Precursor Systems Analyses of Automated Highway Systems

RESOURCE MATERIALS

Institutional and Societal Aspects

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PRECURSOR SYSTEMS ANALYSES

OF

AUTOMATED HIGHWAY SYSTEMS

Activity Area O

Institutional and Societal Aspects

Results of Research

Conducted By

Delco Systems Operations

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.

Original signed by:

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

NOTICE

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* PATH, Richmond, CA; ** Daniel, Mann, Johnson, and Mendenhall, Phoenix, AZ; *** Hughes Aircraft Company, San Diego, CA, ****General Motors, Warren, MI

16. Abstract
This study addresses institutional and societal aspects of Automated Highway Systems (AHS) in four areas: impact on State and local governmental agencies, environmental issues, privacy and driver comfort, and vehicle-driver interface. Issues relating to the feasibility and practicality of developing and implementing AHS are discussed and potential courses of action for issue resolution are identified.

The study discusses the impact of design, operations, and maintenance issues on State and local government agencies. Issues include: uniform design standards, educational capabilities, agency coordination, cost effectiveness, staff training, emergency response, liability, and maintenance needs. Environmental issues are discussed in three main areas: travel issues relating to demand, emissions, fuel usage, noise levels, and others; infrastructure and urban form issues such as visual impact, neighborhood cohesiveness, impact on non-automated roadways, seismic safety, and others; and institutional issues such as barriers among stakeholders, incomplete and inaccurate information, and lack of sufficient involvement by non-highway institutions. Suggestions for resolving these issues include: models to more accurately forecast AHS impacts, education, communication, and participation to help dissolve barriers. Privacy and driver comfort issues include: vehicle and driver information requirements, potential technology requirements, psychological factors, and legal aspects. Vehicle-driver interfaces are illustrated with sketches of potential vehicle displays and controls. Driver interface concepts vary in complexity, hardware usage, and ease of retrofit. Typical AHS situations such as check-in, check-out, entry/exit, maintenance operations, and driver activities are also shown.

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EXECUTIVE SUMMARY

Institutional and Societal Aspects is devoted to the investigation of institutional and societal issues and risks of importance for the implementation and operation of Automated Highway Systems (AHS), focusing on the following four areas of inquiry: impact on State and local transportation agencies, environmental issues, privacy and driver comfort, and driver/vehicle interface.

The investigation of impacts on State and local governmental agencies includes an inquiry into design, operations, and maintenance-related issues. Relative to the design issues category, uniform design standards, educational and technical capabilities, agency coordination and cooperation, program management and cost-effective design can be addressed if sources of risks have plans of action early in post-PSA programs. Once these areas are addressed, then funding is fundamentally reduced to a liability concern related to how AHS is operated and maintained beyond the design phase.

It is recommended that a plan of action involve transit expertise to justify funding necessary for adequate AHS design. The builders and users of AHS defined by the AHS implementation planned by State, regional or local transportation planners subject to Federal guidelines or standards would be a good forum to discuss funding.

Ways to handle tort liability depend on making a highly reliable and safe AHS. The issue of a privately owned vehicle on a public right-of-way will have a variety of liability issues that depend on the chosen representative system configuration (infrastructure or vehicle based). Inadequate funding of operating and maintaining AHS that affects system safety impacts liability and would probably stop further funding of future AHS projects because of fatalities shown to be a direct result of inadequately operating and maintaining AHS.

It is recommended that adequately trained staff planning would lessen liability concerns. The realization of a multi-mode transportation network linking the separate State highway systems may be a realistic approach to upgrading safety and maintainability of our present highways. Most importantly it provides a vehicle for incorporation of an AHS and minimizing and insuring potential liabilities associated with AHS infrastructure highway lanes. The aforementioned transportation network would also provide a way to impose Federal standards that further define operator diagnostics and driver accessibility to the AHS.

The acceptance of system safety and maintainability principles as a necessary step at all phases of AHS development is integrally related to the number of fatalities, injuries, and equipment failures on AHS. Increased emphasis on maintainability using preventive with corrective maintenance planning for AHS and non-AHS public right-of-way is critical to the long-term success of AHS.

The deployment, operation and maintenance of automated highways systems will present unprecedented challenges to all levels of State and local government agencies. These two groups will ultimately be responsible for implementing and maintaining the system. Since

AHS will encompass multiple jurisdictions involving Federal, State, and local governmental agencies, it will require coordination and cooperation by these agencies to produce a smoothly flowing system. Equally important for the overall success of AHS is for the agencies to generate and maintain political support.

The second area of investigation was environmental issues that have generated a considerable level of intense discussion and debate and may pose a greater challenge for resolution than the more technical issues. The major sources of information for the environmental issues discussed was a group of approximately two dozen individuals from regional governmental organizations such as Metropolitan Planning Organizations, professionals in the engineering, planning and economics fields, and members of the environmental community. Data was gathered by means of individual interviews and a focus group.

Environmental issues associated with automated highway systems fell into three major categories: travel-related, infrastructure and urban form, and institutional. Travel-related issues arise from concerns over the consequences of automated highway systems implementation and operation on how much additional travel will be made, by what means, and its secondary impacts on vehicle emissions and fuel usage. The major infrastructure and urban form issues relate to impacts from infrastructure changes resulting from automated highway systems such as visual impacts and seismic safety concerns, as well as the impact on the local neighborhood as a result of potentially substantial increases in vehicle egress onto non-automated roadways. The institutional issues are centered around the relationships among groups of participants in automated highway systems research and development. One group consists of members of the engineering professions while another consists of planners, economists and members of the environmental community. Issues include the barriers that exist between these two major groups, as well as the lack of complete and accurate information and attitudes that each group believes about the other.

Primary suggestions for resolving these issues include: (1) further research into developing modeling tools to more accurately represent automated highway driving to produce reliable estimates of the impacts in areas of travel volume changes, mobility, land use, emissions, and energy consumption, (2) investigation of current methods of environmental impact review processes for applicability to the automated highway systems case, and (3) incorporation of an aggressive process of education, communication, and participation to help dissolve the barriers and help forge a more common vision of a future transportation system with automated highway systems as an integral component.

The next area of research, privacy issues associated with public acceptance of the AHS, fall into two general categories. The first category involves the type of information which may be collected prior to approval for entry or exit to the system. The check-in procedure may include processing of financial, medical, or driving records to verify potential users' qualifications. The objections to usage of this type of data include fear that the security of the data will be compromised, and overall discomfort with the modern trend toward routine collection of personal data. The check-out procedure can range in depth from a simple push button response to verify driver readiness to accept manual control to a complex set of reflex and sobriety checks. There is concern that an exhaustive check-out screening will be perceived as invasive, and will place increased liability on the system for preventing accidents following the transfer of control to the driver. A procedure which requires the driver to request control at the termination of his route may simplify the check-out process and place liability more clearly with the driver for his actions in the manual mode.

The second category involves the ability of the system to track vehicle position. Collection and storage of vehicle routes and travel times for toll or billing purposes may be viewed as invasive to rights of privacy. The storage of route data may not be necessary, depending on the system configuration selected. This aspect may be taken into consideration when the funding issue is discussed. There are several options available which may eliminate the need for storage of the position data for billing, and these may influence the design of the communication and processing functions of the longitudinal control system.

The fourth area of investigation, AHS user interface, will be one of the most important influences on the commercial success of AHS as an option on future vehicles. Even after AHS is fully developed and a technical success, it must sell in the marketplace. The consumer will primarily view AHS in two ways at the important time of decision-making to buy AHS equipment on a new vehicle. The first will be the benefits of safety, travel time, trip convenience, etc. The second will be the look and feel of the interface equipment installed in the vehicle. The vehicle-driver interface is an area of vehicle development which continues to receive a very significant share of new vehicle development funding. Some of the important considerations in the design are:

- Orientation of the displays and controls.
- Method of display (dials, display screens, projected images, digital versus analog, synthesized voice, etc.).
- Method of control input and selection (push/pull/rotary/sliding switches, push buttons, touch sensitive screens, voice, etc.).
- Styling and illumination of the display and control space.

As new vehicles are developed, designs are tested in clinics to gauge consumer acceptance of the new design. When vehicles are produced and sold , the accompanying advertisement presents each as a new level of refinement. The ultimate decision of what works well for the user, however, in made in the marketplace.

Various scenarios that a driver may experience while using the AHS have been produced in the form of sketches and accompanying descriptions of representative concepts. These concepts, while not strictly defining the future of AHS, do present visual aids to stimulate the thought process concerning the driver interface and typical AHS situations. The driver interface concepts include potential electronic interface units and their positions within the vehicle, while typical AHS situations include check-in, check-out, entry/exit, commercial, transit, and maintenance situations, as well as potential driver activities while on the AHS.

INTRODUCTION

This report presents the findings for research conducted on the Precursor Systems Analyses (PSA) of Automated Highway Systems (AHS) work on Activity O – Institutional and Societal Aspects. Work in the following four areas of inquiry was performed: (1) impact on State and local governmental agencies, (2) environmental issues, (3) privacy and driver comfort, and (4) driver and vehicle interface.

The objective of this activity is to identify the issues that will influence the feasibility and practicality of developing and implementing automated highway systems and to define potential courses of action for dealing with each issue in these four areas.

The investigation of impacts on State and local governmental agencies includes an inquiry into design, operations, and maintenance-related issues. Design issues include uniform design standards, educational and technical capabilities, agency coordination and cooperation, program management, and need for cost-effective design. Operational issues include the operations of Transportation Operations Centers, staff training, response to emergencies, planning during transition phase, and liability and require attention. Maintenance issues discuss the need for increased emphasis on maintainability using preventive measures with corrective maintenance planning for AHS and non-AHS public right-of-ways.

The set of environmental issues examined was based on a set of approximately two dozen interviews conducted with members of governmental organizations, specifically Metropolitan Planning Organizations (MPO), professionals in engineering, planning, economics, and members of the environmental community. Issues were grouped into the following three areas, travel-related, infrastructure and urban form, and institutional. Travel-related issues were concerned with the consequences of AHS implementation and operation on how much more travel would be made, by what means, and its secondary impacts on vehicle emissions, fuel usage, and noise levels. Infrastructure and Urban Form issues were concerned with the visual impacts of AHS, potential deterioration of neighborhood cohesiveness, increases in traffic on non-automated roadways due to AHS vehicle access and egress, and seismic safety. Institutional issues focused on barriers among major AHS research and development participants, incompleteness and inaccuracies in information each “side” has of each other, and lack of sufficient involvement from non-highway institutions.

Privacy and driver comfort issues considered were those that arise from AHS information requirements, vehicle information requirements, driver information and potential technology requirements, AHS equipment needs and psychological factors.

The investigation of the AHS vehicle-driver interface was based on the development of concepts to illustrate what is possible for the driver interface as well as for typical AHS situations. Important design concerns for vehicle displays and controls include their orientation, method of implementation, styling, and illumination. Driver interface concepts include potential electronic interface units and their positions within the vehicle, while typical AHS situations include check-in, check-out, entry/exit, commercial, transit, and maintenance situations, as well as potential driver activities while on the AHS. Potential issues include the compatibility with malfunction management strategies of concepts which allow the driver to rest with the steering wheel and foot pedals moved to out-of-the-way positions, the potential need for standardization of certain details of AHS control and communication interfaces from vehicle to vehicle, the sharing of AHS driver interface with front seat passenger, the extent to which the AHS interface would be able to use components already present as part of the more general Intelligent Transportation Systems interface.

REPRESENTATIVE SYSTEM CONFIGURATIONS

The representative system configurations (RSC's) were generated very early in this Precursor Systems Analyses of AHS program. These RSC's are used throughout the various areas of analysis whenever a diversity of system attributes is required by the analysis at hand. The RSC's identify specific alternatives for 20 AHS attributes within the context of three general RSC groups.

Since the RSC's have such general applicability to these precursor systems analyses, they are documented in the Contract Overview Report. There are, nevertheless, issues discussed in this activity report that are related to the RSC's. For example, the vehicle emissions and fuel usage impacts component of the environmental issues investigation may vary across the RSC's resulting from differences in the coordination unit, whether platoon (small or large) or single vehicle slot.

TECHNICAL DISCUSSION

Task 1. Impact Of AHS On State And Local Governmental Agencies

Introduction

The deployment, operation and maintenance of Automated Highways Systems will present unprecedented challenges to all levels of State and local government agencies. These two groups will ultimately be responsible for implementing and maintaining the system. Since AHS will encompass multiple jurisdictions involving Federal, State, and local governmental agencies, it will require coordination and cooperation by these agencies to produce a smoothly flowing system. Equally important for the overall success of AHS is for the agencies to generate and maintain political support.

The objective of this Activity task is to identify a range of institutional and societal issues and risks of concern to AHS based on the knowledge from all team members. Inputs and critiques have been incorporated by all team members in order to better develop a prioritized list of issues and concerns. The researchers for this task have long backgrounds as employees of State and local transportation agencies and in providing professional engineering services to these agencies. The conclusions derived within this task, and in other related activities conducted by the same researchers, are based in part on this experience but they are not simply the opinions of the researchers. They are also based on many conversations with personnel from operating agencies. The conversations were held at AHS conferences during the project, at Transportation Research Board meetings, in other face to face conversations, and in telephone conversations. Every effort was made to faithfully synthesize the opinions of the numerous personnel interviewed during the course of the project, without favoring any preconceived ideas.

The objective of the risk analysis to be presented here is to bring up issues and concerns that would affect the long-term success of AHS. In this subtask activity topic section, classification of risks into facets will be introduced and utilized. Each facet requires an examination of the source of the risk. The facet categorization of the risk is not as important as understanding the source of the risk and the impact area(s). This approach provides a structure to examine the risks as critical elements for effective risk management.

The conclusion/summary section will have grouped, prioritized, and eliminated issues and also highlighted concerns for further analysis beyond PSA.

Once concerns have been isolated for recommended risk analysis/management beyond PSA , one primary use of this analysis in the post-PSA will be to provide a Risk Factor Method.(1) This Risk Factor Method can be used to estimate the total added program costs that might be expected due to risks related to any future program's Work Breakdown/Task Structure. The structured framework of faceted risks (issues and concerns) can be used to determine factors which would increase individual baseline tasks or subtasks costs to cover additional costs resulting from those risks.

The overall objectives beyond PSA of the risk analysis presented for this section are to: 1) provide a risk assessment that can be used to define future plans of action, and 2) determine a reasonable budget when including the identified risks. Clearly there is a further AHS program(s) (future) risk due to the potential for cost growth beyond the baseline cost estimate.

Design Issues

Uniform Design Standards And Guidelines

Uniform design standards and guidelines must be developed and adopted by the State and local agencies to ensure compatibility, uniformity, and efficiency while maintaining the integrity of the environment. Because of unique requirements in different regions of the country, special guidelines must be developed. In developing these standards and guidelines, consideration must be given to the esthetic consistency with the surrounding terrain or urban setting while producing an AHS that is safe and efficient for users and also acceptable to nonusers.

Education and Technical Capabilities

Deployment of AHS nationally will place technical demands on public agencies, which must be dealt with before large scale commitments can be made. It will be imperative to keep the technical managers of public agencies informed of the AHS developments so that they can begin planning for their future involvement. This can be done through a number of ways such as workshops, courses, and professional societies.

Once an AHS project begins, special training for the engineering and technical staff should be provided so that they can become progressively familiar with the new technology during design and installation.[(2)]

In addition public agencies should coordinate with the academic institutions over the technologies and applications needed for future AHS programs.[(3)] Academic institutions must be encouraged to be active partners with the Government early-on with regard to AHS plans and programs. This will ensure that research activities stay on the leading edge and new technologies are rapidly transferred to standard transportation practice.

Organizational changes will be needed in order to meet the wide range of new activities required by an AHS program. As a transition phase, public agencies should seriously consider soliciting private consortiums to design, implement, and operate the AHS. Private companies have more flexibility in acquiring and maintaining the necessary technical skills required for a successful AHS program.

Agency Coordination And Cooperation

A national AHS program will require the commitment of Federal, State, and local governments to work towards a common goal. The States are responsible for maintaining and operating the Interstate Highway System and other State highways where AHS will normally be deployed. Jurisdiction over the highway network within metropolitan areas is usually fragmented between a State and a multitude of local agencies with individual agencies trying to maintain control of their own "world." This situation can lead to jurisdictional fragmentation, inter-jurisdictional project delays, as well as other problems.

Federal and State highway funding programs should contain provisions that will encourage the establishment of organizational structures for agency cooperation and coordination. The concepts of partnering and Total Quality Management (TQM) can be used to achieve this goal.(4)

Some issues are:

- Are the State and local acquisition requirements sufficiently flexible for long-term AHS development?
- Will these same acquisition requirements make it difficult for State and local agencies to work with private sector companies on AHS technology development and testing?
- Are State and local governments, universities, and private companies able to put together and carry out cooperative agreements regarding technology development, implementation, and operations of AHS?

Program Management

In addition to an effective organizational structure, an ongoing program management is critical to the success of the AHS program. Program managers and support staff must be assigned full-time to the AHS effort and not devote only a limited portion of their time as a subset of their broader responsibilities. In the initial stages, outside consultants could be brought in to support this effort. The consultants' role in this situation will be different from the more traditional role in that they will be required to continuously interact and coordinate with the agency in all aspects of the work.

Funding

Funding for the AHS program will be a major issue. Initial capital costs may be substantial and beyond the capability of most local agencies. Federal participation will be necessary for local agencies to successfully implement the AHS. Funding incentives should be devised that will encourage participation of local jurisdiction in joint AHS operations and maintenance programs. A privatization program could be another way of financing AHS projects, if AHS tolls are used to recover capital and operating costs.

Recognition of the critical nature placed on Operations and Maintenance planning, adequate and assured funding must be identified. Federal standards placed on the Operations and Maintenance functions may require Federal dollars.[(5)]

Cost Effective Design

A cost effective design should not only compare user benefits with costs, but also reflect the needs of nonusers and the environment. This approach will add complexity to the analysis, will take into account the needs for a given project, as well as the relative priorities among other projects. The goal of a cost effective design is not merely to give priority to the most beneficial individual projects, but to provide the most benefits to the overall system of which each project is a part.

The primary goal of future AHS programs is to develop and operate a safe and cost-effective AHS that provides an acceptable level of service. It is recommended that State and local governmental agencies emphasize the incorporation of reliability, maintainability, and availability principles into AHS designs. In order to provide cost-effective AHS design(s), programs need to be in place for managing reliability, maintainability, and maintenance planning requirements throughout the whole life cycle. In addition to providing designs that fulfill maintenance planning requirements, highway design methodology must provide design criteria and subsequent technical specifications for detailed design implementation that provide the key system functions necessary to implement an RSC. These requirements should include:

- Applying principles of redundancy in AHS design where necessary.
- Incorporating maintainability principles in all AHS designs.
- Procuring AHS equipment with a history of reliable service in similar AHS or related applications such as rail transit systems, DME instrumentation, and avionics equipment.

It is recommended that the AHS design phases be monitored by State/local agencies (a transportation authority) to ensure that procedures, equipment, and manpower are planned and provided for, when AHS designs are completed, in order to maximize operational service with minimum downtime.

It is further recommended that eventually, a Federal/State/local program to record operating incidents be implemented to make evaluations to determine primary causes, and issue periodic summary reports.[(6)] As in rail transit systems, the goal is to eliminate hazards that cause single and multiple fatalities due to AHS design.

The objective of monitoring all phases of AHS design by State/local agencies is to provide a cost-effective way of requiring all participants to substantiate, control, and minimize the cost of their design contributions. The safety issues related to cost-effective (reliable) AHS systems are discussed in Activity N – AHS Safety Issues.

Operational Issues

Transportation Operations Center(s)

AHS will require a major change in operations and maintenance within a Transportation Operations Center (TOC). Departments of Transportation realize that operations must now become a higher priority because of the various key AHS components or system elements that are absent from conventional highway systems. As a consequence, the TOCs must operate, monitor, and maintain AHS to provide acceptable levels of service, system safety, and reliability.[(5)]

Poor or slow maintenance could create huge liabilities because of multiple fatalities and/or injuries. It is recommended incorporating system maintenance principles into design, through to Operations and Maintenance planning in anticipation of and for AHS operation. As a result more funding for maintenance and achieving acceptable (guideline) maintenance levels are required.[(5)]

The decisions/actions by those in a TOC take on greater importance because of the potential for disaster if errors in judgment are made. Personnel required at the TOCs will most likely have more extensive training and higher salaries.

Adequately Trained Staff

Most public agencies do not currently have the technical capability to manage and operate an AHS.[(2)] Currently the engineering staffs who are experienced in highway and traffic engineering are unfamiliar with the complexities involved in an AHS infrastructure. It is anticipated however that the system will be phased in incrementally over a period of years. Under such a scenario this transition period would allow public agencies to acquire the necessary skills through training and recruitment.

It is assumed that other elements of the Intelligent Transportation System (ITS) will already be in place by the time AHS is deployed. Therefore AHS could be viewed as a logical evolution from other ITS user-services thus making the transition easier for operators.

Incident Response

Since the AHS is a controlled facility, local agencies will be faced with the responsibility of responding to incidents on the automated highway. Incidents may include vehicular breakdowns, foreign objects on the road, inability of the driver to assume control of his or her vehicle, and system malfunctions (see Activity E – Malfunction Management and Analysis). A network of incident response stations may have to be established along the system in order to respond quickly and efficiently.

Transition Period

To achieve an efficient and smoothly flowing system, a great deal of effort must be dedicated to careful planning prior to the actual deployment of AHS.[7,8] It is generally agreed that AHS will be implemented gradually, thus allowing adjustments to the implementation during this transition period. It is anticipated that operational issues can be resolved during this period.

Liability

A major concern is that liability issues may vary significantly depending on the chosen RSC. For example, whether the RSC chosen for detailed design is infrastructure or vehicle-based, a range of issues/implications is generated for:

- The automobile/equipment manufacturer for faulty equipment.
- Operating agency for poor maintenance and poor operating decisions.
- Vehicle owners for poor maintenance of their own vehicles and the AHS on-board components.
- Lead-vehicle owners in a platoon for poor maintenance; other vehicles in the platoon are relying on lead vehicle/driver integrity.

One of the major issues facing State and local governmental agencies are the potential liabilities as technology assumes functions presently performed by the driver. How much responsibility and/or liability are State and local agencies willing to assume? It is recommended that the privately-owned vehicle on a public highway approach to highway transportation be maintained as closely as possible for AHS because of the uniquely AHS liability issue of shared liability between the AHS and the privately-owned car. For example certain RSC variations will have varying degrees of car-smarts vs. infrastructure smarts. Does this then mean that the liability is then divided differently between the owner of the vehicle and the AHS for different RSCs in the event of a failure or accident? It is recommended that a good deal of emphasis on future development be placed upon malfunction management and incident reporting strategies that clearly document system failures since the strategy or approach toward minimizing liability impacts on AHS needs to be devised. As mentioned earlier, AHS scenarios that are highly reliable and safe can minimize the number of liability impacts/uncertainties.

Statewide roadway transportation plans supported by local maintenance programs need to include AHS highway lanes and conventional highways. State and local liability and safety are different concerns that are interrelated. The State trend toward multi-modal coordination of highway and transit systems would minimize failure conditions (potholes, etc. – direct potential liability) by implementing statewide mandatory programs that stress system safety, improved reliability and maintainability of the highway infrastructure. A statewide system maintainability of conventional highways would be better prepared to minimize potential liabilities of, and maintain AHS highway lanes.

One of the major deterrents of acceptance of the ITS concept in the early 1970's was the absence of electronics technology accurate enough to provide the system safety required. This directly impacts the State/local liability issue since the number of accidents and fatalities is closely coupled with the AHS' ability to maintain infrastructure highway lanes and electronics, electronic sensing of equipment malfunctions, and accurate guidance and control. The realization of a multi-mode transportation network linking the separate State highway systems may be a realistic approach to upgrading safety and maintainability of our present Interstate Highway System. Most importantly it provides a 'vehicle' for incorporation of an AHS and, minimizing and insuring potential liabilities associated with AHS infrastructure highway lanes. The aforementioned transportation network would also provide a way to impose Federal standards that further define operator diagnostics, and driver accessibility to the AHS. These minimum standards would help access, clarify, and mold long-term public acceptance of State/local liabilities of a privately-owned vehicle on a public highway.

Several examples of specific liability issues are:

- Unauthorized access to the AHS would produce liability for State and local agencies. An alternative might be that the liabilities be viewed in the same manner as individuals riding a public transit system. This may be a reasonable approach if system safety and reliability is comparable to the catastrophic probabilities of passenger air travel.

- Another example of a State/local liability involves operator's vs. drivers' responsibilities.(9) Should the diagnostics utilized at the off/on ramp be minimized to ensure a minimum level of acceptability (a standard) or be more comprehensive? Clearly the operator responsibility should be minimized. Public acceptance would therefore depend on the inherent safety and reliability of the vehicle and the AHS infrastructure.

- Another concern that might impact State and local agencies are the potential liabilities associated with operator diagnostics and driver accessibility of a large variety of vehicle-types (varied car and truck models and sizes). Specifically, how much information should be made available about the driver (privacy issue) and how much responsibility (and potential liability) should the operator be allowed to assume.

- A key liability issue is generated by a platoon scenario where the lead vehicle has responsibility for detecting obstacles ahead of the platoon. Line-of-sight detection instrumentation makes this a necessity. It may be practical to look at fallback scenarios that use roadside infrastructure control instead of line-of-sight detection from the lead vehicle. This approach removes liability from the lead car and transfers it to the system operator. As in transit train control, the reliability and safety of such a wayside (for AHS, roadside) control system needs to be highly reliable, safe, and standardized.(10)

Maintenance Issues

A primary goal of this analysis is to determine what is expected of and the issues related to State and local governmental agencies developing a safe and cost-effective AHS that provides an acceptable level of service. Maintaining an operational level of service must be achievable by incorporating reliability and maintainability principles into AHS designs and by effectively planning for the maintenance of the operational AHS.

It is recommended that State and local agencies establish a comprehensive and coordinated program for managing maintainability and maintenance planning requirements well before the deployment of AHS. This recommendation is based upon first, the newness of infrastructure electronics, and second, the need for interstate cooperation for the AHS infrastructure.

These State/local requirements include:

- Achieving level of service goals for rural and urban corridor(s) by establishing appropriate maintenance programs and procedures for the AHS.[10]
- Applying the principle of redundancy in design when necessary so that the failure of a single component will not prevent safe, reliable AHS operation.[10]
- Incorporating maintainability principles in all designs. This would require suppliers to demonstrate through formal tests that their equipment meets their stated maintainability goals.[10]
- Procuring electronic infrastructure equipment must be based on a nationwide performance standard and that has a history of reliable services in testbed or other AHS systems, where appropriate.[10]

Technical Capabilities And Equipment

In the public sector, past emphasis of transportation agencies on new construction could create a major maintainability issue. Transportation agencies have emphasized new construction and placed less emphasis on efficient operation of existing facilities. Consequently, maintenance and operations receive low budget priorities. Also the current professional staff typically lacks expertise in communications and electronics. Another maintainability issue is how to maintain the level-of-service and concurrently reduce congestion. Minimizing and monitoring congestion would require traffic regulation of a metropolitan-wide network of streets. There is a need for more coordination in the operation of signals and traffic control measures and maintenance activities between municipalities, or State agencies/freeways and local governments/surface streets. The leadership factor is essential whereby each public sector agency takes initiative to contact neighbor sectors and work toward a framework whereby appropriate cost-effective maintenance levels are uniform, justifiable, and achievable. Public sector agencies might exert their leadership by hiring private contractors or umbrella agencies that cover many localities. For example, coordination in operation of signals, traffic control measures, and maintenance levels would be applied to local streets, arterials, and highways.

Advanced Traffic Management Systems (ATMS) have been available worldwide in varying degrees of traffic control and management over the past 30 years.[4] Despite the readiness and availability of advanced traffic management technology, the integration of freeway and non-freeway applications has been infrequent.

The current and future issue with traffic management is whether to invest in applications of existing technologies for widespread computer-assisted freeway management and signaling control systems. Consequently a concern arises as to what will happen to the long term AHS technology implementation if an investment of a country-wide ATMS is not in place to some degree over the transition phase of AHS development.

Due to the new technology necessary for AHS maintenance several manpower questions are evident:

- What happens to the existing staff?
- Where do the people come from?
- How do the State departments of transportation retain them?

Definitions

1. ISSUE – Items identified in PSA Systems Analyses where there are reasonable questions concerning how to proceed: Issues may arise as concerns are addressed. Issues in this document are posed as questions and are usually resolvable.

1. CONCERNS – Items identified in PSA Systems Analyses that may be risks or issues, but sufficient analyses have not as yet been done to know for sure.

2. RISK – The probability of an undesirable event occurring and the significance of the consequence of the occurrence (relevance: project risk management).

3. RISK ANALYSIS – Utilization of divergent, varied, and comprehensive expert judgment inputs that involve risk identification and quantification.

4. RISK MANAGEMENT – method of managing that concentrates on identifying and controlling the areas or events that have a potential of causing unwanted change.

5. PSA – Precursor Systems Analyses.

6. SYSTEMS ASSURANCE – A system approach to establish and maintain an efficient reliability program (Reliability, Maintainability, and Availability-RMA) to support a cost-effective achievement of overall program objectives for each AHS system element comprising an AHS system. The RMA Programs are applied from early design through operational AHS phases.

7. SYSTEM SAFETY – A system approach for the elimination or mitigation of hazards, through design criteria oriented towards hazard reduction. In addition it involves the utilization of hazard analyses to indicate potential areas of concern that must be addressed from design through operational AHS phases.

8. RELIABILITY – The probability that the system or subsystem will perform satisfactorily for a given period of time when used under stated conditions. The probabilistic definition is converted to an equipment attribute by converting probabilities to equivalent component failure rates. As a result the reliability becomes an equipment attribute that reflects the ability of the equipment to perform its intended function under stated conditions for a stated period of time.

9. MAINTAINABILITY – The probability that a device will be restored to its prescribed functional operation within a given time period when the maintenance action is performed in accordance with prescribed procedures. As with reliability, this defined probability can be converted to equivalent component repair rates or Mean-Time-To-Repair (MTTR) values for easier measurement in tests or in service.

10. AVAILABILITY – An attribute that reflects the readiness of the system to perform its intended function when called upon at a stated instant of time or over a stated period of time. It is usually expressed as the probability that the item will be available when required, or as the proportion of total time that the item is available for use. Consequently, the availability of an item, system element, or system is a function of its reliability and maintainability attributes.

11. O&M – Operations and Maintenance as applied to AHS.

12. TOTAL QUALITY MANAGEMENT (TQM) – A concept or philosophy which emphasizes the prevention of errors rather than merely checking and correcting. It is a departure from relying on inspection for quality control.

13. DME – Distance Monitoring Equipment.

14. CATASTROPHIC PROBABILITY – Probability levels of safety usually expressed in units of (catastrophic failure/ hours). For example for passenger air travel typical numbers are, for human intervention ~(1×10^{-6}) and for equipment ~(1×10^{-9}).

Task 2. Environmental Issues

Introduction

Automated Highway Systems have the potential for providing considerable improvements over current roadway conditions in the areas of vehicle throughput, traffic safety, user comfort, as well as numerous other areas of significance. At the present time, however, issues exist about numerous aspects of AHS deployment and operation as well as the risks involved if these issues are not resolved. Issues may be classified as technical, non-technical, or a combination of these two types. The non-technical issues generally fall under the heading of institutional and societal concerns including, for example, privacy, liability, equity, funding, and environmental issues.

The objective of this task is the investigation of the environmental area issues and risks associated with AHS. In fact, environmental issues straddle both the technical and non-technical domains. Environmental issues have generated a considerable level of intense discussion and debate, and may, in fact, pose overall a greater challenge to resolve than the more technical issues.

The phrase "environmental issues" in the context of AHS is open to varying interpretations. These range from the more restricted view of air quality impacts and vehicle fuel use only, to a broader picture that goes beyond these two characteristics to include certain attributes of urban form or quality of life relative to the local or regional roadway transportation system. Such attributes include:

- The degree of dependence on the automobile for mobility.
- Community or neighborhood cohesion.
- The level of induced travel demand.

In this analysis, the broader perspective is adopted to derive as comprehensive an examination of such issues vis-à-vis AHS as possible.

Prior to the discussion of the issues and risks identification and analyses is a description of the sources of information for this qualitative analysis endeavor. Such information sources consisted of the best professional judgment, opinions, and insights from approximately two dozen individuals conducted by means of both the focus group methodology and individual interviews.

This research into environmental issues associated with AHS consists of the identification and analysis of potential issues and risks that have emerged or are likely to emerge and recommendations for an approach for their resolution. Such recommendations would include action items that could be taken to resolve a problem directly or further research that needs to be conducted to increase understanding to the level needed to produce a well-supported recommendation for direct action.

Sources Of Information

An interesting and significant feature of environmental issues which could help explain part of the intensity of debate surrounding the subject as well as the additional barriers to resolve them is the vast array of groups of individuals from diverse backgrounds with frequently conflicting interests in this subject. Such interests are probably more diverse than for purely technical problems which at least give the perception of a higher degree of cut-and-dried quality about them and thus more readily attained and less controversial solutions. Such groups include:

- Governmental organizations (local and regional Departments of Transportation, MPO's, Councils of Governments, and Transit Agencies).
- Professionals in engineering, planning, economics, and related fields (transportation engineers and planners, urban planners, land use planners, academic researchers).
- Other professionals (public policy analysts, administrators, lawyers, and politicians).
- Interest groups, primarily the environmental community.
- The media.
- The general public, both traveling and non-traveling.

A complete analysis and resolution of environmental issues associated with automated highway systems should draw on all these groups for input to provide both technical and qualitative analysis from different perspectives.

The sources of information for this paper were principally governmental organizations such as MPO's, professionals in engineering, economics, and planning, and members of the environmental community. Data was gathered by the of focus groups and individual interviews.

A focus group was conducted prior to an Institute of Transportation Engineers meeting in the San Diego, California area in March, 1994. The meeting was a collaborative effort between two of the PSA contractor teams.(11) The overall purpose of the focus group was to investigate user acceptance issues of automated highway systems, with an emphasis on environmental issues. The focus group consisted of fifteen professionals attending the conference from throughout the United States in the transportation engineering, urban planning, transportation planning, and land use planning areas as well as members of the environmental community. The conference itself had an environmental theme to it, and a short list of candidate focus group participants was culled from the full list of conference registrants, with the aim of achieving at least a modicum of geographical and professional diversity among the participants. Initial introductory telephone discussions were held to ascertain the interest level in focus group participation. It was felt that a group of no more than approximately twenty individuals would be the most suitable and appropriate to use for this focus group setting. Each participant received prior to the meeting a brief written introduction to automated highway systems that also described the AHS Federal program under the direction of the Federal Highway Administration (FHWA). Prior to the beginning of the focus group session, additional material on AHS was presented that described possible AHS evolutionary deployment and operational scenarios.

While the focus group was very structured in format, the individual interviews were conducted in a more open, less-structured way. Ten interviews were conducted, for which each participant received in advance the same write-up on automated highway systems that was distributed to the focus group participants. A few specific questions were asked of the interviewees in combination with a rather structure-free format of receiving input from them.

Both the focus group participants and the individual interviewees possessed different levels of knowledge of automated highway systems, differing in accuracy and sophistication. The purpose of providing AHS-related information to them was to at least insure that all participants had at least a basic common information base with which to form opinions and provide input. The participants' different levels of accurate information on AHS and how it may lead to reinforcing certain beliefs and attitudes about automated highway systems and the Federal AHS program is an issue that will be discussed in detail in the following section.

Issues: Analysis And Recommendations

A review of the issues raised during the focus group and the individual interviews has resulted in their division into the following three primary groupings: travel-related, infrastructure and urban form, and institutional, from which numerous other issues were derived. This divisional structure serves to facilitate the process of understanding and integrating the issues on a macro-level.

<u>Travel-Related Issues</u>

The travel-related issues stem from concerns over the consequences of AHS implementation and operation on how much more travel is generated, by what means, and its secondary impacts such as vehicle emissions and fuel usage. The issues presented below have linkages and thus are not mutually exclusive.

Current Transportation Paradigm

The current transportation paradigm or model of “how things are done” or “the way the urban transportation system works” may be described succinctly as people driving alone in their cars on vast networks of urban freeways that over time has led to urban sprawl. The issue is that AHS, as currently envisioned, would only encourage the continuation of this same type of “business as usual” behavior, i.e. more driving, more single-occupancy-vehicle (SOV) driving, and more sprawl. Automated highway systems would also emphasize the further development of highways, make SOV driving more attractive by increasing its convenience and comfort at the expense of other modes of travel, such as public transit and high-occupancy-vehicle (HOV) driving. A considerable level of resources have already been invested in such non-SOV travel modes and this investment should be continued.

Impact On Trips

The encouragement of more SOV driving could then mean an increase in trips, trip length, and volume of drivers, even above what such increases might be over time without automated highway systems. These effects could be the result unless there were in place strong measures to counteract them, such as:

- Transportation demand management.
- Congestion pricing.
- Parking pricing.
- Land use planning and management.

At present, the AHS program is not viewed as having such mitigating measures at a central and important place in its research and development effort.

Mode Of Travel

The encouragement of more SOV driving would also mean an emphasis on a single mode of travel, when the emphasis should be placed on the multimodal nature of the transportation system. AHS research and development work should not exclusively focus on the automated mainline portion of a trip, but should consider more holistically the entire trip from origin to destination, which could involve the use of more than one mode of travel.

Associated with the potential encouragement of longer trips at the expense of shorter trips with automated highway systems is the concern over the decrease in use of other travel modes used primarily for shorter trips, such as walking and bicycling. This impact could possibly lead to a degradation of what is referred to in the environmental community as the short-trip network or infrastructure in local neighborhoods.

Vehicle Emissions

The issue of automated highway systems encouraging an increase in driving is also referred to as the induced or latent demand effect. Recall that induced demand may be moderated by the advent of the measures previously discussed. Associated with induced demand is a concern for the potential increase in vehicle emissions. However, several variables play a role in the determination of the actual net impact on emissions. On the negative side, automated highway systems may have the impact of leading to an increase in driving, which on an aggregate basis in terms of total emissions' tonnage would mean an emissions' increase. Moreover, certain pollutants, namely, oxides of nitrogen, tend to increase with increases in speed. Thus, with more freely flowing traffic and greater speeds with AHS, amounts of such pollutants could increase. Also, if vehicles accessing or egressing the AHS develop into lengthy queues, additional emissions build-ups could result at the on- and off-ramps. However, AHS research and development will proceed along with other technological advances, in particular, in areas such as emission control technologies, clean fuels, electric vehicles and others that would have the effect of reducing emissions on a per kilometer basis.

In addition, automated highway systems have the potential for smoothing out the flow of traffic, removing or at least reducing stop-and-go, idling, and sharp acceleration and deceleration driving modes which are known to contribute to vehicle emissions. Moreover, in the context of automated vehicles traveling with much smaller headways than presently possible, i.e., in platoons, preliminary research has indicated there are emission reductions for all vehicles, including the lead vehicle.(12) The true net effect on vehicle emissions is unknown at the present time.

Vehicle Fuel Usage

Also associated with induced demand is a concern for the potential increase in vehicle fuel usage. However, as in the case for vehicle emissions, several variables play a role in the determination of the actual net impact on fuel usage. On the negative side, automated highway systems may have the impact of leading to an increase in driving, which on an aggregate basis of total fuel consumed would mean a fuel usage increase. Moreover, fuel economy is a function of speed, and increases in speed associated with automated highway systems could lead to increases in fuel consumption. Also, if vehicles accessing or egressing the AHS develop into lengthy queues, vehicle fuel consumption would be affected. However, AHS research and development will proceed along with other technological advances, in particular, in areas such as vehicle fuel economy in addition to possible increases in the national corporate average fuel economy (CAFE) standards. This latter change would have the effect of reducing fuel consumption on a per kilometer basis. In addition, automated highway systems have the potential for smoothing out the flow of traffic, as previously described, which could reduce vehicle fuel usage. As in the case for vehicle emissions, in the context of automated vehicles traveling with much smaller headways than presently possible preliminary research has indicated there are fuel efficiency increases for all vehicles.(13) The net effect on fuel usage is unknown at the present time.

Noise Levels

Another travel-related issue resulting from possible increases in traffic volume and travel speeds would be an increase in noise levels at and adjacent to the automated highway system facility. With a potential increase in hourly-lane capacity for automated lanes by a factor of possibly two or more over conventional non-automated lanes, actual noise increases are a possibility.

Recommendations For Resolution Of Travel-Related Issues

When making recommendations for the resolution of any of the issues discussed, the following three questions must be answered:

- What are the action items?
- Who should perform them?
- What is the timeframe for their completion?

Recommendations to help alleviate the travel-related issues consist primarily of further research studies into the following areas that incorporate tools such as analytical techniques, simulation modeling, and empirical data:

- Develop modeling tools and the supporting data to more accurately represent the automated highway driving mode so that high-fidelity estimates of the impacts of AHS may be produced, in the areas of travel volume changes, mobility, land use impacts, emissions, and energy consumption.

- Develop applications of AHS in the context of multimodal transportation systems, with particular emphasis on alternatives to SOV driving modes, such as public transit and HOV driving.

- Determine accurate estimates of the impacts of automated highway systems operations on noise levels, and then develop noise mitigation measures.

- Identify AHS-related technology applications with potential environmental benefits, such as diagnostics upon AHS check-in to determine vehicle emissions' and fuel economy profile.

- Continue identifying advanced technology research areas with potential AHS applications, and investigating methods of developing beneficial linkages and synergistic effects, such as through emission control technologies, electric vehicles, and clean fuels.

- Investigate the feasibility of linking more closely with AHS such measures as travel demand management, land use management, congestion pricing, and parking pricing.

Such research could be conducted at academic institutions, national laboratories, regional MPO's, USDOT, or a myriad of private companies with expertise in the transportation area. Establishing an appropriate timeframe for all aspects of this research should be investigated in the next phase of the national AHS research and development program.

Infrastructure and Urban Form Issues

Infrastructure and urban form issues stem from concerns over the consequences of potential AHS-related infrastructure modifications at the neighborhood level, including visual impacts, impacts on non-automated roadways, and seismic safety concerns.

Visual Impacts And Neighborhood Cohesiveness

There is the possibility that in certain very dense urban areas where automated highway systems may be deployed, there could be additional infrastructure requirements. Such changes could mean either the construction of new AHS facilities in entirely new rights-of-way (ROW), within the same ROW, a lateral expansion to accommodate additional lanes, median space, or shoulder space, or the construction of a new elevated facility if there is no space to build "out", only to build "up." This right-of-way expansion requires infrastructure changes that could have negative visual impacts as well as possible impacts on the neighborhood cohesiveness.

Impact Of Non-Automated Roadways

With the ability of an AHS facility to accommodate a sizeable increase in the hourly lane capacity on the highway, especially with an increase in the volume of SOV driving, another issue is the impact on the local neighborhood. This impact results from trying to accommodate the increase in vehicle access and egress in terms of the possible need for additional parking facilities, the capacity of non-automated roadways adjacent to the AHS facility, and especially during an incident when traffic is diverted off the roadway onto surface streets.

Seismic Safety

Another potential concern, not unique to automated highway systems, but possibly exacerbated with AHS are the seismic safety issues related to new construction of elevated structures for AHS use.

Infrastructure And Equity

Another concern expressed with the deployment and operation of automated highway systems combines environmental with equity issues. Areas in the neighboring vicinity of freeways are generally in less well-to-do sections of a city relative to other areas. Freeway infrastructure modifications for AHS, additions in particular, could further exacerbate already existing negative impacts of living near a freeway for the residents in such areas. These people are probably less likely to be able to afford AHS-equipped automobiles than other more affluent individuals, and so the negative impacts of freeway modifications add to the following frequently stated AHS equity issue: Residents of poorer areas cannot afford to own such a vehicle, thus do not receive benefits since they would not be users of the system, and they must also absorb the consequences of infrastructure changes in their neighborhood. The infrastructure modification issues are of concern and need to be addressed. The equity issue must be more thoroughly analyzed because early research results have shown that non-system users can also derive benefits from AHS, i.e. travel-time benefits for users of non-AHS freeway lanes as well as arterials.[(14)]

Recommendations For Resolution Of Infrastructure/Urban Form Issues

Infrastructure modifications and impacts on the urban form of local neighborhoods resulting from the deployment and operation of automated highway systems would have similarities to the implementation of highway projects today. Before any concrete is poured, the project must successfully pass through a multitude of requirements, including in particular, a lengthy environmental impacts review process. This process should be reviewed to determine its applicability to the AHS case and plans made to develop modifications where needed.

Measures to mitigate potentially negative consequences of AHS such as visual impacts or excessive traffic egress onto roadways adjacent to the AHS facility would be developed at the local level. For example, it may be mandated that lighter weight material be used or methods be found to reduce the spatial requirements of elevated structures, including entry and exit areas. To accommodate increases in traffic volume resulting from access to and egress from an AHS facility onto non-automated roadways could require street widening, modifications to signal timing plans, or other measures.

Institutional Issues

Institutional issues are primarily concerned with the relationships among the stakeholders in AHS work (research, development, deployment, and operation), the level of accurate information stakeholders have about each other, and barriers to making progress in the work.

Barriers Among AHS Participants

Numerous groups from a wide range of professional disciplines are involved in automated highway systems work. This involvement varies from the level of spectator to more active participant. Even with the wide range of professional groups involved there seems to be a split into two groupings, based on differences in educational background, professional training, work experience, one's view of the world, and approaches to problem-solving. The barriers, unfortunately, help to maintain an "us versus them" mentality. On one "side" is the engineering profession while the "other side" consists mainly of planners (urban, transportation, land use), economists, and members of the environmental community. The environmental community actually draws their members from all such disciplines, including the engineering fields. Each group holds views spanning the full spectrum from extreme to moderate so that the division between the groups is not a wide gorge with little opportunity for bridging the gap or compromise, i.e. there are areas of overlap. In other words, this is not to imply that all engineers do not care about environmental issues or that the environmental community does not see the benefits of at least portions of AHS operation, in particular, the safety benefits. While the existence of barriers is real, the perception of the extent of the differences is quite large, makes the barriers harder to break down.

Incompleteness And Inaccuracies In Information

Another issue made apparent during the focus group and individual interviews is the lack of complete and accurate information and existence of misinformation about each "side" from each "side." Some elements of the non-engineering disciplines do not yet have a full and accurate appreciation of the AHS program from either the microscopic or macroscopic view. The microscopic view includes the set of individual technologies under investigation or in the context of individual user services,[15] whereas the macroscopic view means user services' inter-relationships. It has been difficult for some individuals to grasp the global picture of AHS research, and more generally ITS research. To some individuals it is still an "alphabet soup" without a unifying purpose and objectives. Unfamiliarity and misconceptions on both sides prevent a full and accurate appreciation of each other's standard and traditional methods of analysis and problem solving. There is also a tendency to view such methods and practices as not completely effective and compatible with solving the other sides' problems. This situation results in further distancing these two primary groups. For example, one non-engineering view is that solutions to engineering problems have not had to account for the human element–uncertainty, randomness, much greater degree of unpredictability–on the scale present in AHS-related problems. Numerous pieces of legislation beyond the Intermodal Surface Transportation Efficiency Act (ISTEA) have relevance and applicability to automated highway systems and are unfamiliar to at least portions of the engineering community, such as the Americans with Disability Act (ADA), the National Environmental Policy Act (NEPA), and the Clean Air Act and its Amendments (CAAA).

Lack Of Sufficient Involvement From Non-Highway Institutions

An institutional issue related to the view that the AHS program is too "highway" oriented, even in its name, is the need for much more active and central involvement in the program from the non-highway agencies. At the Federal level such agencies include the Environmental Protection Agency (EPA) and the Federal Transit Administration (FTA) who continue to have relatively minor roles in the program. At the regional and local level, the Metropolitan Planning Organizations (MPO's) are the principal agencies to get involved.

Recommendations For Resolution Of Institutional Issues

The following three words are key ingredients to resolving the institutional issues: education, communication, participation. To break down barriers and correct misinformation among the major participants to forge a more common vision of a future transportation system with automated highway systems as an integral component, the following suggested action items may serve as a first step toward achieving this goal and are offered for consideration:

- Perform systematic review and analysis of recent national legislation to find relevant and applicable pieces of legislation to the automated highway systems program, of which ISTEA, CAAA, NEPA, and ADA are important examples. The next phase of the AHS program to begin shortly after the completion of the Precursor Systems Analyses projects should pursue this research activity.

- Attendance and participation at the Precursor Studies Results Conference (PSRC) in November from the non-engineering fields should be actively promoted and pursued, as well as the wide distribution of the compendium of final reports among these groups. This will serve to more fully inform those groups without a direct involvement in AHS research of the full extent of the work and the findings conducted during the PSA projects, which will help to alleviate the concerns that AHS research is not addressing certain issues.

- Consider instituting on a regular basis research/policy forums focused on AHS analogous to the following such conferences on ITS and the environment: Intelligent Vehicle Highway Systems (IVHS) Policy: A Workshop on Institutional and Environmental Issues (Monterey, California 1992), National IVHS and Air Quality Workshop (Diamond Bar, California 1993), and National Policy Conference on Intelligent Transportation Systems and the Environment (Arlington, Virginia, 1994). These forums were, however, held annually, and holding such forums with greater frequency could be more valuable. Moreover, holding such forums around the country with a wide audience should be sought, analogous to the Systems Architecture Program forums. Because of the breadth and depth of valuable information available from the PSA studies and the attendance at the PSRC being limited, the first set of such nationwide forums could be in the form of presenting the PSA results, though probably in condensed form. Results must be presented in an organized and coherent manner, given the extent of the PSA research endeavor.

- FHWA, continuing sponsors of the AHS Program's Phase II, should suggest encourage, or even require that the winning consortium, i.e., the research and development team for Phase II, actively engage the non-engineering communities in the next phase of AHS work. Since the National Policy Conference on Intelligent Transportation Systems and the Environment (NPCITSE) was well attended by members of the non-engineering professions as well as members of the environmental community, work could begin by establishing contact with those groups' representatives for which there is a greater level of overlap or commonality of views with the AHS engineering community. Strategies for working with such groups should also be developed.

- AHS community should learn of and participate in conferences, forums, committees, special projects, and other related meetings sponsored by planning (transportation, urban, and land use), public transit, and environment-related communities.

- Recently completed NPCITSE will soon publish proceedings that will contain policy action item recommendations. These should be reviewed and applied where appropriate to AHS.

- FHWA has recently begun a set of training courses to be implemented over the next three years that begins the process of educating regional planning professionals of the rudiments of the ITS planning process as it relates to standard regional planning methods.(16) In concert with evaluating the effectiveness of these training courses geared toward ITS in general, the feasibility of tailoring the courses to the needs of AHS should be made and if found to be of potential value, preparations should be made for their implementation.

- Stronger linkages with other transportation-related Federal agencies, e.g. FTA and USEPA needs to be made, possibly beginning through the FHWA.

- Closer linkages among ITS America committees could help bridge gaps between the professionally disparate memberships, in particular between the Advanced Vehicle Control Systems and Energy and Environment committees. The current committee structure focuses on individual subject areas and can have the result of insulating each committee within its own "world." Committee chairs should meet regularly to determine areas of mutual interest and concern for further investigation. Moreover, dual committee membership could be strongly encouraged so as to establish a group of individuals cognizant of and sensitive to both committees' agendas.

- Continue and investigate the feasibility of expanding the partial subsidization of ITS America membership dues as well as travel expenses to those groups in financial need so as to foster the continued growth of those participating in the program.

Risks

Whether dealing with the travel-related, infrastructure and urban form, or institutional issues, the risks inherent in not resolving the issues will only result in the program being beset with continuing problems by not being able to successfully address the issues raised. More significant than a particular opposition group is that user acceptance of automated highway systems is crucial for its successful implementation and operation and this potential success is put at risk without all issues resolved.

The following statement was delivered at the National Policy Conference on Transportation Systems and the Environment and is quite applicable toward avoiding the risks inherent in not resolving these issues:

> Not only is it important to address societal and economic issues for what we may consider as altruistic reasons, but it is also important to do so because it is good business. It will save time and money in the long run and produce a product that will better serve society. Noting, in 1972, how important it was to address societal issues in their business planning process, the Business Environment Studies component in General Electric noted "Without a proper business response, the societal expectations of today become the political issues of tomorrow, legislated requirements the next day, and litigation the day after."[17,18]

The terms "societal" and "economic" in this quote may justifiably be replaced with "environmental" to provide food for thought for the risks involved in not resolving the issues.

Task 3. Privacy and Human Factors Issues

Objective

The goal of this topic is to highlight areas of sensitivity the driving public may have to implementation of certain features of the Automated Highway System. This task will discuss privacy issues related to driver check-in and check-out for the AHS. Consideration of privacy issues regarding driver monitoring and tracking of vehicle location is included. Human factors issues involved with driver comfort while operating under automated control are addressed.

Introduction

Use of the AHS will require drivers to provide information to the traffic operations center (TOC) to insure that the driver and vehicle are capable of operating within the automated lanes. Specific information may include driver licensing data, and the status of current vehicle operating criteria. Automated navigation of vehicles will require the collection and processing of position data by roadway and TOC computers. The recording of such information may be a privacy concern for certain drivers. The extent to which drivers must relinquish their privacy in order to drive within an AHS may affect user acceptance and marketability.

Precedents have been set regarding collection and dissemination of consumer data which may influence public acceptance of increased automation. The public may become more opposed to easily available records as Federal, State and private data banks increase. The use of telephone records by law enforcement, and monitoring of individual computer workstations by employers are becoming more common. Both practices are current battle grounds concerning privacy issues. Other examples of electronic data collection include radar imaging sensors used to record license plates of speeders, and video cameras used to record license plates of toll road violators.

Automated systems contain more detailed information than manual systems and this information is more accessible and can be freely transferred. Abuses of privacy by government agencies appear to be an increasing social concern in the US and other countries. The failed 1985 attempt to implement electronic road pricing in Hong Kong has been blamed on fears of a tax increase and concerns over privacy.[19] This toll collection scheme proposed sending a monthly bill to all vehicle owners showing the time and location of every charge.

Many of the same types of privacy issues have been raised in automatic toll debiting being used in several operational systems. Also of importance is the loss of anonymity in the toll collection transaction which has application to vehicle/driver monitoring requirements for AHS. Current non-stop tolling systems require identification of each vehicle using a Vehicle Identification Number, and the charge is deducted from the users account or the user receives a periodic billing. Both of these methods require maintaining a record of vehicle movement in a computer system or data bank. This collection and retention of data may be unacceptable to the driver.

Recent trends in congestion management may provide a solution to this dilemma. The existence of electronic toll collection technology permits so-called "congestion pricing". A recent article in the Washington Times quoted the National Research Council claim that charging drivers tolls to use public roads and bridges during rush hour would ease traffic jams and cut air pollution.[20] The article also quoted estimates that within a decade, more than 15 million vehicles will have transponders used for toll collection. One thousand of the current 10,000 toll lanes worldwide are now equipped with electronic collection devices of some kind.

The prepayment method of toll collection reduces a number of the publicly expressed reservations concerning the obtaining and retention of vehicle/driver use data. This method allows an account to be established and automatically debited without creating a record of vehicle movement. Gradual implementation of this type of electronic tolling could lead commuters to appreciate the advantages related to drive time reduction and convenience. Elimination of driver concerns with excessive data collection in conjunction with realization of the potential benefits will be important to the success of any automatic system of revenue collection or vehicle monitoring function. This approach has been successfully demonstrated by the installation of the PREMIN toll collection system in Sweden, showing that potential users are attracted to the new automatic system as the benefits become apparent. More than 85 percent of the system users fully accept the prepayment method after the first year of operation in this example.

The preceding discussion presented a background covering current issues regarding modern technology and public concerns with privacy as data collection becomes more prevalent. The following paragraphs will outline the type of driver information which may be required to implement the AHS. The issues which may affect public opinion of AHS are summarized and recommendations concerning security are discussed.

Privacy Issues

AHS Information Requirements

The required data to be verified falls into two general categories. The first category is concerned with the capability of the vehicle to be safely controlled in the automated lanes. The vehicle information data set is important because the ability to guide a vehicle electronically implies the capability to track and store its route, along with entry and exit points from the AHS. The sensitivity of this technology to issues of privacy have been raised in the recent cases discussed in the introduction. The second category includes information regarding driver qualifications for travel on the AHS. The specific types of driver information collected and methods for driver performance monitoring during the entry and exit process may be the most critical issue in evaluating the impact of privacy on user acceptance.

Driver Information And Potential Technology Required By AHS

- AHS users may require special licensing, absolute proof of insurance and more stringent vision and reaction time testing to operate within AHS.
- Licensing and driver proficiency testing may be required more often than current issuance of drivers' licenses.
- AHS drivers may require some level of training with periodic testing and/or re-training to operate with AHS.
- Driver inputs and requests to AHS may include voice recognition technology.
- Driver certification, verification and review of driving records may be required upon vehicle/driver check-in an/or access onto automated lanes.
- AHS may incorporate methods to determine the competence of the driver to assume manual control. AHS may activate driver monitoring systems within the vehicle to verify that the driver is capable of assuming manual control.

General Views on Privacy Issues

The importance of privacy in current public opinion was highlighted by a recent ABC News Night Line special aired on June 9 and 10, 1994.(21) Ted Koppel hosted an in-depth interview, discussion and commentary entitled *Privacy: Your Secrets for Sale.* The thrust of this program focused on the concept that in the computer and wireless communication age, the private lives of common citizens has become a big business. The program noted that it is not necessarily the Federal Government who is gathering and selling information about the consumers, it is the business sector. This TV report demonstrated that privacy is a commodity – given time and money, computer snoopers can uncover a wide variety of information many people consider personal. A computer snoop may charge as little as $50 to find a person's earnings, a list of creditors, a report of medical records, criminal records, or a list of telephone calls, and can potentially monitor the calls. Employers, marketers and even private investigators use high technology and scan databases to pry into everyday lives.

A poll conducted for the TV program reported that 85 percent of the people questioned were concerned about privacy. The amount of information about the general public that is stored in computers quadruples every few years, and consumers provide this information every time a credit card is application is submitted. Major purchases are another frequent source of personal information to sensitive information to retail data bases. The information freely revealed on warranty registration cards has the potential for use among marketers, and mailing lists are often sold.

There may be little in the life of a citizen that will remain private in the computer and Information Super Highway age. The General Accounting Office (GAO) reported in 1990 that there were 910 Federal Data Banks around the country. The data banks contain health, financial, Social Security and other personal files, many of which are shared with corporation and commercial data banks. Data concerning credit or medical histories are commonly held in bank and insurance company computer files as well. This information is easy to obtain given a Social Security number in many cases. This type of invasion of privacy is often illegal and is considered a misdemeanor by most State and local governments. There are no Federal privacy laws in effect to stop electronic snooping and selling of personal information at this time.

Other surveys reveal that Americans have mixed feelings concerning privacy issues. Most people want to have their privacy protected, but if a real benefit is shown, privacy becomes less of a concern. Privacy pragmatists recognize that benefits can often be obtained when certain personal information is readily available. Transactions with credit cards, driver licenses, and insurance are completed much more easily when records stored in a data base are accessible to complete inquiries.

The Constitution protects our privacy only from the Federal Government. Local and State governments provide tremendous amounts of information about persons that are considered a matter of public record, including civil filings, court records, traffic tickets, divorce records, tax rolls, property rolls and voter registration information. Congress is currently being asked to come up with a “Privacy Bill of Rights” where the individual would be notified when electronic information gathering takes place. Permission of individual persons would be required regardless of who is collecting the data. Information gathered for a specific purpose would also require permission prior to dissemination purposes other than originally intended. Legislation of this type may be required to obtain a sense of public confidence that data required for safe and efficient operation of the AHS will not be abused.

The advent of a national health care system may provide the trail blazing effort in this arena. Congress may be forced to act on instituting some measure of privacy control in a system where personal identification may be stored on a single card that could provide access to medical profiles from a stored database anywhere in the nation. Implementation of legislation in this area may provide a step in the direction needed to deploy AHS with a minimum of privacy concerns.

ITS America Legal Issues Committee

An ITS America newsletter published in Spring 1994[(22)] reported that some members of the ITS community believe that motorists would be willing to give up some privacy for increased highway operating efficiency, safety and access to useful travel information. Others in the same group suggested motorists may be reluctant to use improved transportation systems and technologies because of concerns over invasion of their privacy. The committee discussed several privacy issues in this document, including:

- Implications of ITS surveillance technologies.
- Methodology used to implement electronic payment services.

- Inappropriate access to ride sharing information.

ITS Surveillance

ITS will employ automated surveillance technologies. Certain of these services raise concerns over privacy. ITS will monitor incidents along the highways and evaluate these data to provide improved route guidance information and traffic management.

Electronic Payment

The ITS service which provides automatic vehicle identification (AVI) could be used for tracking of the vehicle operating in the automated lanes and for the purpose of establishing miles driven and even billing for AHS usage. AVI involves radio frequency interrogation of an electronic tag on the vehicle. User records are typically compiled, raising privacy concerns over the electronic payment methodology selected for AHS.

Ride-Sharing Information

Ride-sharing databases have been in existence for more than a decade. Many companies are required by local and State environmental agencies to set up and maintain ride sharing programs to meet regulations pertaining to air pollution reduction. The method that employers use for providing this information concerning employees raises privacy issues. The information is currently freely given by most employees and many drivers take advantage of ride sharing data, due to the perceived benefits of convenience, reduced travel costs, improved travel times, and incentives given by the employer.

Methods to assure confidentiality of vehicle movement records could include encryption and identification on a zone basis, rather than a regional operations network. Control of vehicle position through vehicle to vehicle communications while moving along an AHS, rather than providing control through a roadside tracking network might reduce concerns over privacy. This consideration implies that the system configuration has a potential impact on the acceptability of AHS to the user.

Based on DOT findings reported in the ITS Legal Issues Newsletter, privacy is less likely to be of concern when:

- The benefits of new AHS technologies are clearly understood.
- The benefits are perceived as outweighing any adverse effects on privacy.
- It is perceived that the information will be properly protected.
- Basic principles are followed to safeguard privacy.

Candidate Privacy Solutions

Equipping AHS authorized vehicles with electronic identification tags may be one way to minimize the risk of privacy invasion. Travel records could be kept in a computer chip on the vehicle. Information concerning a prepaid debit account could be stored to allow toll charges, if used, to be deducted as the vehicle enters or exits AHS without transferring data between vehicles and a central TOC. Other options include removing vehicle location records as soon as possible to assure confidentiality of vehicle movements. Encryption and identification on a zone basis may also be used to resolve privacy concerns. Methods for guaranteeing confidentiality must be developed early in the system design process. Public assurance, through broad educational efforts aimed at potential AHS users will also be required to develop a “trusted” system.

The public will feel less threatened as new AHS technology matures and demonstrates its value, as with any developing industry. New technology is seldom accepted overnight, even when it offers considerable advantages to the consumer. A trend has been established in recent years by the public to provide information about personal habits to gain personal convenience. The information the AHS would require may not be perceived as an infringement on privacy as the driving public acknowledges the benefits of AHS.(23)

Driver Comfort

People tend to be skeptical of new high-tech products until the technologies are proven. The successful development of an Automated Highway System provides a real challenge in assessing public opinion concerning acceptance of a driving environment which incorporates advanced technology in a complex system. Full AHS deployment may be more than twenty years away, and during this time the driving public will see tremendous technological advances in automobile on-board systems designed to improve occupant comfort, increase general safety, and reduce fuel consumption. Vehicles with interactive displays and equipment that provides navigation are currently being test marketed. Future models may feature improved entertainment systems and vehicle trip execution. Voice input and voice recognition systems that will reduce driver workload are anticipated. Smart cruise controls that will allow the driver to select fixed, (safe) vehicle following distances are on the horizon. Potential AHS users will become gradually acclimated to the future highway system as the enabling technologies are developed and introduced into the market place in an evolutionary manner. Early emphasis must be placed on educating the driving public as to what features the Automated Highway System will provide, its advantages in increased vehicle and occupant safety, reduced travel time, and environmental benefits in order to ascertain public acceptance for the AHS.

The level of driver comfort while operating in an automated driving mode will be an important concern in ensuring the effectiveness of an Automated Highway System. The degree to which the driver is comfortable while traveling in an AHS is a function of the user friendliness of the interface equipment. Other facets of driver comfort deal with the psychological stress and potential increased mental workload related to a high speed, hands off, or close vehicle following mode of operation.

AHS Equipment

The in-vehicle equipment that the driver will use to interact with and communicate with AHS must be user friendly and easy to operate. Providing AHS with trip planning (trip origin and destination) information may occur off-line prior to the driver entering AHS for check-in. Trip planning functions that are completed manually by the driver through the use of a keyboard, touch screen or some other data entry device, should only be done while the vehicle is stationary while the driver is not pre-occupied with other driving tasks. The equipment that the driver will interact with must be designed for a full range of drivers and their capabilities, including young, faster reacting drivers as well as mature, slower reacting drivers.

Frequently used routes may be stored in the vehicle's on-board memory. This type of trip may be entered by simply selecting a personalized route number, very similar to telephones which have the capability to store frequently dialed numbers. Other options which may be available in the deployment time frame for AHS include voice input and voice recognition technologies which permit error free voice interaction and voice recognition so that the driver could be in continuous communication with AHS even as the vehicle is moving. A driver to AHS interface which requires manual input must be designed to minimize driver workload. The voice data entry solution may provide a way to minimize driver tasks while optimizing the time required to complete the check-in process.

Psychological Issues

Very little is known about driver comfort or anxiety associated with high speed, hands off, close vehicle following operation. A platoon configuration which proposes less than ten meter spacing with no driver intervention in emergency maneuvers may introduce a high level of driver discomfort. Traveling at high speeds in close proximity to a lead vehicle with no control over steering, braking and acceleration is not an experience which inspires confidence in most drivers. A passenger often feels feel nervous about not having vehicle control when the driver is following the lead vehicle too closely. A primary reason for the fear some people have concerning air travel is that they are not in control. Drivers and passengers will continue to have these fears and will always be reluctant to give up control, regardless of the AHS safety record.

Research will be required to assess the stress, workload and psychological factors associated with high speed platoon operation. Research data obtained using a driving simulator is one method of evaluating driver response to certain driving scenarios. The psychological stress factors associated with hands off AHS travel may not be accurately measured using simulators, because risk taking has no penalty in the simulator. Alternate methods may be warranted to fully evaluate driver responses, including test tracks and demonstration rides.

AHS researchers may address the effects of close following by introducing techniques of occupying the driver via trip progress, or video and audio information that might include movies, games, news, weather, sporting or cultural events. The object of providing the occupants with diversions is to reduce the perceived length of the trip and/or alleviate stress associated with the specific configuration under which the vehicle is operating. Drivers may be more comfortable with the forward windshield blanked or darkened to reduce the psychological discomfort of the close following scenario. The value of providing any of these options must be balanced with the capability to maintain the driver alertness in preparation for the transition back to manual control.

Task 4. Public Acceptance – User Interface

Introduction

The AHS user interface will be one of the most important influences on the commercial success of AHS as an option on future vehicles. Even after AHS is fully developed and a technical success, it must sell in the marketplace. The consumer will primarily view AHS in two ways at the important time of making a decision to buy AHS equipment on a new vehicle. The first will be the benefits of safety, trip time, trip convenience, etc. The second will be the look and feel of the interface equipment installed in a vehicle. The vehicle-driver interface is an area of vehicle development which continues to receive a very significant share of new vehicle development funding. Some of the important considerations in the design are:

- Orientation of the displays and controls.
- Method of display (dials, display screens, projected images, digital versus analog, synthesized voice, etc.).
- Method of control input and selection (push/pull/rotary/sliding switches, push buttons, touch sensitive screens, voice, etc.).
- Styling of the display and control space.
- Illumination of the display and control space.
- Application of human factors principles to ensure that vehicle-driver interface tasks do not interfere with the primary task of driving the vehicle.
- Ease of use.

As new vehicles are developed, the designs are tested in clinics in order to gauge consumer acceptance of the new design. When the vehicles are produced and sold the accompanying advertisement presents each as a new level of refinement. The ultimate decision of what works well for the user however is made in the marketplace.

Additional discussions of the design and testing of driver interface units may be found in task 3.3 of the Activity G – Comparable Systems Analysis report.

User Interface Scenarios

In order to conceptualize various scenarios that a driver may experience while using the AHS, a vehicle design artist at GM was enlisted to provide rough sketches of representative concepts. These sketches, and their associated descriptions, are not intended to strictly define the future of AHS. They simply present visual aids which will hopefully initiate the thought process concerning the driver interface and typical AHS situations.

The scenarios are divided into two categories: driver interfaces and typical AHS situations. The former category includes potential electronic interface units and their positions within the vehicle, while the latter includes check-in, check-out, entry/exit, commercial, transit, and maintenance situations, as well as potential driver activities while on the AHS. Note that the driver interface illustrations show equipment which is associated with Intelligent

Transportation Systems and basic vehicle operations other than AHS as well as AHS-specific equipment. Specifically-labeled items are considered a part of the AHS driver interface.

Driver Interfaces

Figure 1 depicts a possible AHS instrumentation suite and its placement within a vehicle. The voice/keypad input unit could be used by the driver (or passenger) to request entry to the AHS, define or change a destination, and request information such as the current weather and estimated time of arrival. The interactive location map could graphically display the driver's position with respect to the surrounding environment. For routine trips to work or a shopping district, the driver could use a preprogrammed disk to provide all necessary trip information to the AHS. A vehicle condition/status monitor screen could be used to inform the driver of AHS maneuvers, provide responses to driver information requests, relay information about equipment malfunctions, etc.

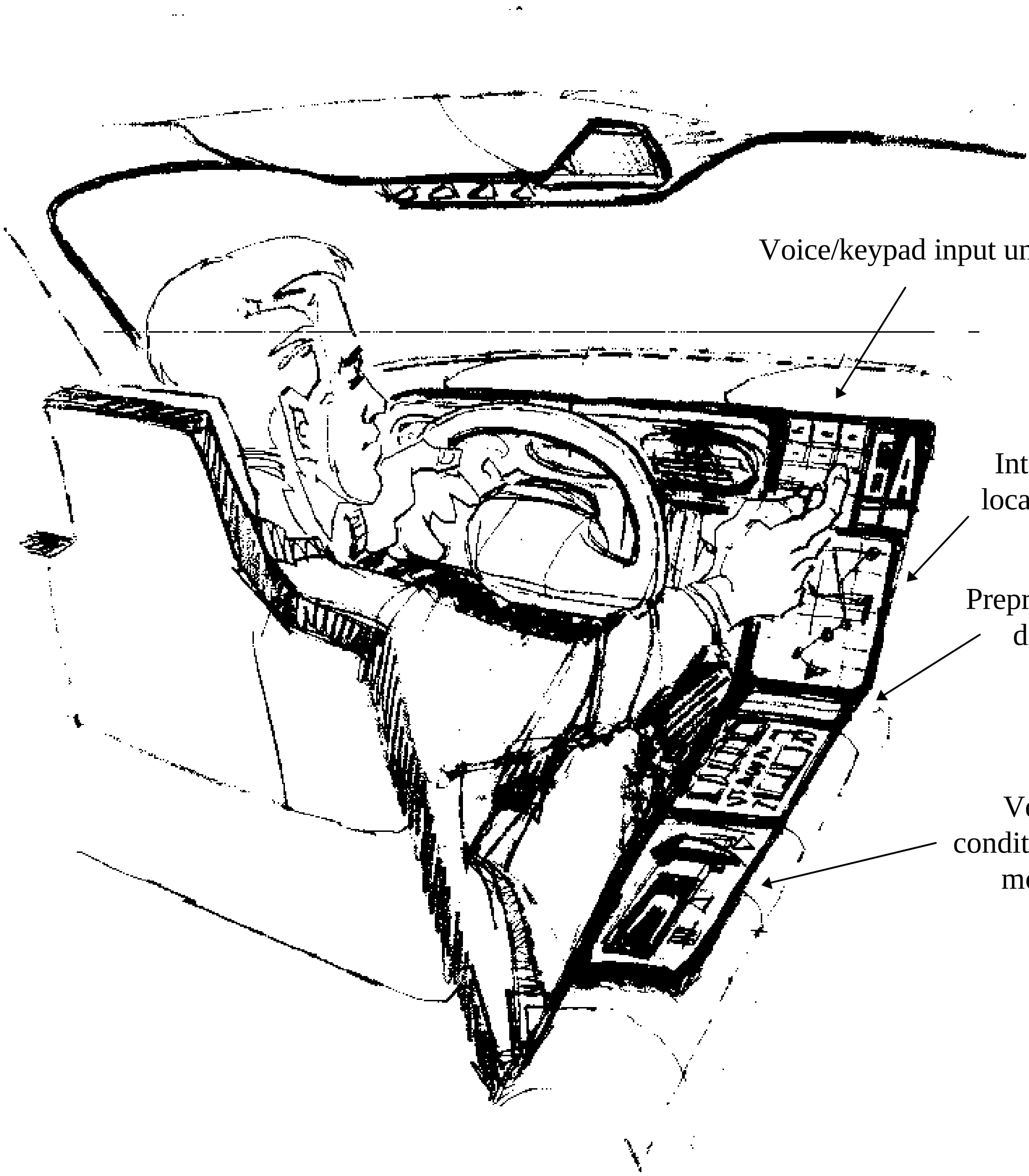

Figure 1. AHS Instrumentation Suite

Figure 2 displays the interior of an AHS vehicle with a minimal amount of electronics. The driver has access to a monitor screen and simple push-buttons above the visor for wayside communication. Since the monitor unit rises above the center console, it is easier to retrofit than one that is installed into the interior instrument panel.

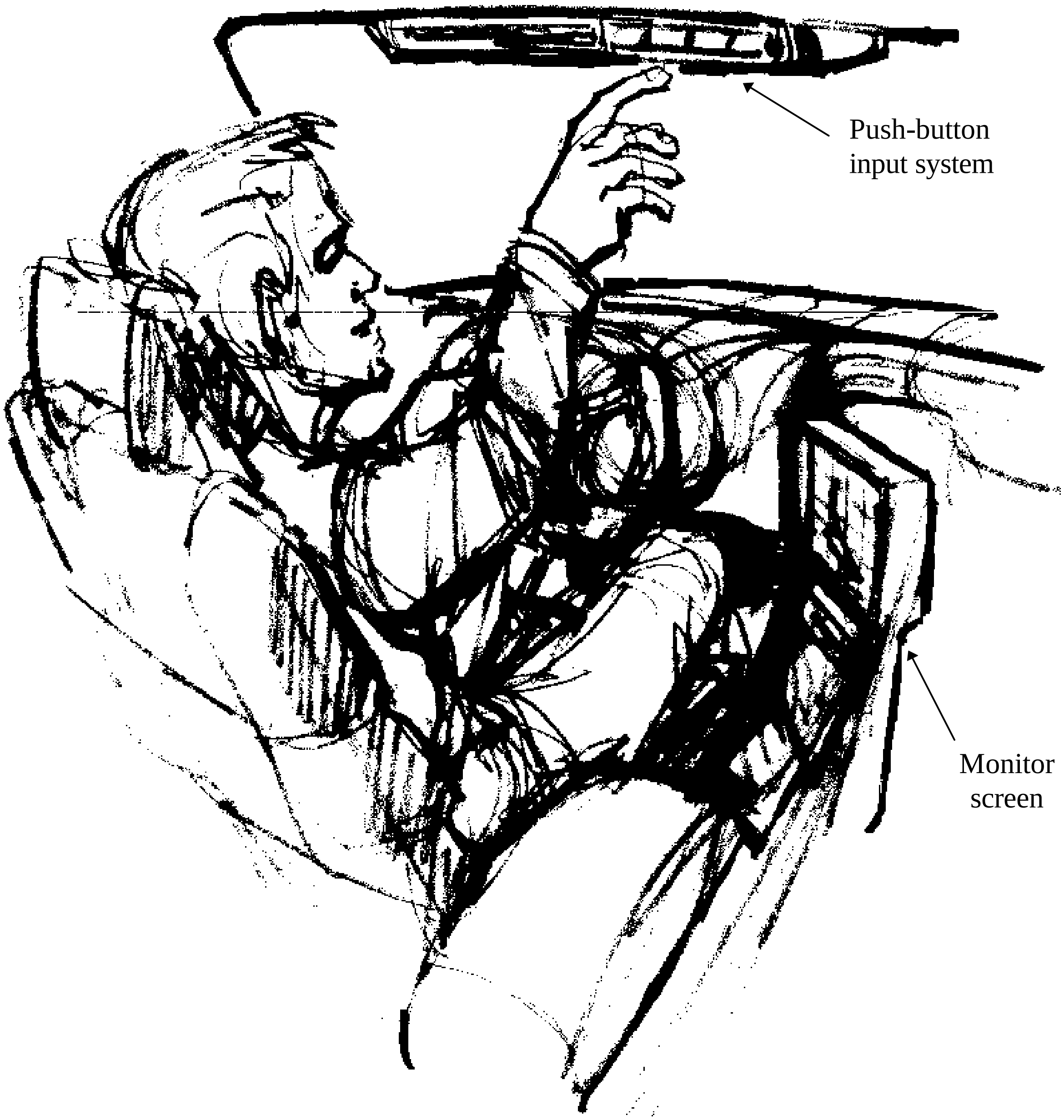

Figure 2. Minimal AHS Instrumentation

The head-up display shown in figure 3 can be used to provide route/map information as well as text to the driver. Text information can include vehicle status, estimated time of arrival, weather information, etc. A simple push-button input system can be used by the driver to communicate with the wayside.

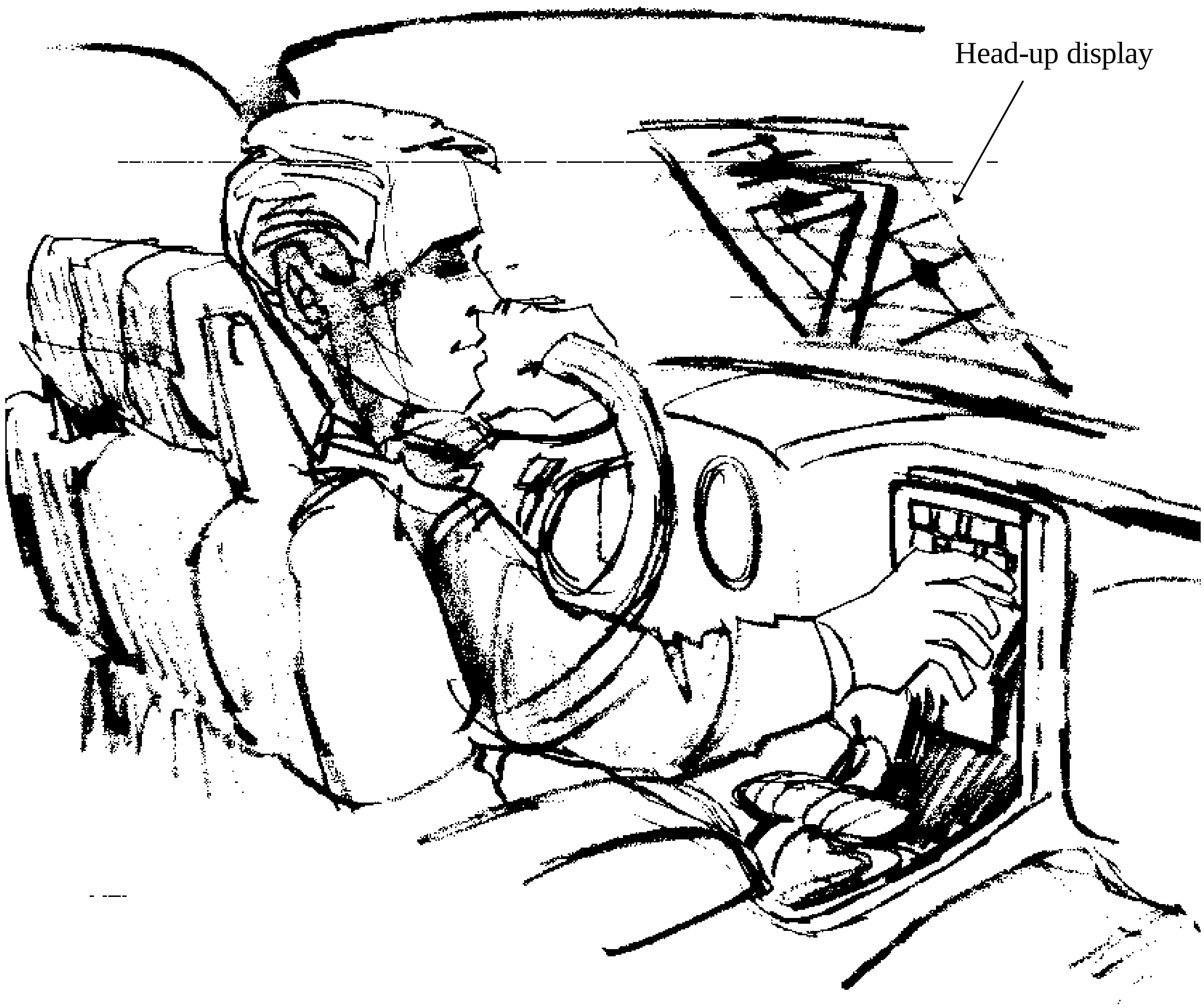

Figure 3. Head-Up Display Instrumentation

Figure 4 presents the idea of a pop-up screen as part of the internal AHS vehicle electronics. This concept is made possible by the advent of flat screen technology. The pop-up screen would be particularly convenient for drivers who infrequently use the AHS and don't want bulky electronic units cluttering the interior of their vehicle. The pop-up screen would serve the same purpose as a standard monitor. It would display driver information and communication from the wayside.

Figure 4. Pop-Up Screen Instrumentation

The concept of retrofitable vehicle electronics is presented in figure 5. Here, the center console can be used to house the bulk of the interior electronics. In addition to the center console, controls can also be mounted in the door panel and above the sunscreen. The vehicle electronics could consist of an information/map screen, an input panel, a unit that accepts prerecorded route disks, a vehicle diagnostic and status monitor, and a “no hands” voice communication system. In this picture, the steering wheel and the foot pedals can be moved out of the way when the vehicle is in the AHS mode. Clearly, this would imply no driver involvement in the direct vehicle control function.

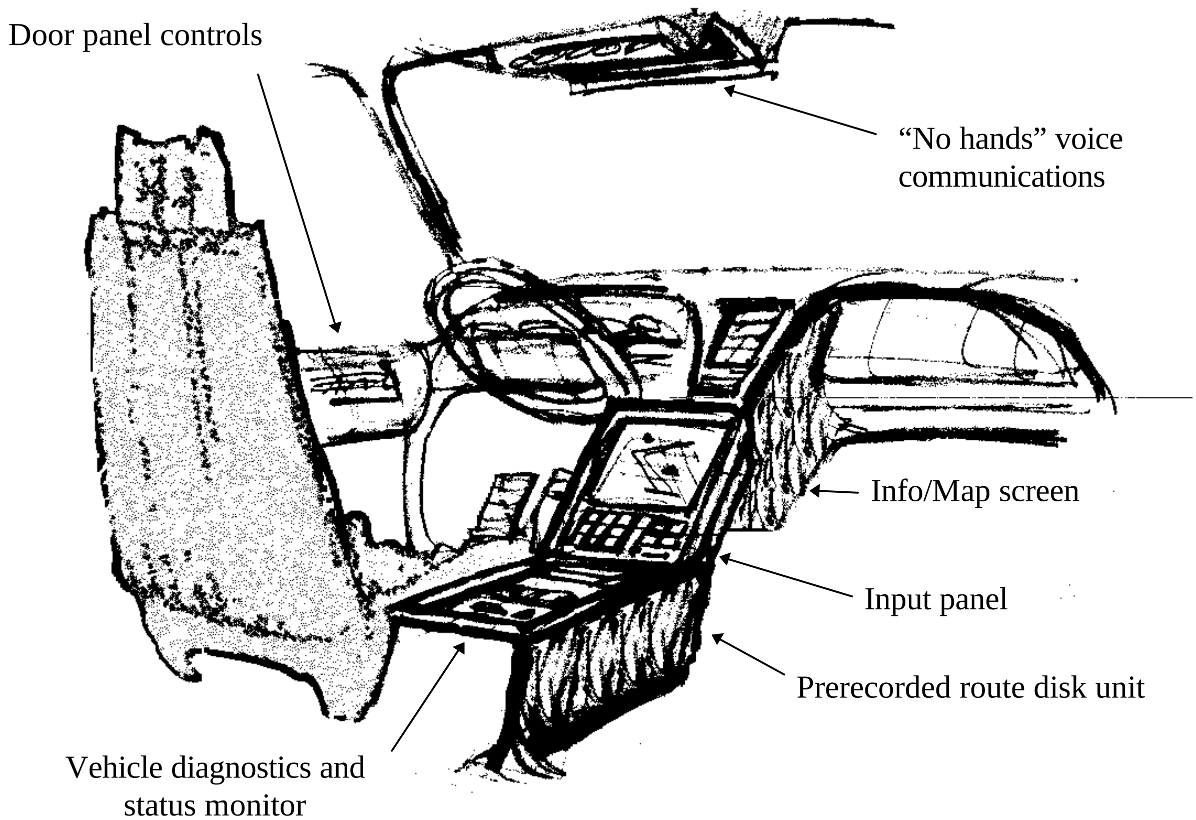

Figure 5. Retrofitable Instrumentation

Figure 6 shows a driver and the interior of a truck used for interstate commercial trucking. The driver is shown entering a prerecorded route into the system. This concept applies quite well to this type of AHS use. The driver may wear a special helmet to allow communication with other vehicles.

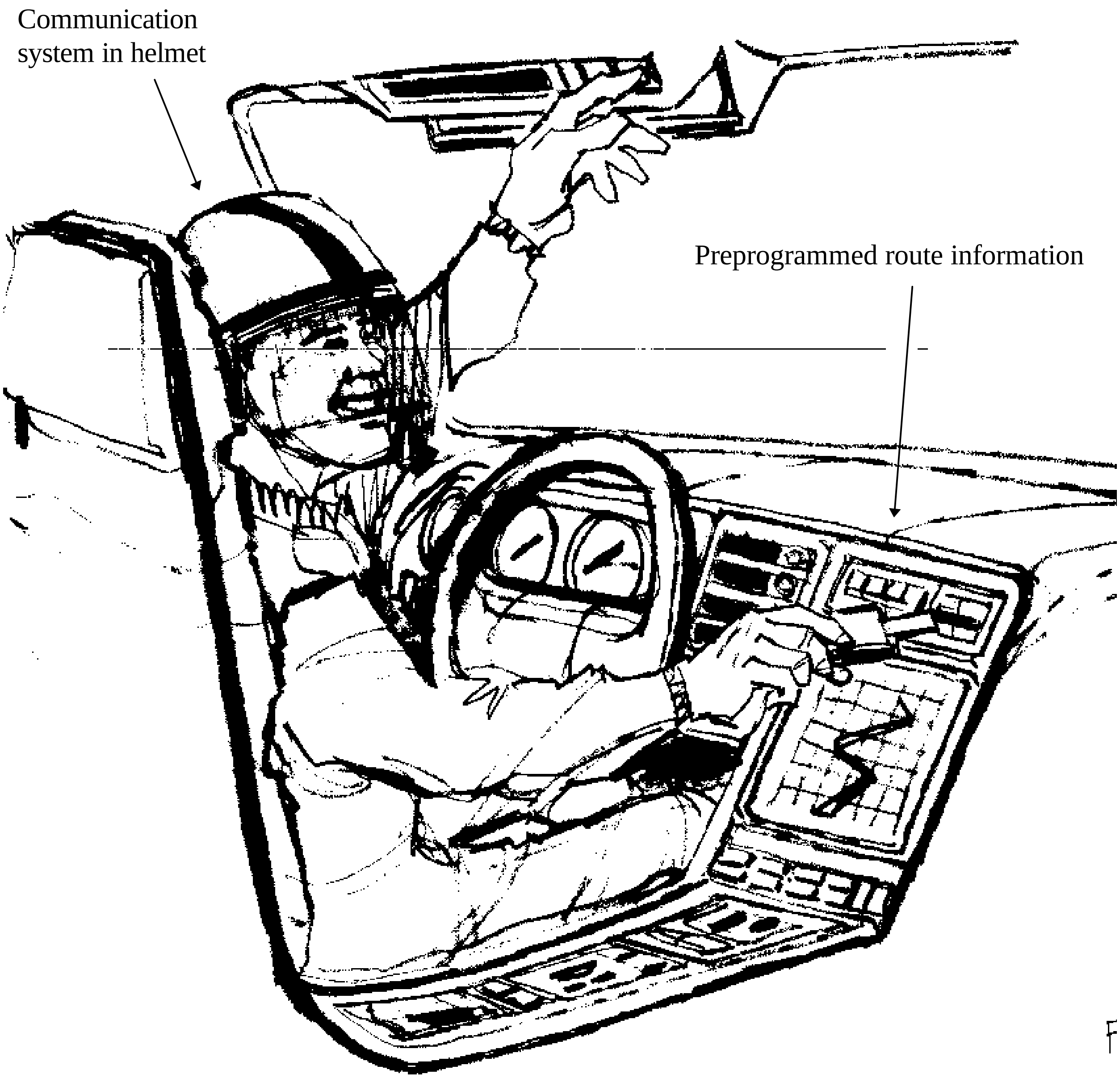

Figure 6. Commercial Trucking Instrumentation

Figure 7 displays a hand-held driver interface system. This concept is very attractive from a system retrofit standpoint. The unit could contain push-buttons for information entry and a display for AHS information. A communication link could connect the unit to an electronics package with more functionality (if necessary) inside the vehicle. The hidden electronics package would allow the entire system to be easily retrofitted on existing vehicles without experiencing major interior design changes. This package could be installed in the trunk of the vehicle or in another convenient place.

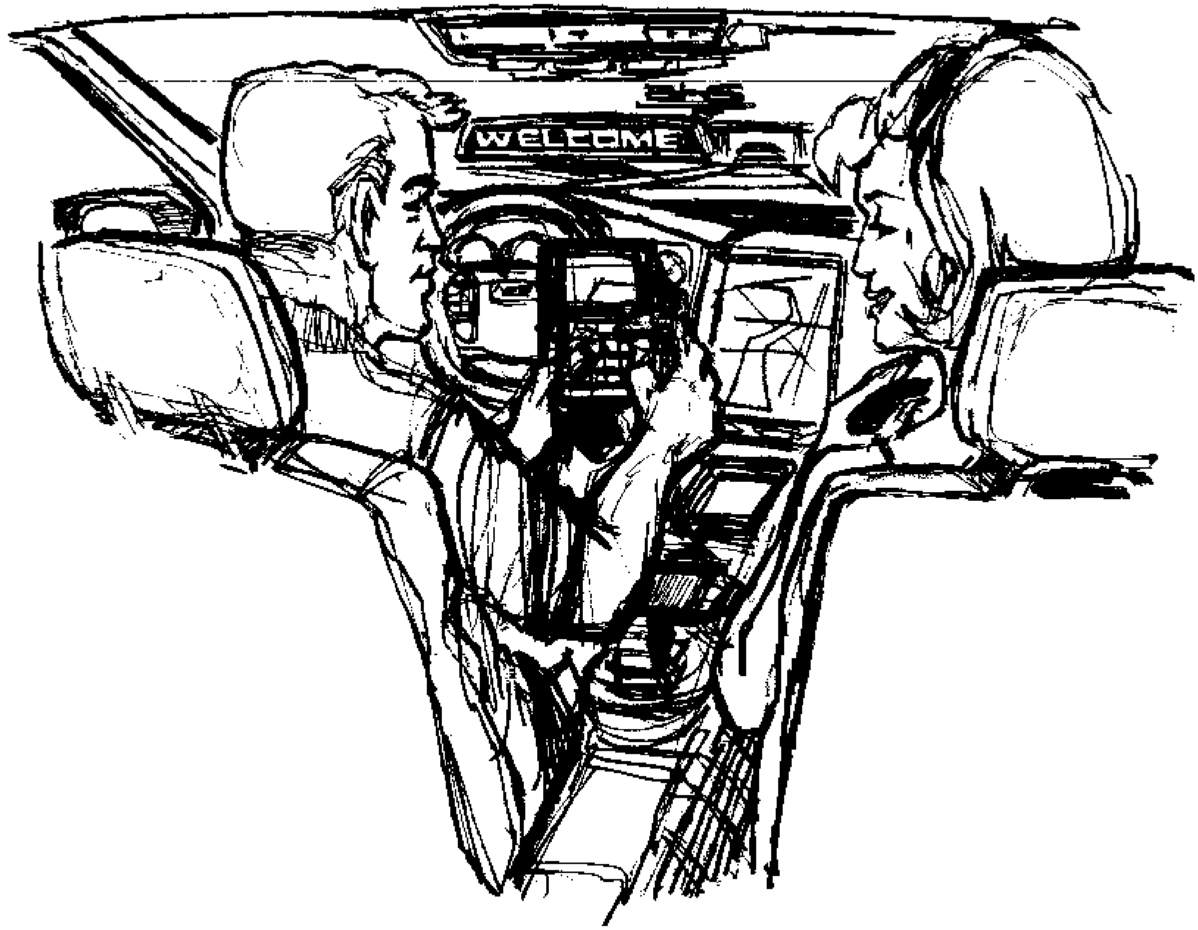

Figure 7. Hand-Held Instrumentation

Situations

An example of a possible monitor inspection unit is given in figure 8. This vehicle could test the functionality of automated components of the roadway and infrastructure while it travels the AHS. The driver and passenger could also perform routine inspections and perform maintenance of certain systems. The vehicle could contain various systems that would test infrastructure automated systems, such as magnetic markers and passive reflectors for position location. As an example, the monitoring system could check for missing or misaligned magnetic markers in the roadway. The unit could contain a data recording storage system to log automated system responses. It could also contain a transceiver for communication with the roadside. An automated (no driver) drone can also be envisioned to perform routine inspection and system test functions.

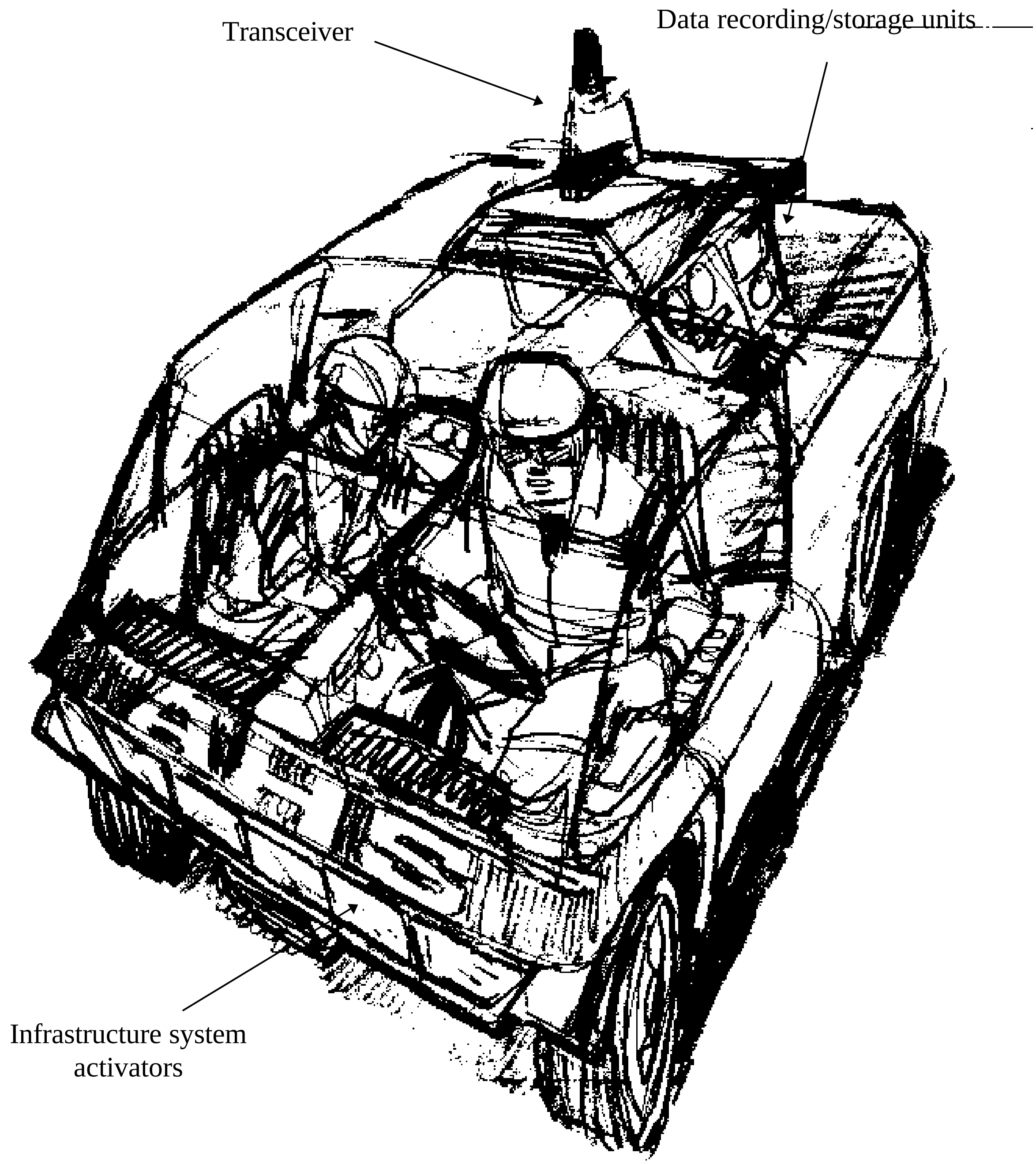

Figure 8. AHS Maintenance Vehicle

Figure 9 shows a typical roadway situation, where segregated lanes allow passenger vehicles and commercial/transit vehicles to access the AHS. Barriers are placed on either side of each lane to separate the different types of traffic as well as possibly supply a reference for the lateral control function.

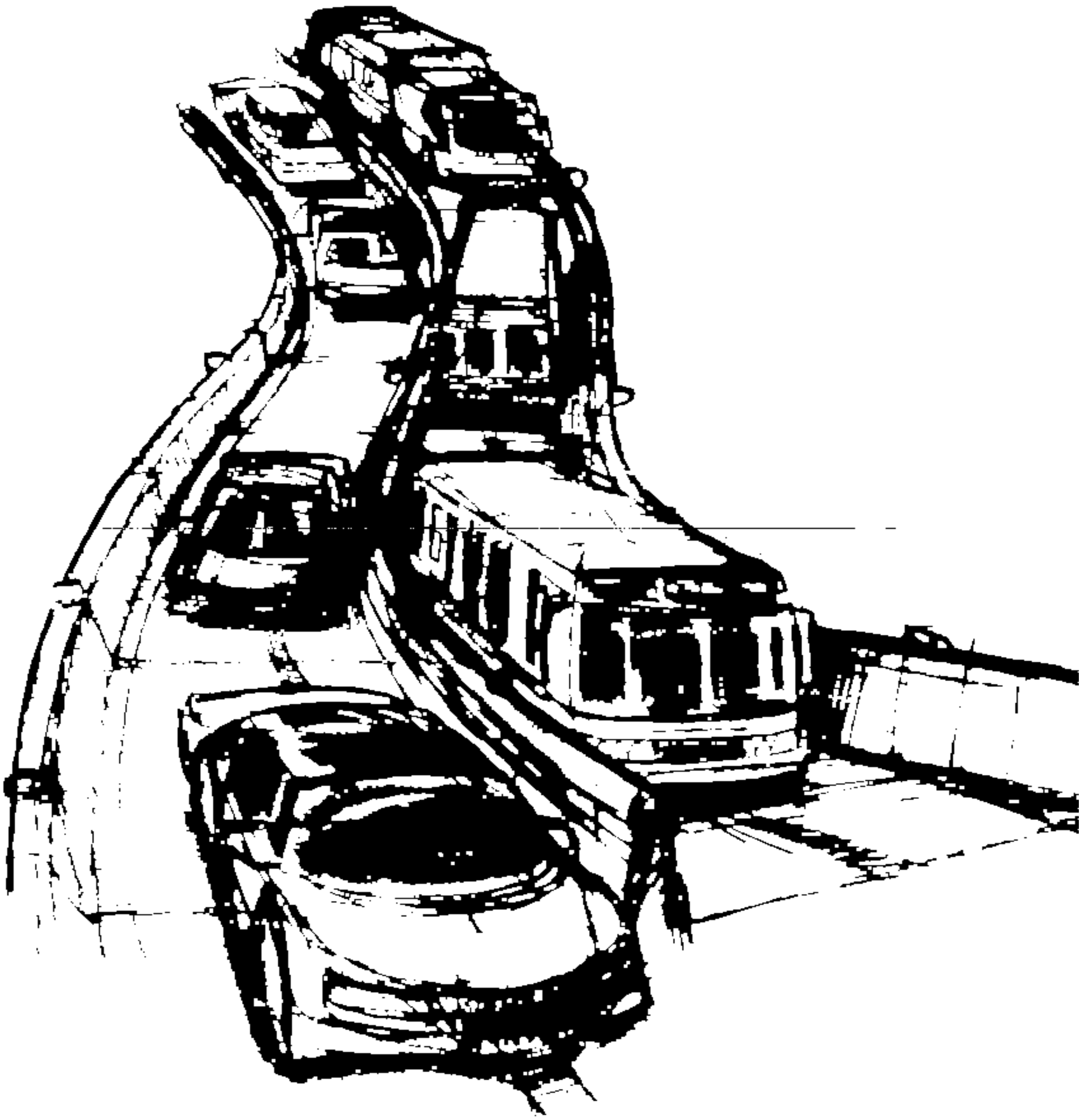

Figure 9. AHS Lane Configuration

Commercial trucks can be prechecked and programmed at terminal stations to avoid possible congestion at check-in areas. Figure 10 depicts this scenario.

Figure 10. Commercial Truck Check-In

Figure 11 depicts a situation where a passenger is entering a transit vehicle. The passenger pays for the service by using a plastic card embedded with a magnetic strip. The transit operator logs the passenger's destination into an on-board computer that communicates with the AHS Traffic Operations Center (TOC). The TOC is responsible for optimizing the route for the transit vehicle to its next destination. It is conceivable that some level of route priority could be given to mass transit vehicles over that given to single occupancy vehicles.

Figure 11. Transit Scenario

An AHS exit station scenario is shown in figure 12. In this representation, vehicles are ensured of a safe stop by pop-up soft barriers. The exit station shown is staffed by AHS employees. They could be responsible for ensuring that each driver seems capable of continuing their trip safely in manual traffic. This could encompass as little as a visual inspection, or as much as a short question and answer session. The staff could also handle emergencies, such as driver/passenger health problems, and situations where the driver is not capable of retaking control from the automated system.

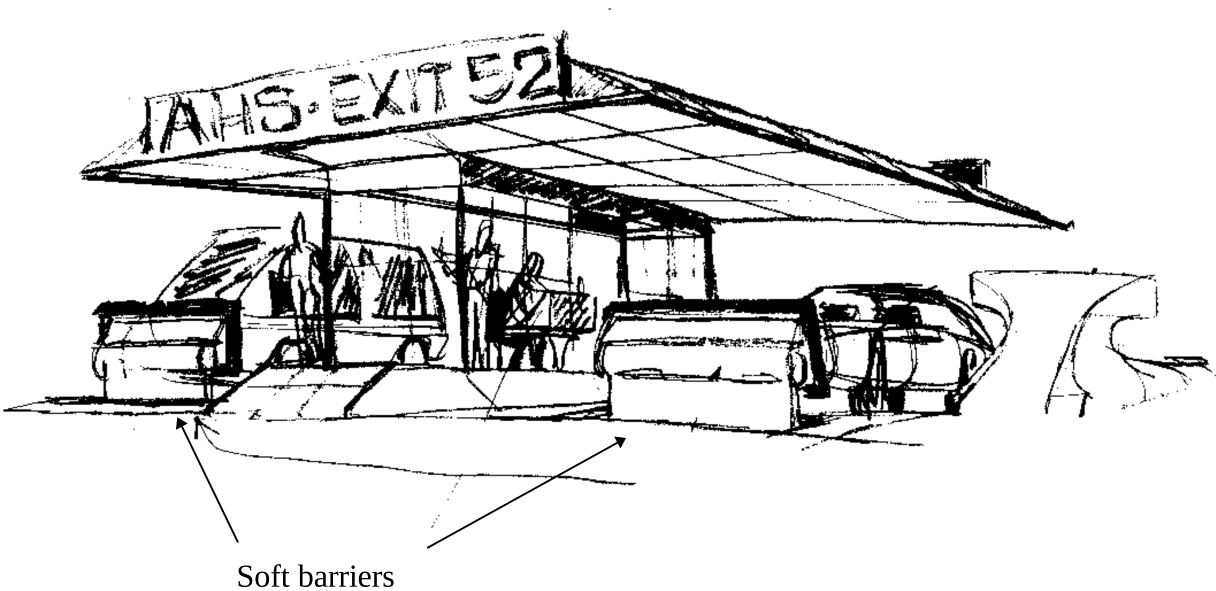

Figure 12. AHS Exit Situation

Figure 13 shows a check-in situation from the driver's viewpoint. The driver simply enters a destination using an input device (push-button, keyboard, etc.) and waits for a confirmation from the AHS. Once this is received, and the vehicle has been inspected, the AHS takes control of the vehicle and the driver becomes a passenger.

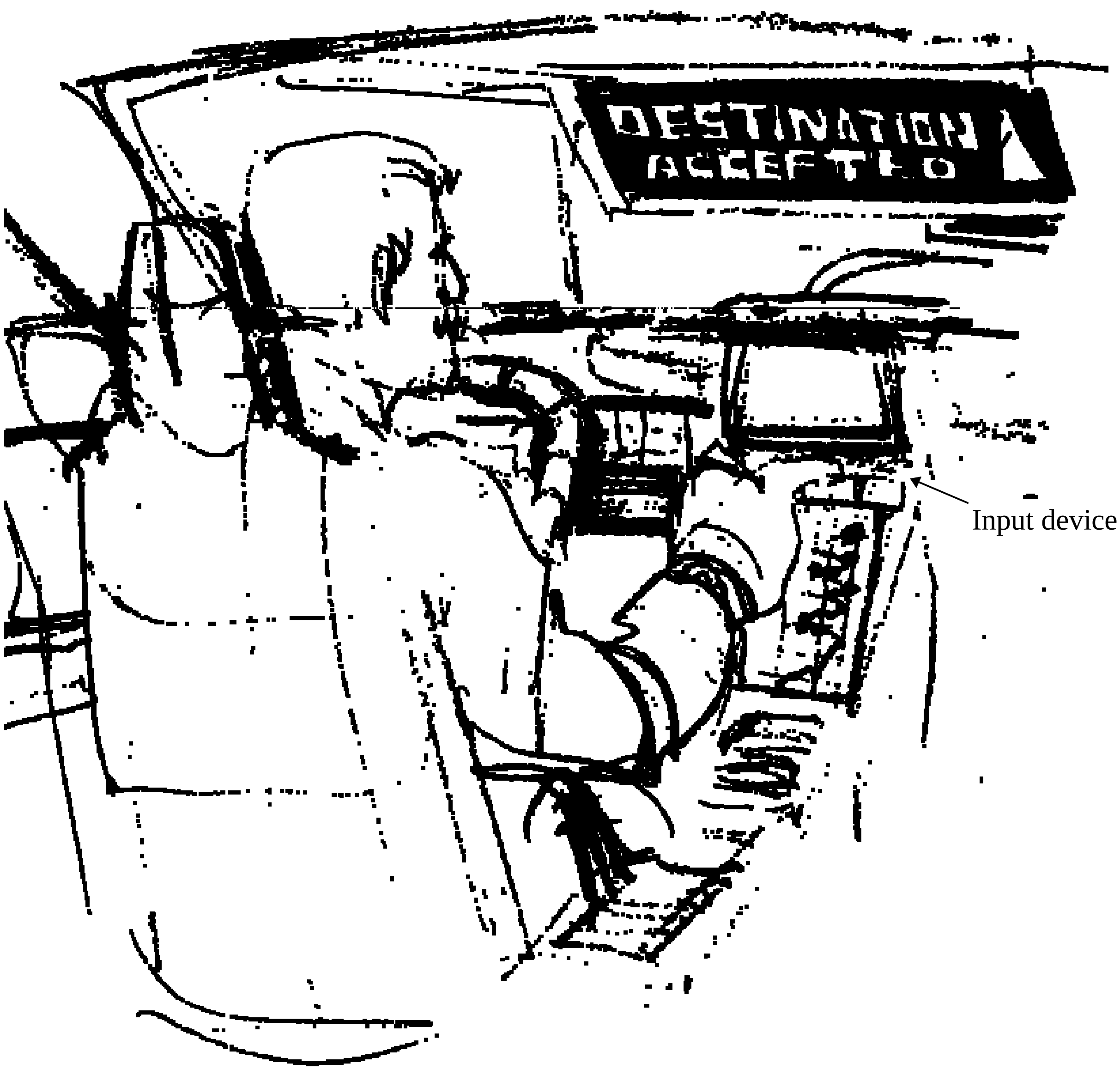

Figure 13. Driver Check-In

Figure 14 displays an AHS entry setting. As in the exit case, this station is also staffed by AHS employees. Vehicles could run through a check-in procedure by driving under check-in units located above each lane in the station. Driver information displays would direct vehicle operators to the appropriate lane for their type of vehicle.

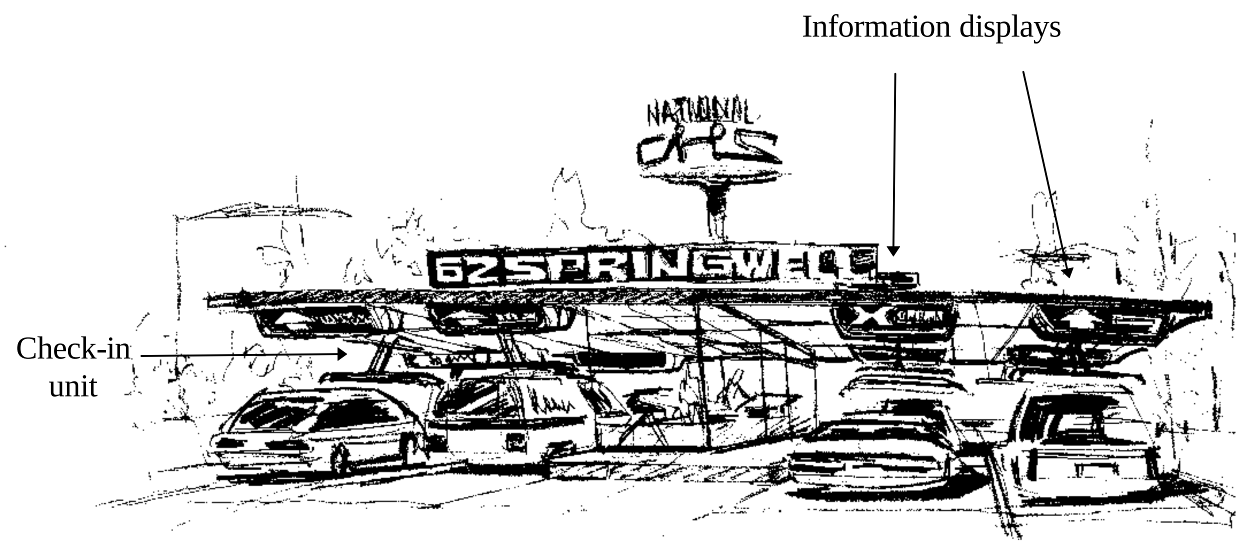

Figure 14. AHS Check-In Situation

Automated vehicle control can allow the driver the opportunity to perform other tasks while the system operates the vehicle. This can be especially advantageous for those who commute long distances to and from their place of work each day. In the scenario displayed in figure 15, the driver completes some work while the system controls the vehicle.

Figure 15. Driver Work Scenario

Figure 16 depicts a driver in a "rest mode." Here, a headrest can provide relaxing music, emergency alarms, or wake-up notification.

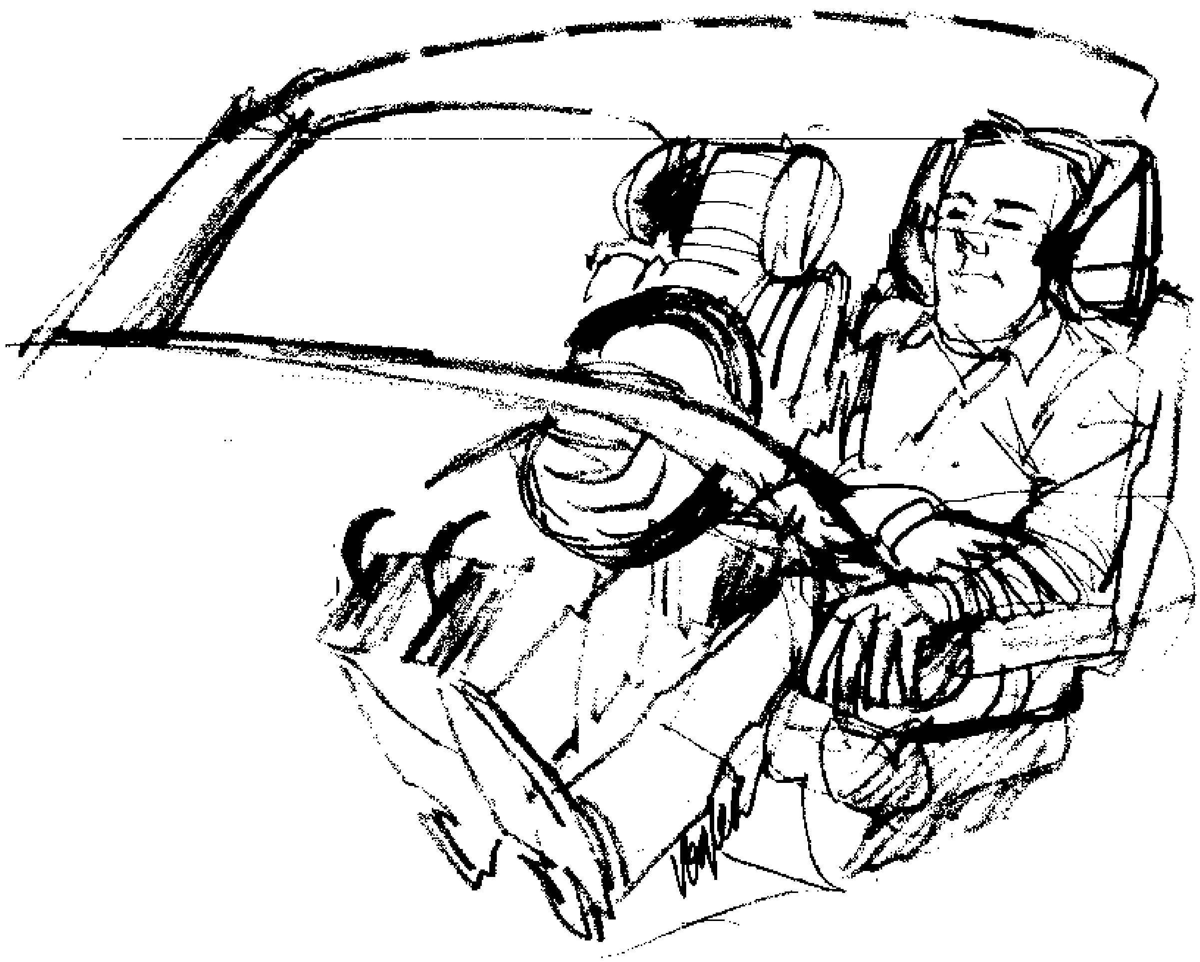

Figure 16. Driver Rest Mode Concept

The scenario depicted in figure 17 is similar to that shown in figure 15. Here, the driver operates a lap top computer and talks on the cellular phone at the same time. Again, this is very convenient for those whose work commute (or other commute) requires a significant amount of their time.

Figure 17. Driver Work Situation

While driving on the AHS, the driver can monitor trip progress, estimated time of arrival, vehicle status, local historical sites, restaurants, lodging facilities, etc. by interacting with the Traffic Operations Center. This concept is depicted in figure 18.

Figure 18. Driver Monitoring Scenario

CONCLUSIONS

This report consists of an analysis of institutional and societal issues associated with automated highway systems. Focus is placed on the following four areas of investigation:

- Impact on State and local governmental agencies.
- Environmental issues.
- Privacy and human factors.
- Public acceptance – user interface.

The first task is devoted to a discussion of the grouping of issues and concerns as summarized in figure 19, entitled Risk Assessment Rank Areas And Prioritization. Risk indices and risk indices descriptions have been chosen for quantification and prioritization ranking with an issue being of lower risk and a major concern, of highest risk. The relative risk priority index ranking used here, is as follows:

- An issue is *
- A concern is **
- A serious concern is ***
- A major concern is ****

Beyond PSA, it is strongly recommended that more definitive risk assessment(s) be made once a baseline AHS approach has been chosen from the RSC(s). For example, prior to a bid award, a detailed risk analysis should be performed to determine risk rating tradeoffs of, probability of occurrence vs. severity of impact (in dollars). Information and conclusions derived from Activity P – Preliminary Cost/Benefit Factors Analysis could be used as additional inputs in further quantifying, controlling, and re-evaluating risks during long-term AHS implementation.[24]

Of all the design issues previously discussed and summarized in figure 19, funding is a major issue which can lead to a number of other issues and accompanying risks. For example, inadequate institutionalized funding resulting in substandard AHS designs and inadequate system safety designed into AHS (e.g. design for minimum risk concept-fail/safe, hazard analyses, hazard mitigation, systems assurance, etc.) causing AHS-related fatalities is unacceptable.

It is recommended that a plan of action using transit expertise to justify the necessary funding for adequate AHS design be a forum for discussion.[25,26] The rationale for this approach is that System Safety design and much of the cost justifications and proven system design methodologies exist, especially in the area of train control (wayside and vehicle).

In summary, uniform design standards, educational and technical capabilities, agency coordination and cooperation, program management and cost-effective design are solvable if sources of risks have plans of actions early in post-PSA programs. Once these aforementioned areas are addressed then funding is fundamentally reduced to a liability concern related to how AHS is operated and maintained beyond the design phase (see Operational Issues–Liability).

RISK INDICES	RISK INDICES DESCRIP-TION	DESIGN ISSUES (Risk Index in parentheses)	OPERA-TIONAL ISSUES (Risk Index in parentheses)	MAINTE-NANCE ISSUES (Risk Index in parentheses)
* ** *** **** *,**: Solvable. ***,****: Requires more investigation to resolve.	ISSUE CONCERN SERIOUS CONCERN MAJOR CONCERN	Uniform Design Standards(*) Educational and technical capabilities(*) Agency coordination and cooperation(*) Program Management(*) Funding(****) Cost effective design(**)	Adequately trained staff(**) Emergency response(*) Transition period(*) Liability(***)	Technical capabilities and equipment(**)

Figure 19. Risk Assessment Rank Areas And Prioritization

Liability has been a long-standing issue that affects how one views the AHS concept implementation. In brief, in the AHS concept, the control of the vehicle is assumed by the AHS system. The issue of a privately-owned vehicle on a public right-of-way will have a variety of liability issues that depend on the chosen RSC (infrastructure or vehicle based). The safety issues that cause liability concerns for all RSC's are summarized in the Activity N –AHS Safety Issues report. There are two categories then to consider, liabilities common to all RSC's (e.g. system safety hazards–direct liabilities) and those liabilities unique to a specific RSC. Prior discussion on various ways to handle tort liability clearly depend on making a highly reliable and safe AHS.

Inadequate funding for operating and maintaining AHS that affects System Safety impacts liability and would probably stop further funding of future AHS projects because of fatalities shown to be a direct result of inadequately operating and maintaining AHS.

As discussed earlier the acceptance of system safety and maintainability principles as a necessary step at all phases of AHS development is integrally related to the number of fatalities, injuries, and equipment failures on AHS. Increased emphasis on maintainability using preventive with corrective maintenance planning for AHS and non-AHS public right-of-ways is a paradigm shift in current thinking that is critical to the long-term success of AHS and the safety of our private citizens.

An analysis of environmental issues associated with automated highway systems was made in task 2 to develop as comprehensive an examination as possible. The principal sources of information used in the analysis, individual interviews and focus group participants in the engineering, planning, economics, and environmental areas allowed for a deep probe into views that might otherwise not come to light.

Environmental issues associated with automated highway systems fell into three major categories: travel-related, infrastructure and urban form, and institutional. Travel-related issues arose from concerns over the consequences of automated highway systems implementation and operation on how much additional travel will be generated, by what means, and its secondary impacts on vehicle emissions and fuel usage. The major infrastructure and urban form issues relate to impacts from infrastructure changes resulting from automated highway systems such as visual impacts and seismic safety concerns, as well as the impact on the local neighborhood as a result of potentially substantial increases in vehicle access and egress to and from non-automated roadways. The institutional issues are centered around the relationships among the participants in automated highway systems research, development, deployment, and operation. Examples of such issues are the barriers that exist between the two major groups of participants in this research, as well as the lack of complete and accurate information and attitudes that each group believes about the other group.

Primary suggestions for resolving these issues include:

- Further research into developing modeling tools to more accurately represent the automated highway driving mode to produce reliable estimates of the impacts in areas of travel volume changes, mobility, land use, emissions, and energy consumption.
- Investigation of current methods for environmental impact review processes for applicability to the automated highway systems case, determining and making necessary modifications.
- Incorporating an aggressive process of education, communication, and participation to help dissolve the barriers and help forge a more common vision of a future transportation system with automated highway systems as an integral component.

The most significant recommendation of all would be to make every effort to begin the process of resolving these issues as well as issues in other areas of investigation in the near term, and not delay this process. Delay would only add to the difficulty by contributing to the exacerbation of the issues and probably the expense of resolving them.

The third task presented a discussion of privacy issues, driver comfort, and driver acceptance. Current studies indicate that the driving public will be more likely to use the AHS if a concerted effort is made to offset the privacy issue. This can be accomplished by providing a full explanation of the AHS system operations and highlighting the benefits. The evolutionary deployment of AHS technologies, such as toll debit cards and incident surveillance cameras through ITS implementation, would be an initial step. The remaining AHS requirements including vehicle inspection and driver monitoring can be introduced with the added benefits of increased safety, reduced travel time and operating costs. Gradual introduction of control features and associated electronics will allow the driving public to benefit from the convenience of the system in proportion to the level of risk to privacy.

The level of driver comfort during the operation of a vehicle in automated mode is discussed from the perspective of in-vehicle AHS equipment and potential psychological stress factors. In-vehicle equipment the driver would use to operate the automated vehicle must be user friendly, easy to operate, and be designed for as complete a user capability profile as possible, including age and reaction time differences. A driver-vehicle interface must take into consideration the potential for driver work overload if manually entered input is required. The combination of high speed, automated control, potentially very close vehicle following would likely contribute to added psychological stress that must be addressed. Research is needed to accurately assess the extent of this problem and develop and assess potential solutions. Driving simulators could be used but their effectiveness may be limited since there really is no risk of an accident in a simulator, yet stress may still be present. Alternative test strategies to evaluate driver responses may include test tracks and demonstration rides. Methods to address the potentially stressful effects of automated driving by reducing the perceived trip length include diverting the driver's attention with information, either trip-related or recreational.

An investigation of the AHS vehicle-driver interface was presented in task 4 and was based on the development of concepts to depict the possibilities for driver interface and for representative AHS situations. Important design concerns for vehicle displays and controls include their orientation, method of implementation, styling, and illumination. Driver interface concepts include potential electronic interface units and their positions within the vehicle; typical AHS situations include check-in/out, entry/exit, various vehicle types (commercial and transit), maintenance situations, and potential driver activities while using the automated facility. These concepts generate numerous issues among which include the compatibility with malfunction management strategies of allowing certain vehicle components (steering wheel, foot pedals) to be moved to different positions to provide the driver more room for other activities, the potential need for standardization of details of AHS control and communication interfaces among vehicles, the degree to which driver-vehicle interface is extended to encompass the front seat passenger or possibly back seat passengers as well, the extent to which the AHS interface would be able to use components already present as part of the more general Intelligent Transportation Systems interface.

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