliminated by tolls, some effect is likely to remain. Tolls could, however, change the pattern of development. If, for example, tolls are so high that only the relatively wealthy resident will be able to afford them, then changes in land use patterns will be especially pronounced among the highly skilled and their employers. Skilled service firms and their residents will find accessibility to the LIE AHS valuable, and will locate so as to maximize their ability to use the system for their commutes.

Suffolk

The land use effects of an AHS in this location would be felt beyond Nassau County. The average commute in Suffolk County is about 28 minutes, noticeably less than in Nassau. While 70% of Suffolk residents work within the County, the remaining 30% work elsewhere, largely in Nassau and New York City. Much of this 30% will see their commute reduced with the adoption of AHS on the LIE, meaning that they can live farther out the island (where land may be cheaper) for the same length of commute. In addition, businesses may find Suffolk locations, from which it will be easy to draw workers from densely populated Nassau County, newly attractive. There is the potential for substantial environmental impact on the remainder of Long Island if substantial development occurs in Suffolk County.

New York City

Fewer than one in ten New York City residents works outside the five boroughs. Thus changes in the time cost of commuting along the LIE can be expected to have little direct effect on New York City commuters. They will benefit little, if at all, from the adoption of AHS on the LIE. Importantly. however, businesses may be induced to move out of the city and into Nassau-Suffolk, with negative impacts to the city's tax and employment bases.

V. THE PHOENIX-TUCSON-NOGALES CORRIDOR

INTRODUCTION

The site in Arizona is a 180 mile mute that moves along portions of Interstate Routes 17 and 10, southward from the northeastern edge of central Phoenix through Tucson (120 miles), and then along Interstate Route 19 from Tucson to Nogales (60 miles). Half of Arizona's population resides in Maricopa County, which includes Phoenix. Together with Pima County, which includes Tucson, and Pinal County between the two, this area accounts for almost three quarters of the state's population of four million. I-10 between Phoenix and Tucson is the busiest road in Arizona for both passenger traffic and commercial vehicles into the Phoenix area.

Most of the designated site runs through fiat desert or grasslands. The site ends at the United States border across from Sonora, Mexico and is at the southern end of the Desert Pacific Trade Corridor (CANAMEX). It is two lanes wide in each direction for most of the way. but has up to five lanes in metropolitan Phoenix and will soon have three lanes through all of the Tucson area. In 1992, the average daily traffic in the Phoenix area reached almost 200,000 vehicles on a section of the I-10 known as the Broadway curve (located on the edge of Southwestern Phoenix and the City of Tempe). This number is twice as high as any point on the road outside that area, including central Phoenix; downtown Tucson, for which no comparable information is available, may be an exception, but this is unlikely. Truck traffic accounts for approximately 35% of the traffic in most of the corridor, except in Phoenix where the percentage of passenger cars and vans increases.

The state expects that truck traffic will rise substantially along this corridor with the reduction of restrictive trade practices specified under the North American Free Trade Agreement (NAFTA). The state has in fact designated the Nogales-Tucson stretch as the most important for the future movement of freight through to the North, and is considering the reconstruction of either U.S. Routes 60 and 93 northwest from Phoenix, or an extension of I 17 north of Flagstaff, (probably the former) to complete the corridor through to Interstate Route 15. General traffic in this area may increase still further if a controversial proposed regional airport between Phoenix and Tucson is ever built.

A. ISSUES Of COST AND EQUITY

Any proposal for an AHS at this site would compete with an enormous list of defined transportation needs in Arizona. The Arizona Department of Transportation (ADOT) 1990 plan determined that during the next ten years these needs might outstrip revenues by as much as $13 billion. The needs cited in the study included: 1) Construction and maintenance of roadways at the local, county and state levels ($16.1 billion); 2) Mass-transit needs in Phoenix and Tucson ($695 million-S1.5 billion); 3) Rural and small-city transit programs ($73.3 million-S293.4 million); and 4) Airport improvements ($696 million-S904 million). Maricopa and Pima counties, mostly through the activities of their MPO's, have also developed regional transportation plans.

Phoenix has an ambitious plan for freeway construction, which is only partially built, much of it in unconnected segments. In 1985 the citizens of Maricopa County approved an half-cent excise tax to construct the entire 230 mile MAG freeway system over a 20 year period (1986-2006) as well as some mass transit, but it will raise only half of its estimated revenue. Without the authorization of additional local funds, much of the freeway system will remain unbuilt. Another tax referendum may occur this year in Phoenix; the most recent proposals to support a freeway system around Tucson (in 1984 and 1986) were defeated.

In early 1993, the Arizona Department of Transportation (ADOT) began work on the first of series of projects to implement a freeway management system (FMS), a traffic monitoring and control network designed to relieve congestion on the existing Valley (Phoenix area) freeways. Phase I calls for implementing the FMS along 29 miles of freeways and focuses on I-10 and I-17; those portions of the I-10/17 in Phoenix contained in our defined route are included among these. Completion of the first phase will cost $21 million, and the FHWA provided majority funding support.

Local mass transit could considerably reduce congestion in Phoenix, but that approach has little or no constituency. Another referendum to fund transit projects has already been defeated there. More support exists in Tucson, where a proposal for light rail along a main thoroughfare (Broadway Road) has received serious consideration; no funds, however, are yet available for anything more than a demonstration project.

The combination of environmental restrictions and neighborhood opposition make it almost impossible to increase the number of lanes through Phoenix or Tucson. There is, however, an HOV lane in Phoenix which is barely utilized and unlikely to survive the mandated five-year trial period; it is a candidate for an AHS lane. The new third lane in Tucson could also be available for such a purpose, although it would be much easier to dedicate it to AHS before the driving public gets used its availability for mixed traffic.

In the rest of the corridor an additional lane would be necessary for an AHS; using one lane of the two existing lanes for an AHS would leave insufficient capacity for general traffic. Constructing an additional lane is possible, but would confront the usual problems of road building in this area: road subsidence is a serious problem because of the declining water table; the existing right of way (which should be sufficient) borders Indian reservations and cannot be expanded without difficult negotiations and substantial expense; and there are potential archaeological sites everywhere. Again, spending local money on such construction would be very difficult, because of competing transportation needs.

Tolls are the logical method for financing an AHS in the corridor, but there are no toll roads in Arizona. State law discourages ADOT from constructing toll roads without the participation of private partners, but these partnerships have been complicated by the inability of such entities to be given state land under the Arizona constitution, and by questions concerning the mixing of public with private funds in the development of these roads. Requiring tolls for autos on any public road in Arizona would be extremely controversial.

Assuming the law could be changed, tolls for trucks may be a more manageable issue, especially if clear benefits can be shown for auto traffic on the general lanes. Unless federal funds were available, truck tolls may have to be set to pay all the costs of maintaining and operating the road. Although an AHS would provide clear benefits to truck owners in safety and reliability, the toll structure would also have to make financial sense to the truckers,. especially the fleet owners. The technology in the trucks would probably have to be widely usable elsewhere, or otherwise be subsidized. Again, tolling in this corridor would also require a change in the Interstate Highway Law.

Unlike an AHS lane for relatively wealthy private vehicle owners, an AHS lane for trucks should not raise volatile equity issues. In any case, to move additional people along this corridor, especially between Phoenix and Tucson, rail connections are likely to be preferable. The state has already studied the construction of a railroad transportation line and concluded that both a Phoenix-Tucson and a Tucson-Nogales route were viable, although their impact would initially be limited. Additional mass transportation studies have been authorized and funded; they focus on airport connections from Phoenix and Tucson which may be financed in part by airport taxes.

B. ISSUES OF POLITICAL STRUCTURE

ADOT is responsible for the state highway system, including Santa Cruz, Pima, Pinal and Maricopa County freeways and expressways. The Maricopa Association of Governments (MAG) has responsibility for planning the freeway system funded by the original excise tax in Maricopa County; it is also the MPO for metropolitan Phoenix. The Pima Association of Governments (PAG) is the MPO in the Tucson area. Other relevant MAG and PAG, are relevant for transportation planning along 82.4 miles of this corridor. The remaining 97.6 miles fall within Pinal County (67.5 miles) and Santa Cruz County (30.1 miles) which have no MPO's involved in their transportation planning processes. There are numerous smaller local governments along our defined corridor.

Only ADOT is concerned with the entire state. MAG has substantial technical capacity, but it has functioned more as a regional legislature than a planning organization; as evidenced by the fragmentary freeway segments around Phoenix, each municipal government represented by MAG has demanded benefits for their area rather than setting system-wide freeway priorities. The proposed regional airport between Phoenix and Tucson has divided politicians at all levels of government.

Transportation issues in general have been one of the most volatile in the state for a long time, particularly within Maricopa and Pima Counties. The credibility of at least one of the relevant transportation agencies (MAG) has been substantially undermined by the revenue shortfall for the freeway system. There is a high level of skepticism about all new proposals, which would certainly be extended to proposals that include new or untried technology. It may be difficult to overcome suspicion that any new project, however it is funded, would come at the expense of a project under discussion for a long time. Taken together, the constituents for these unbuilt projects make up a considerable political force.

It is possible that an AHS truck lane proposal would be sufficiently different from previous recommendations, and sufficiently limited in its direct effects on the general population, to be politically acceptable. It could engender opposition from other segments of the freight industry, and it may be inconsistent with an intermodal approach to freight movement in this area, but it is less likely to be seen to be in competition with other proposed transportation projects for mixed use. The difficulties in deploying any AHS project in Arizona, however, should not be minimized.

C: ISSUES OF LAND USE AND, ENVIRONMENTAL PROTECTION

Between 1960 and 1990 the population of Maricopa County increased 219%, while employment increased 465%. The highest rates of population and employment growth occurred in the 1970's. Of the thirty largest United States Metropolitan Areas, the MAG area ranked first in population growth with a 41% increase between 1980 and 1990. Over the next 30 years, growth should continue, but at a slower rate than in the past.

From 1990 to 2020, MAG projects that Maricopa County population will increase by 93% to 4.1 million and employment will rise 85%. To determine population density in its Municipal Planning Area (MPA), MAG divides its MPA into Regional Analysis Zones. In 1990, the density per square mile ranged from below 250 people per square mile in the most outlying areas of the region, to densities greater than 6,000 per square mile, mostly in the central areas of the earlier developed cities. MAG projects that this central density will increase further, and that more development will also continue in the outlying areas of the MPA so that become more densely populated.

Pima County will also grow in population, but its absolute numbers will remain far below those of Maricopa County. PAG projects a doubling of the population by the turn of the century for both the cities of Marana and Oro Valley, northwest of Tucson along the I-10. Marana's population, which now contains 3,000 residents, should rise to 100,000 by 2035. Tucson is expected to grow at about a 1% yearly rate, South Tucson should stay about the same, and the unincorporated areas of Pima County should' see substantial increases. PAG predicts an average of about 2.1% annual population growth'for Pima County over the next ten years, and that it should exceed 1 million in population by 2010. Both Marana and Oro Valley have been aggressive in their annexation policies.

The actual land areas contained within the defined Metropolitan Statistical Areas (MSA) for both the Phoenix and Tucson areas are almost identical, but Phoenix is much more developed. In 1980, the land area for the Phoenix MSA encompassed 9, 127 square miles, and increased slightly to 9,204 square miles in 1990. The Tucson MSA encompassed 9, 187 square miles in 1980 and remained there in 1990.

The Phoenix and Tucson areas resemble those of California in that they are low-density, auto dependent cities whose. growth occurred after World War II. Unlike Northeastern cities, they generally do not have one strong city that is surrounded by a number of suburban satellites.. Phoenix and Tucson have engaged more strongly in annexation policies which prevented the rise of numerous little suburbs. Between 1950-90, Phoenix proper grew from 17 square miles to 420 square miles, and Tucson grew from 10 to 156 square miles.

The Phoenix area does have a serious air pollution problem, especially in the Winter when the pollution become trapped near the ground because of meteorological and geographical factors. The state requires the use of oxygenated fuels during the winter months which helps to decrease carbon monoxide levels, but does nothing for the visible pollutants. On November 15, 1993, Arizona submitted its most recent pollution abatement plan to the Environmental Protection Agency (EPA). It is not clear how an AHS would affect the plan.

Automation of a truck lane along the Nogales-Tucson-Phoenix corridor can be expected to exacerbate some of the problems already faced by southern Arizona. Since segregating trucks will presumably reduce congestion on the mixed lanes, travel cost will fall for private passenger vehicles, encouraging further decentralization. In the Phoenix area, southward development along the corridor is currently constrained by the Gila Indian Reservation, which lies along the designated route just south of Tempe. The Tucson metropolitan area, however, may experience significant decentralization as a result of the system. Increasing the efficiency of the transportation network between intermediate localities and the larger cities of the area can be expected to enhance the already substantial growth expected in towns such as Marana and Oro Valley. Attendant to this decentralization may be further air pollution, as vehicle miles travelled increase, albeit at less environmentally damaging speeds.

For businesses, the effect of an automated truck lane along the corridor will depend largely on the location of exits and entrances. The Southern Pacific railroad parallels the route from Phoenix to Tucson, raising the possibility, already under consideration by local planners, of more truck-rail transfers for trans-continental freight. Both Phoenix and Tucson plan improvements in their intermodal freight facilities in the post-NAFTA era. The value of these improvements could be greatly influenced by truck lane automation. Planners in Tucson expressed strong hopes that such a system include access to south Tucson, where a significant truck-rail transfer facility is under consideration. One likely result is that freight bound for the eastern United States would travel the corridor from Nogales to Tucson, then load to rail in that city, while westbound truck freight would continue to Phoenix and join rail there, with the opposite obtaining for Mexico-bound goods. The relative size of the developmental effects would then depend on the relative volumes of east- and westbound freight. Regardless of the direction of trade, truck lane automation of the Nogales-Tucson-Phoenix corridor is likely to draw freight from other corridors, notably routes passing through El Paso, Texas, encouraging development in arid southern Arizona.

VI. CONCLUSIONS

Within the parameters defined in Part I of this paper, it is clear that a large number of institutional problems must be overcome before an AHS with dedicated lanes can be deployed. There will always be site specific problems, as there were in the locations under consideration here. Nevertheless, some general conclusions can be drawn from the discussion in Part II and from a review of some of the major issue areas examined in Parts III, IV, and V.

First, a great many of the institutional issues are endemic to any plans to build roads in the 1990's or beyond. Road expansion in congested places is constrained by geographical limitations, neighborhood opposition, environmental restrictions, and high construction costs. In these locations, as well, there are usually a large number of jurisdictions, or a large number of transportation agencies, which make highway construction more difficult. Conversely, the least congested areas present the fewest problems for road building, although complicated issues can also arise here, including alternative calls on transportation funds and serious land use and environmental effects. Where the congestion is least, however, the traffic management benefits of an AHS are also minimized.

Second, there are a number of institutional problems which arise because AHS is in the early stages of development. If the technology is not generally available at modest cost, there are important equity issues involved in reserving or constructing a lane for the use of relatively wealthy private vehicle owners. These equity issues may be more manageable if the AHS lanes are for the use of trucks or buses. For all vehicles, however, there could be significant traffic management problems at the endpoints of a limited AHS network: problems at the exits, up the ramps, on the local streets, in the CBD. These problems reduce the initial benefits from AHS but do not decrease the cost. There are questions as well about the incentive for truck or bus fleet owners to invest in the vehicle technology if its use, or the ability to depreciate its cost, is also initially very limited. Finally, there are political issues which may arise from suspicion about new technology.

Third, regional planners are already planning out there for the next five, ten, and twenty years, and their current proposals do not include AHS. Transportation planners in congested areas are looking in most cases to rail projects, which often address the same transportation issues as an AHS, for a solution. In these places, rail connections often exist, can be enhanced, or can be built with less difficulty than highways, (but not necessarily less cost); from an institutional point of view, rail projects often present a viable alternative to a new AHS for passenger vehicles. In some cases, such as the Urban Core project described in Section III, an AHS would compete with such proposals. In others, like the intermodal freight facility expansions in Arizona, a well-designed AHS could complement current plans. Planners in less congested areas are considering more conventional approaches, including highway construction, but these may be intended mostly for restricted use, such as commercial traffic.

Taken together, these three factors lead to some possible suggestions relevant to the deployment of AHS. Those plans for conventional highways which make sense and are consistent with later conversion to AHS ought to be encouraged or assisted; in this category, for example, would be the truck lane in the Nogales-Tucson-Phoenix corridor, now in the early stages of discussion. Similarly, the use of at least some AHS technology to help solve otherwise intractable transportation problems, such as those involving the XBL at the Lincoln Tunnel, should also be encouraged or assisted; projects at such sites could pay substantial dividends. Application of the technology to a mode of transportation that serves moderate-income commuters on an existing, heavily used corridor under the jurisdiction of relatively few actors provides the kind of setting that could allow an early success. But AHS advocates must remain aware that the system has an important competitor in rail.

Beginning the general deployment of AHS with reserved or newly-constructed dedicated lanes may not be possible;the political obstacles may be too great and the initial real or perceived benefits too small. A system of subsidies could be considered to overcome some of these problems; such subsidies would make most sense for buses, where the social benefits are likely to be greatest. It may be best, however, to let the technology disseminate in stages and let the demand for reserved or dedicated AHS lanes gradually build. Again, for as long as the technology is on the vehicle and the cost born by the owner at its installation, for as long as the vehicles 'travel on existing highways and within the current mix of traffic, there are few institutional issues, if any.

This gradual approach, combined with assistance to specific projects which are promising from an institutional and engineering point of view, would avoid much of the long list of problems outlined in this paper. It would not produce nearly as many traffic management benefits as a dedicated system, but there could be clear benefits for the users in safety, reliability, comfort and convenience. In the long run, that may be a sufficient foundation to build demand for an extensive automated highway system.

REFERENCES

Adler, Howard Jr. in IVHS Legal Issues, Vol. 2, No. 2 (Spring 1994), pp. 11-15
Bryant, Adam, 1994

Cadieux, Gena in IVHS Legal Issues, Vol. 2, No. 1 (Winter 1994): pp. 8-9
Horan, Thomas A. and Gifford, Jonathan L., 1993, pp. 349-350

Horan, Thomas A., ed., March 29-30, 1993

IVHS America Legal Issues Committee

IVHS America Legal Issues Committee
in IVHS Development and

meeting, November 9, 1993

Procurement Task Force. Procurement Issues
Deployment, pp. 4ff.

IVHS America Legal Issues Committee Procurement Task Force. Procurement Issues
in IVHS Development and Deployment, pp. 9-10, 23-27

IVHS America Legal Issues Committee Procurement Task Force. Procurement Issues
in IVHS Development and Deployment, pp. 11-15, 18-22

IVHS America Legal Issues Committee Procurement Task Force. Procurement Issues
in IVHS Development and Deployment, pp. 16ff.

IVHS America Legal Issues Committee IVHS Legal Issues, Vol. 2, No. 1 (Winter 1994).
pp. 17-20

IVHS America National Program Plan, Draft May 1994, pp. V-22-24

IVHS America National Program Plan, Draft May 1994, pp. V-5ff

IVHS America "Strategic Plan...", 1992, pp. 1-15, 11-39, II1-116-122

IVHS America "Strategic Plan...", 1992, pp. II1-125-127

IVHS America "Strategic Plan...", 1992, pp. II1-128-129

IVHS America "Strategic Plan...", 1992, pp. II1-130-131

Jovanis, Paul, 1993

National Program Plan for IVHS, Draft, May 1994, "Societal Issues"

Regan, Priscilla M. in IVHS Legal Issues, Vol. 2, No. 1, pp.21-22

Russell, Beverly in IVHS Legal Issues, Vol. 2, No. 1 (Winter 1994): pp. 9-13

Smith, Brian L. and Hoel, Lester A., 1994

Soden, Joel and Kogan, Vadim, March 1994

State DOT comments, Calspan Team review meeting with FHWA, December 1993
Stern, Claude M. et al., in IVHS Legal Issues, Vol. 2, No. 1 (Winter 1994): pp. 3-8
Syverud, 1993, pp. 23, 30

Syverud, 1993, pp. 25ff.

Syverud, Kent, 1993, pp. 8

Syverud, Kent, 1993, pp. 12, 20, 30

U.S. Department of Transportation. Nontechnical Constraints and Barriers to Implementation of Intelligent Vehicle-Highway Systems. June 1994, pp. 6-4 - 6-7

U.S. Department of Transportation. Nontechnical Constraints and Barriers to Implementation of Intelligent Vehicle-Highway Systems. June 1994, pp. 7-7 - 7-8

U.S. Department of Transportation. Nontechnical Constraints and Barriers to Implementation of Intelligent Vehicle-Highway Systems. June 1994, pp. 8-5 - 8-8

U.S. Department of Transportation. Nontechnical Constraints and Barriers to Implementation of Intelligent Vehicle-Highway Systems. June 1994, pp. 9-2 - 9-7

Walsh, Michael P., August 1994

"Workshop on IVHS & Intellectual Property: Breakout Sessions", IVHS Legal Issues, Vol. 2, No. 2 (Spring 1994), pp. 25-27

BIBLIOGRAPHY

American Road & Transportation Builders Association, Public/Private Partnerships in Transportation: The State-of-the-Art, Washington, D.C., n.d.

Benekohal, Rahim F. and Wienrank, Charles J., "Institutional Barriers for Implementation of IVHS Technologies to CVO - an Illinois Case Study", University of Illinois at Urbana-Champaign, December 1993

Booz0Allen & Hamilton Inc., Institutional Impediments to Metro Traffic Management Coordination, Task 5-Final Report, Volpe National Transportation Systems Center, Sept. 1993

Brown, Kirk, "IVHS and the Future of State Departments of Transportation", IVHS Review, Spdng 1993, pp. 51-62

Bryant, Adam, "Aviation Bill Encourages Manufacturers". New York Times, September 4, 1994, pp. 20

Cadieux, Gena E., Testimony before Subcommittee on Investigations and Oversight of the US House of Representatives Committee on Space, Science and Technology, Nov. 10, 1993

Calspan Team review meeting with FHWA, New York, NY, December 7-8, 1993

Card, Andrew H., Jr., Statement before Subcommittee on Investigations and Oversight of the US House of Representatives Committee on Space, Science and Technology, Nov. 10, 1993

Congress, Nita, "The Automated Highway System: An Idea Whose Time Has Come", Public Roads: Summer 1994

Conroy, PJ, "Transportation's Technology Future. Prospects for Energy and Air", Transportation Research Board Journal, Tr News Issue 148, Transportation Research Board, Washington, DC, 1990

Doi, Randolph M., Testimony before the Subcommittee on Investigations and Oversight of the US House of Representatives Committee on Science, Space and Technology, Nov. 10, 1993

Ema, Chris E., Letter to the Editor, ITE Journal, December 1993, pp. 8

General Accounting Office, Smart Highways: An Assessment Of Their Potential To Improve Travel, 1991

General Motors Technical Center, Warren, MI. Systems Studies of Automated Highway Systems. Federal Highway Administration, Washington, D.C., 1982

Haines, Marsha J. And DeBlasio, Allan J., "Identification and Definition of Institutional Issues". Volpe National Transportation Systems Center, Cambridge, MA for Transportation Studies Division, Federal Highway Administration, Nov. 1992

Horan, TA, Shucet, P, Stephens, BW, IVHS and Air Quality: Results of a National Workshop, IVHS America; Washington, DC; 1993

Horan, Thomas A., editor, "National IVHS and Air Quality Workshop: Proceedings". George Mason University, March 29-30, 1993

Horan, Thomas A. and Gifford, Jonathan L., "New Dimensions in Infrastructure Evaluation: The Case of Non-Technical Issues in Intelligent Vehicle-Highway Systems. Policy Studies Journal, Vol. 21, No. 2, 1993

Huffman, Bart W., Kornhauser, Alain L., and Huber, Eric C., "The Law and Automated Highway Systems: Investigations of Cruise Control and Anti-Lock Brakes", Transportation Program, Department of Civil Engineering & Operations Research, Princeton University, 1994

IVHS America Federal IVHS Program Recommendations for Fiscal Years 1994 and 1995 (Report No: IVHS-AMER-92-5), IVHS America, Washington, D.C., October 15, 1992

IVHS America Legal Issues Committee and Federal Highway Administration. "Intelligent Vehicle Highway-Systems Public and Private Partnerships: Managing the Legal Issues", Summary of Conference Proceedings, Dallas, TX, January 25-26, 1993

IVHS America Legal Issues Committee meeting, November 9, 1993, Northbrook, Illinois

IVHS America Legal Issues Committee. IVHS Legal Issues, Vol. 1, No. 1 (Fall 1993)

IVHS America Legal Issues Committee. IVHS Legal Issues, Vol. 2, No. 1 (Winter 1994), including Stern, Claude M. et al., "Intellectual Property Rights and the National IVHS Program" (excerpt), Nossaman, Guthner, Knox & Elliott (for FHWA), San Francisco, CA, December 31, 1993, pp. 3-8; Cadieux, Gena. "Intellectual Property Components of Procurement Reform", pp. 8-9; Russell, Beverly, "The Government License Under Federal Funding Agreements", pp. 9-13; Regan, Priscilla M., "Privacy and IVHS", pp. 21-22

IVHS America Legal Issues Committee. IVHS Legal Issues, Vol. 2, No. 2 (Spring 1994), including Adler, Howard Jr., "The General Electric-DeBeers Indictment --Does It Portend More Aggressive Criminal Antritrust

Enforcement, pp. 11-15; "Workshop on IVHS & Intellectual Property: Breakout Sessions", pp. 25-27

IVHS America Legal Issues Committee Procurement Task Force. Procurement Issues in IVHS Development and Deployment, n.d.

IVHS America, National Program Plan for Intelligent Vehicle-Highway Systems, Draft May 1994

IVHS America Proceedings of the 1992 Annual Meeting of IVHS America, Vols. 1 and 2. IVHS America, Newport Beach, CA, May 17-20, 1992

IVHS America Strategic Plan for Intelligent Vehicle-Highway Systems in the United States, IVHS America: Washington, D.C., May 20, 1992

Jovanis, Paul P., "Responding to IVHS Training Needs: A Curriculum for 21st Century Professional Education". University of California, Davis, for IVHS AmeriCa, April 1993

Kentucky Transportation Center Staff, "Identifying Institutional Concerns, A Preliminary Paper, Draft, The Advantage 1-75 Policy Committee, March 1992

Kragh, Brenda, "Assistance Sought in Establishing Network", SEFTalk, Newsletter of TRB Committee on Social and Economic Factors in Transportation: Vol. 1, No. 2, Winter 1993, pp. 1-3

Lamm, Lester P., Statement before Subcommittee on Investigations and Oversight of the US House of Representatives Committee on Space, Science and Technology, Nov. 10, 1993

Marks, Peter, "For a Few Lucky Motorists, Guidance by Satellite," New York Times: April 1, 1994, pp. 1

Pound, Edward and Pasternak, Douglas, "The Pork Barrel Barons", U.S. News & World Report: Feb. 21, 1994, pp. 39-43

Saxton, Lyle, "Automated Control -- Cornerstone of Future Highway Systems". IVHS Review, Summer 1993, pp. 1-16

Slater, Rodney E., Statement before Subcommittee on Investigations and Oversight of the US House of Representatives Committee on Space, Science and Technology, Nov. 10, 1993

Smith, Bdan L. and Hoel, Lester A., "Preparing the New Transportation Engineer: IVHS and Transportation Education". Charlottesville, VA, March 1994, for IVHS America

Soden, Joel and Kogan, Vadim, "Automated Highway Systems and Air Quality". Calspan PSA Interim Report, March 1994

Syverud, Kent, Final Report: Legal Constraints To the Research, Development, and Deployment of IVHS Technology in the United States. FHWA, Michigan Law School, Ann Arbor, Michigan, March 31, 1993

Texas Transportation Institute, Mobility 2000 Workshop of Intelligent Vehicles and Highway Systems, Texas A&M University, College Station, TX, 1990

Transportation Research Board, Sixth National Conference on High-Occupancy Vehicle Systems, Transportation Research Board, Washington, D.C., Transportation Research Circular, Issue Number 409, 1993

Turnbull, KF, The Application of Intelligent Vehicle Highway Systems Technology To High-Occupancy Vehicle Facilities, Transportation Research Board; Washington, D.C., 1993

Urban Transport News, "Slants and Trends". Vol. 22, No. 17, August 17, 1994, pp. 129

U.S. Department of Transportation, Nontechnical Constraints and Barriers to Implementation of Intelligent Vehicle-Highway Systems. June 1994

Volpe National Transportation Systems Center, Byun, JH, Project Monitor. IVHS Environmental Issues, Federal Highway Administration, Washington, D.C., 1993

Walsh, Michael P., "Technological Developments Which Should Lower Emissions from Vehicles on Automated Highway Systems", August 1994