

NATIONAL AUTOMATED HIGHWAY SYSTEM CONSORTIUM



**AUTOMATED HIGHWAY
SYSTEMS —
SOLVING TRANSPORTATION
PROBLEMS**

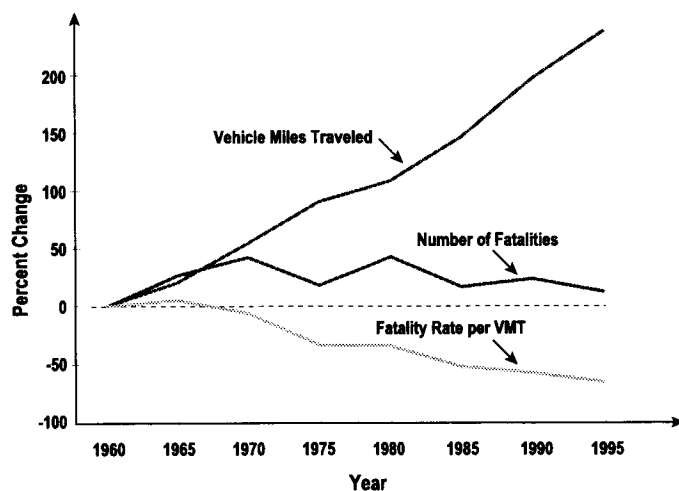
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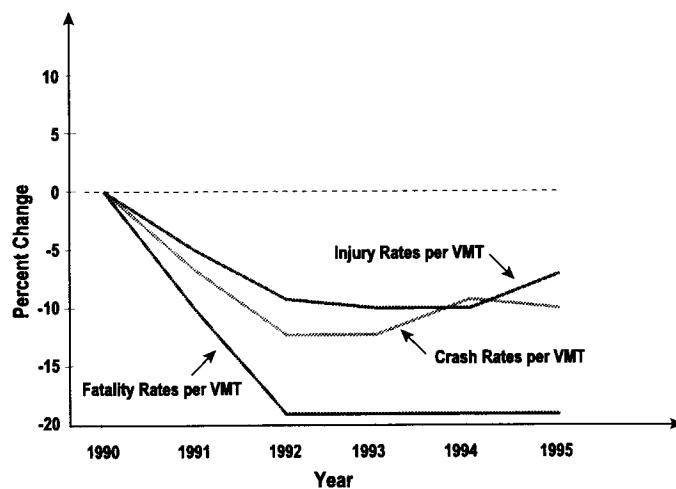
IMPROVING SAFETY

SAFETY PROBLEMS

- The total economic cost of motor vehicle crashes was estimated to be \$150 billion in 1994 by NHTSA,¹ including:
 - Property damage \$52 billion
 - Loss of market productivity \$42 billion
 - Medical expenses \$17 billion
 - Loss of household productivity \$12 billion
 - Insurance administration \$10 billion
 - Legal costs \$ 6 billion
 - Travel delays \$ 4 billion
 - Other (workplace costs, emergency medical services, vocational rehabilitation, funerals) \$ 7 billion
- Of those costs, NHTSA estimated the costs to taxpayers as \$13.8 billion, or \$144 per household in 1994.¹
- Motor vehicle crashes caused almost 42 thousand deaths and 3.4 million injuries in 1995.²
- Although the trends in rates of fatalities, injuries and crashes per vehicle mile traveled have been down, the growth in travel has more than counteracted that, leading to net increases in these impacts.²
- The 1995 traffic injury rate of 141 per 100 million VMT² means that a person who travels the typical 10,000 miles per year by road vehicle has a 1.4% chance of being injured in a traffic crash each year. A person traveling that average distance over 50 years would have a 70% probability of suffering a traffic crash injury.
- The 1995 traffic fatality rate of 1.7 per 100 million VMT² means that a person who travels the typical 10,000 miles per year by road vehicle for 50 years has a 0.85% chance of being killed in a traffic crash.
- Driver task errors and driver physiological state are the primary causes of about 90% of the crashes today (only 2.5% are primarily from vehicle defects).³



Highway Safety Trends Since 1960



Highway Safety Trends Since 1990

HOW AHS CAN HELP

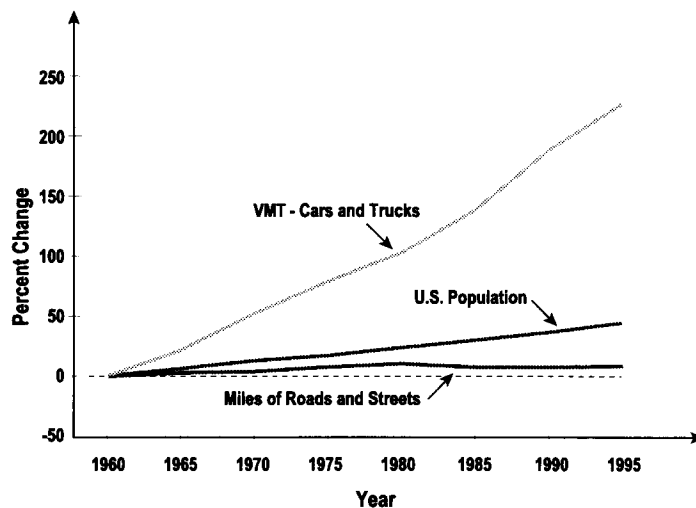
- By relieving the driver of responsibility for controlling the vehicle, the causes of 90% of today's crashes are eliminated on a fully automated AHS.
- In a well-structured AHS environment, vehicle-based sensors can detect hazardous conditions and computers can take corrective actions faster than drivers can.
- Vehicle-vehicle communications enable vehicles that encounter problems to tell other vehicles quickly, so that they can take evasive actions.
- Electronic systems on AHS vehicles are not vulnerable to the fatigue, emotional upsets, chemical dependencies or distractions that can impair human drivers.
- Motions of AHS vehicles are well controlled and predictable, eliminating the hazards of aggressive drivers.
- NHTSA studies have predicted that use of well-designed driver warning systems (which could be precursors to AHS) could avoid 791,000 rear-end crashes, 90,000 lane change/merge crashes and 297,000 road departure crashes per year. These could lead to an annual saving of the economic costs of these crashes of more than \$25 billion.⁴

1. "The Economic Cost of Motor Vehicle Crashes, 1994," NHTSA.
2. National Transportation Statistics, Bureau of Transportation Statistics, U.S. Dept. of Transp., 1997
3. Najm, Mironer, Koziol, Wang and Knipling, "Synthesis Report: Examination of Target Vehicular Crashes and Potential ITS Countermeasures," June 1995, DOT HS 808 263, pp. 3-8.
4. "Preliminary Assessment of Crash Avoidance Systems Benefits," NHTSA Benefits Working Group, October 1996.

REDUCING CONGESTION

CONGESTION PROBLEMS

- Traffic congestion causes loss of economic productivity, loss of quality of life, traveler stress, and excessive fuel consumption and exhaust emissions.
- Traffic congestion has been increasing because the demand for travel has been increasing much faster than the supply of transportation system capacity in many parts of the country.¹
- Estimates of the annual cost of traffic congestion have varied widely, ranging from \$11 billion to \$100 billion per year for the United States, depending upon the year of the estimate and the range of congestion impacts included.² Most recent estimates are toward the upper end of this range.
- The Texas Transportation Institute (TTI) estimated the congestion in 50 metropolitan areas in the U.S. to total more than 14 million person-hours per day in 1993, nearly double the amount in 1982.³
- TTI estimated that person-hours of delay on freeways was about double that on arterials in the 50 metropolitan areas, and found that about 60% of the freeway congestion was related to incidents (crashes, breakdowns, maintenance and enforcement actions).³
- TTI estimated the per-capita congestion cost in the 50 metropolitan areas to range from a low of \$80 in Corpus Christi to \$820 in Washington DC for the year 1993. These costs exceeded \$500 per capita in 12 metropolitan areas, and were between \$250 and \$500 per capita in an additional 25 metropolitan areas.³
- Using the TTI estimate of delay in the 50 metropolitan areas, and assuming a value of time of \$10 per hour of delay and 250 days per year of weekday congestion, the direct cost of travel delays in just these areas exceeded \$35 billion in 1993.
- TTI estimated an annual per capita congestion cost for the San Diego area of \$300. Applying this to the SMSA population of 2.6 million leads to an annual congestion cost for the region of \$780 million in 1993. For the Los Angeles region, the per capita cost was \$710 in 1993, leading to an annual regional cost of \$8.7 billion.



Factors Contributing to Congestion Increases

HOW AHS CAN HELP

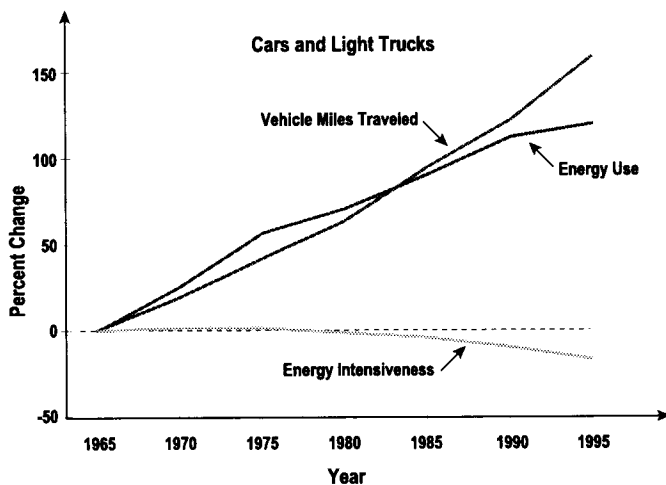
- Fully automated AHS vehicles can maintain safety while operating closer together than manually driven vehicles, which makes it possible to increase the capacity of a lane substantially.
- NAHSC analyses of AHS capacity have shown the potential for an AHS lane to provide double to triple the capacity of a conventional freeway lane.⁴
- AHS operations are conducted at constant cruise speed, and do not degenerate into stop-and-go slow-downs as traffic volume increases.
- Increases in the capacity of a highway corridor using AHS require fewer lanes than increasing that capacity using conventional technology.
- AHS capacity increases can relieve congestion on parallel freeway and arterial lanes as well, providing faster travel times for all travelers.
- AHS safety improvements can reduce some of the non-recurrent congestion caused by today's crashes.
- AHS vehicles are not subject to "rubbernecking" delays because they do not slow down to take a closer look at crashes or police enforcement actions.
- Automated buses in AHS can avoid congestion, providing more competitive service to their passengers.

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1. National Transportation Statistics, Bureau of Transportation Statistics, U.S. Department of Transportation, 1997.
 2. "The Price of Mobility", Natural Resources Defense Council, 1993.
 3. Texas Transportation Institute, "Urban Roadway Congestion - 1982 to 1993, Volume 2", TTI Research Report 1131-8, 1996.
 4. National Automated Highway System Consortium, Milestone 2 Report: Task C2: Downselect System Configurations and Workshop #3, June 1997.

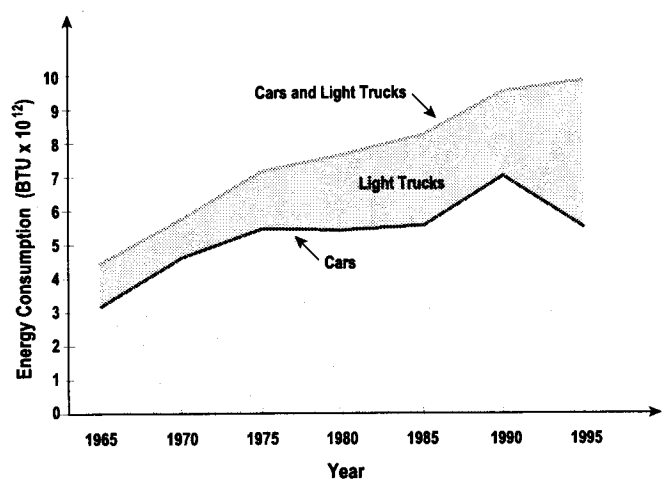
REDUCING ENERGY AND ENVIRONMENT

ENERGY AND ENVIRONMENTAL PROBLEMS

- Transportation represented 26.5% of national energy consumption in 1995, and 66% of petroleum consumption.¹
- Transportation has consumed ever-increasing fractions of national petroleum consumption (52.4% in 1960, for example).¹
- While energy consumption per passenger mile has been improving consistently, travel has been growing at a faster rate, leading to total increases in energy use for road transportation.¹
- Modern automotive vehicles have already been designed to minimize pollutant emissions and waste of energy, so further improvements are increasingly difficult and expensive.
- While pollutant emissions per passenger mile have improved considerably, the growth in travel is making it harder to gain reductions in total emissions.
- Stop-and-go congested traffic makes vehicles operate less efficiently and produce more pollution than if they are flowing at a constant speed.



Growth in Travel Exceeding Improvements in Energy Efficiency

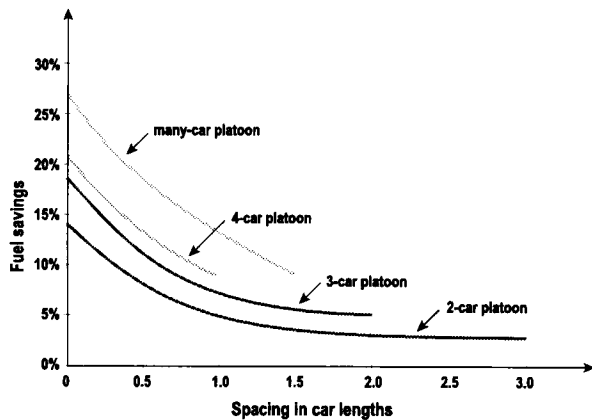


Growing Energy Use by Light-Duty Vehicles

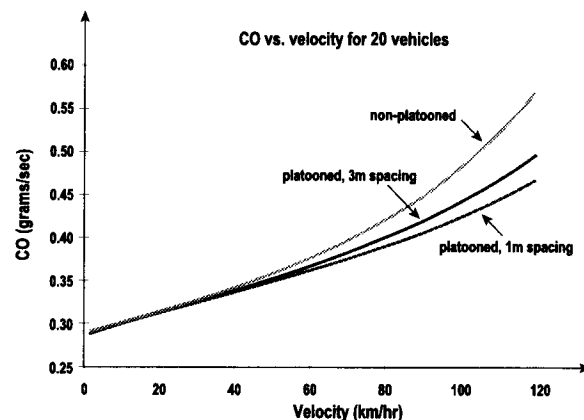
CAL IMPACTS

HOW AHS CAN HELP

- Automatic speed control of vehicles can *reduce severity* of accelerations and decelerations, thereby reducing energy use and emissions.
- Automation of all vehicles in an AHS lane can *eliminate* stop-and-go transients, *significantly* reducing energy consumption and emissions.
- Operation of automated vehicles at very close spacings can cut aerodynamic drag in half, which reduces fuel consumption and running emissions by about 25%.^{2,3}
- Availability of increased capacity on AHS lanes can draw traffic away from today's congested freeway lanes and arterials, reducing stop-and-go problems, emissions and fuel use for manual vehicles operating there.
- Increased proportion of traffic on AHS lanes takes that traffic off neighborhood streets and arterials, improving quality of life for neighborhoods.
- Reduced need for construction of additional highway lanes means that AHS helps conserve right of way and reduce disruptions of neighborhoods by freeway capacity expansions.



Fuel Savings From "Drafting" Within Automated Platoons



Carbon Monoxide Emissions Saved By "Drafting" Within Automated Platoons

1. National Transportation Statistics, Bureau of Transportation Statistics, U.S. Department of Transportation, 1997, Table 4-25.
2. Zabat, Stabile, and F. Browand, "Estimates of Fuel Savings from Platooning," Proceedings of ITS America Annual Meeting, March 1995, pp. 1203-1208.
3. Barth, M., "AHS Reduction of Vehicle Emissions: Preliminary Analysis," Proceedings of ITS America Annual Meeting, March 1995, Washington, D.C., pp. 1137-1145.

RELIEVING DRIVING STRESS

DRIVING STRESS PROBLEMS

- Driving in heavy traffic makes significant attentional demands on drivers.
- The population of drivers is aging rapidly, based on demographic trends.
- Older drivers are increasingly intimidated by high-speed aggressive driving on freeways, which limits their mobility.
- Commute driving is one of the major sources of stress in modern life.
- People's leisure time is diminished by the pace of modern life.

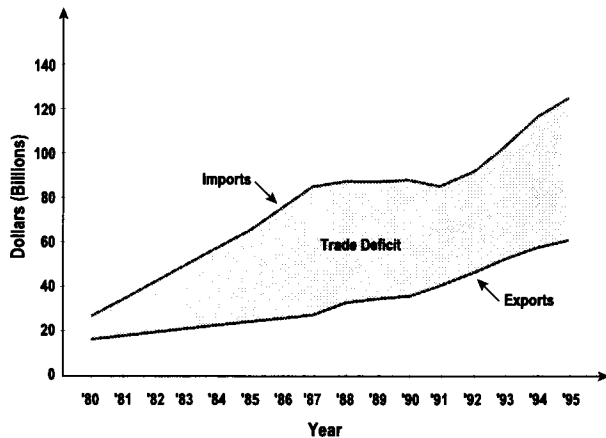
HOW AHS CAN HELP

- Drivers of fully automated AHS vehicles do not need to pay attention to the driving environment, and are relieved of the routine chores of driving.
- Drivers can relax, engage in leisure activities or do productive work while being driven by an AHS “electronic chauffeur.”
- Older drivers can have the freeway driving done for them by the AHS vehicle, so they can still enjoy the mobility of freeway travel.
- Some AHS capabilities such as adaptive cruise control could be used to relieve driving chores on non-AHS roadways.
- Since AHS vehicle motions are well controlled and predictable, drivers do not need to worry about the bad behavior of other drivers.

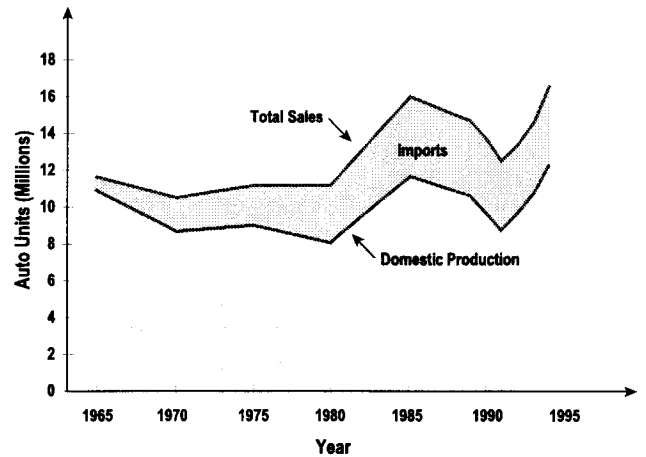
IMPROVING ECONOMIC COMPETITIVENESS

ECONOMIC COMPETITIVENESS PROBLEMS

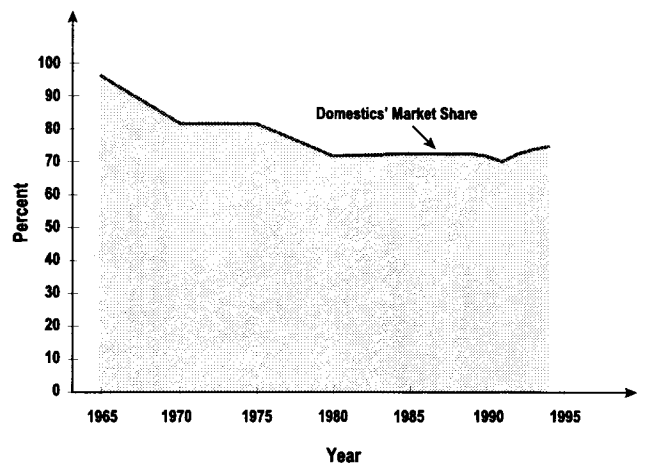
- Automotive sector trade deficit is large.¹
- Need to increase domestic motor vehicle production relative to imports.²
- Traffic congestion reduces economic efficiency of our metropolitan regions, ports and intercity freight corridors.
- Traffic congestion increases the costs of producing goods and services, making us less competitive.
- Our cities and states cannot afford the “conventional technology” approaches to relieving congestion by building new highways or adding many lanes to existing ones.



U.S. Automotive Sector Balance of Trade¹



U.S. Automotive Vehicle Sales²



Domestic Market Share of U.S. Automotive Producers²

HOW AHS CAN HELP

- A new set of automotive technologies in which the U.S. has the chance to gain world leadership.
- Synergy with new technologies where U.S. is the established world leader (software systems, telecommunications, computers, radar,...).
- Opportunity to significantly improve productivity and cost effectiveness of trucking.
- Congestion relief with much less infrastructure than conventional approaches.
- Enables travelers to do productive work while “driving” on commute or long-distance trips.
- Saving some of the economic costs of crashes and congestion.

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1. Statistical Abstract of the United States, 1996, Table 1283 (p. 784).
 2. “Motor Vehicle Facts and Figures, 1995,” AAMA.

A CASE STUDY OF EMISSIONS AND ENERGY IMPACTS OF AN AUTOMATED HIGHWAY SYSTEM



An estimate of the emissions and energy use (i.e., fuel consumption) associated with an Automated Highway System has been made using advanced simulation modeling tools. A highway was modeled after the Katy Corridor (Interstate Highway 10) of the Houston metropolitan region. For this case study, a single lane HOV facility with three merge junctions was examined. Vehicles traveling on this highway were modeled after the automated Buick LeSabres being used in the AHS Demo.

The emissions and fuel consumption of the AHS vehicles have been compared to the case of non-automated traffic under different levels of congestion. The comparative emissions/fuel consumption results for the AHS and non-automated traffic are illustrated in four graphs.

In Figure 1, fuel consumption per unit distance (given in grams per mile) per vehicle is shown as a function of average vehicle speed for different levels of congestion. The top solid line represents non-automated traffic under different "Levels-Of-Service" (LOS),¹ corresponding to different congestion levels. The lower dashed line corresponds to idealized constant-speed traffic (i.e., traffic flow without any acceleration/deceleration events) and represents the lower limit of emissions for the vehicle at different constant speeds. Results for two AHS scenarios are shown to lie between the ideal minimum and the non-automated traffic under light congestion. In the first scenario, vehicles in the AHS act as free agents, cooperating together for smooth merging and traffic flow, but not in platoons. In scenario 2, the vehicles in the AHS can also group themselves in platoons for greater capacity. The platoon-based AHS has lower fuel consumption due to aerodynamic drag reduction when vehicles operate at close spacings.

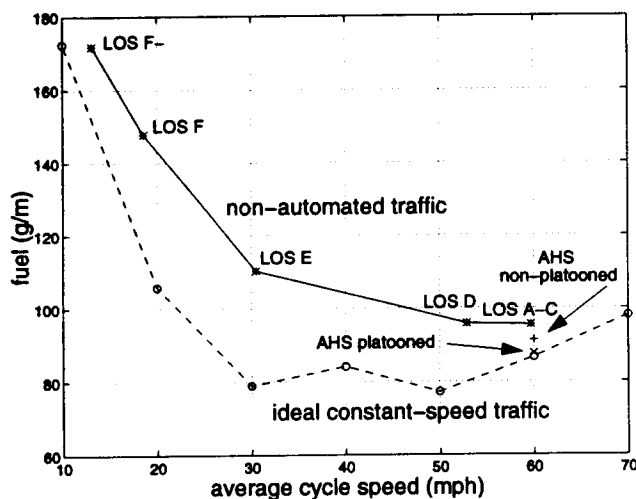


Figure 1. Fuel Consumption vs. Average Cycle Speed.

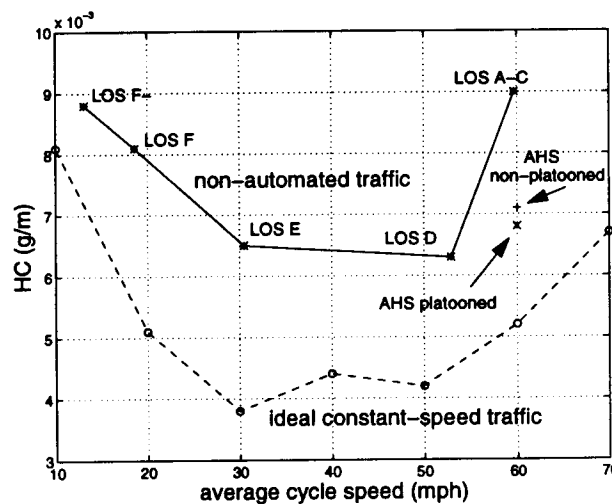


Figure 2. Average Vehicle Hydrocarbon Emissions vs. Average Cycle Speed.

¹The Federal Highway Administration (FHWA) currently employs a Level-of-Service (LOS) measure for congestion that is defined in the Transportation Research Board's Highway Capacity Manual [1]. LOS is a function of both average vehicle speed and traffic flow rate. Primarily due to inter-vehicle interaction at higher levels of congestion (corresponding to LOS values of B, C, D, E, and F), vehicles will have substantially different velocity profiles under different LOS conditions. Under LOS A, vehicles will typically travel near the highway's free flow speed, with little acceleration/deceleration perturbations. As LOS conditions get progressively worse (i.e., LOS B, C, D, E, and F), vehicles will encounter lower average speeds with a greater number of acceleration/deceleration events.

In Figure 2, hydrocarbon (HC) emissions (given in grams/mile) are shown in a similar fashion. It is interesting to note that the average vehicle HC emissions for the LOS A-C case take a turn upwards due to the emissions sensitivity to higher speeds. The AHS scenarios again fall between the non-automated traffic and idealized constant-speed traffic, but represent a significant improvement relative to the non-automated traffic.

Given the travel demand level for the Katy Freeway corridor case study, congestion will remain at the LOS F-level if no improvements are made. In Figures 3 and 4, we compare the fuel consumption and HC emissions for this LOS F- condition against the other scenarios. If additional non-automated lanes are added to this corridor, congestion may return to the LOS A level, but the HC emissions will remain approximately the same. The fuel consumption will be reduced to approximately 55% of the baseline non-automated case (a saving of 45%). If automation is introduced into the traffic system, traffic will flow more smoothly, reducing fuel consumption by 47% (compared to LOS F-) and HC emissions by 19%. If vehicles are capable of platooning, the fuel consumption is reduced by 49% and the HC emissions by 23% relative to the LOS F- base case. For comparison, the idealized constant-speed traffic case is also shown.

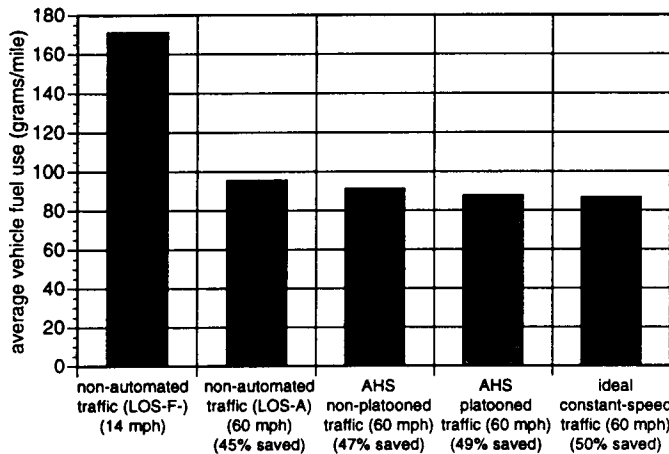


Figure 3. Fuel Consumption Comparison Among Various Scenarios.

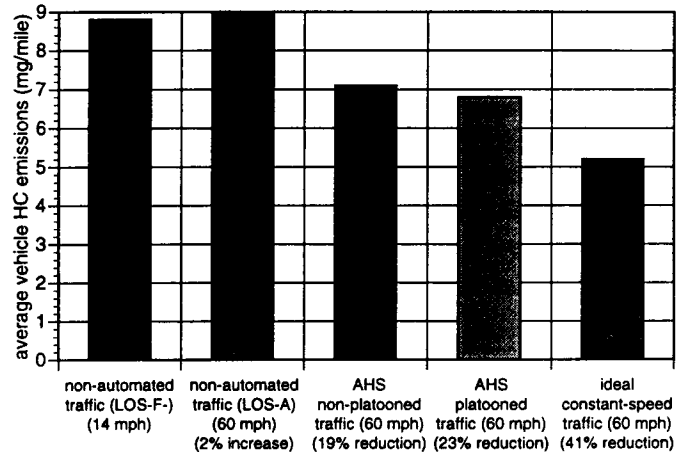


Figure 4. Hydrocarbon Emissions Comparison Among Various Scenarios.

GENERAL CONCLUSIONS

- An AHS has slightly lower average fuel consumption than a non-automated highway operating at free-flow, and much lower average fuel consumption than a non-automated highway operating under congested conditions, because of its smoother traffic flow.
- An AHS operating at 60 mph has substantially lower HC emissions per vehicle-mile traveled than non-automated traffic at the same average speed, because of its smoother traffic flow.
- Vehicles that platoon in an AHS can expect an additional 5 - 15% fuel savings and emission reduction due to the aerodynamic drafting effect, which is dependent on the intra-platoon vehicle spacings.

REFERENCES

- [1] *Highway Capacity Manual - Special Report 209*, Transportation Research Board, 1994.

Automated Highway System: Societal and Institutional Issues



Overview

One of the critical roles identified for the National Automated Highway System Consortium is to “represent the public interest in ensuring that any AHS that is eventually deployed meets the transportation and societal interests of our nation.” In accordance with this goal, the NAHSC has established a Societal and Institutional Issues working group to assure that the AHS that is eventually deployed contributes to social viability, is adaptable to special local and regional needs, and meets the essential transportation needs of the general public. This group’s work helps provide a critical institutional and societal perspective to the NAHSC’s technical and policy development processes and includes research in these task areas:

1. How AHS Can Fit Local Land Use and Economic Development Goals and Plans
2. Integrating AHS with Implementing Agency/State DOT/MPO Planning and Decision-Making Processes
3. Identifying the Most Viable Public and Private Sector Roles in Construction, Operation, and Maintenance of an AHS
4. Institutional Constraints and Considerations for Operations and Maintenance
5. Liability Implications and Monitoring Other Legal Issues
6. How AHS Can Fit into the Concept of Sustainable Development
7. User Needs: Market Demands
8. The Human in the System: Societal Considerations
9. Institutional and Societal Issues Relative to AHS Transit Operations
10. Social Equity Considerations for AHS
11. Institutional and Societal Costs, Benefits, Tradeoffs

1. How AHS Can Fit Local Land Use and Economic Development Goals and Plans

Decisions about whether and how to deploy AHS will be made on the regional/local level, and in the context of local objectives regarding land use planning and economic development. The transportation-land use relationship is complicated, although generally acknowledged to be interdependent, and may differ in different geographic areas. Implications of deploying other ITS technologies are already under study.

As part of this subtask, experts in the area of transportation-land use relationships will be asked to consider and offer guidance on the questions of (1) the likely effects of AHS and under what circumstances it could be most beneficially deployed to support local objectives, and (2) whether a new technology like AHS provides an opportunity for rethinking, or, indeed, for a new community vision of, the urban form different from the land use patterns shaped by the old technologies of the streetcar, the interurban railway, and the present highway. Potential infrastructure/land use-related criteria will be developed to help guide the evaluation of different AHS concepts. Interviews and related studies in different geographic areas will provide additional inputs to this consideration.

2. Integrating AHS with Implementing Agency/State DOT/MPO Planning and Decision-Making Processes

The planning and decision-making processes in each region vary enormously. ISTEA-derived guidance regarding the use of federal funds through the Major Investment Study process recognizes the need for local control to meet local needs, while providing a framework for all locations that works with existing federal environmental process regulations. Related research on MPO procedures as they relate to other ITS technologies is underway. Specific geographic area analyses will be used to understand models of how new investment projects are handled, to further the ability of AHS specification-writers to speak to the issues and information that potential implementing agencies and regional and State officials need to have in order to consider AHS as an alternative for addressing transportation problems and meeting transportation needs in any area.

3. Identifying the Most Viable Public and Private Sector Roles in Construction, Operation, and Maintenance of an AHS

The respective roles of the public and private sectors for AHS construction, operation and maintenance, and in funding each of these, will be decided by states and localities to match specific circumstances and institutional arrangements. State, regional and local governments and interested businesses need to understand lessons learned from previous experience with comparable technologies and systems and with institutional and government-private sector arrangements. Operating and maintaining electronic toll collection systems, government-franchised private toll roads in Virginia and California, and the experience with proposed innovative financing of transportation projects in the State of Washington are examples in the consideration of options on how best to implement AHS and, conversely, what to avoid. Model arrangements based on these and other experiences will be considered for AHS.

4. Institutional Constraints and Considerations for Operations and Maintenance

This task will focus in three areas:

- Organizational
- Operational
- Maintenance

Organizations in which users have some investment and where a broader organization owns and controls the uses of the infrastructure may provide some important lessons for AHS. Examples include telephone companies and railroads.

Results of this subtask are expected to include identification of: a) issues of possible concern to particular groups, e.g. law enforcement, emergency response; b) practical implementations of AHS; c) design concepts that facilitate continued operation and maintenance of the system; d) plans for vehicle inspection, and emergency response plans.

5. Liability Implications and Monitoring Other Legal Issues

After considering many legal issues (e.g., privacy), the PSA research generally concluded that most are either not unique to AHS or that they are being adequately addressed in the context of earlier ITS technology deployments. However, we will continue to monitor these issues throughout the NAHSC process as they relate to AHS design and deployment issues.

By contrast, liability is believed to have unique implications in the context of AHS. For example, an objective of AHS is an overall improvement in highway safety. This would imply that damages and injuries from motor vehicle accidents (and thus liability risk in the aggregate) should be reduced from present levels. However, this reduction in liability may change who bears those risks. Legal requirements and principles pertaining to liability suggest that when an accident occurs as a result of transfer of control from the driver to the vehicle and/or the roadway, an allocation of responsibility might be made among the driver, vehicle manufacturer, vendors of other components, and the highway authority. If so, it is not clear whether vehicle manufacturers will demand a high degree of

standardization in AHS approaches to reduce liability risk. The legal community and the insurance industry will be consulted in considering the importance of this and other legal issues associated with AHS.

6. How AHS Can Fit into the Concept of Sustainable Development

AHS influences community sustainability through its impact on traffic patterns due to increased or changed roadway capacities. For example, AHS, as presently envisioned, may:

- increase traffic flow and efficiency, thereby contributing to a reduced, sustainable level of consumption of non-renewable resources, particularly petroleum
- reduce air pollution and other impacts on the environment to levels that do not exceed absorptive capacity as a result of improved operating efficiencies and reductions in congestion
- alter traffic patterns by offering incentives to users to find the most appropriate means of transportation to reach the chosen destination.

AHS may be judged, in part, on its anticipated impact (positive and negative) on the environment, including both natural systems and human communities. Work performed here will identify how AHS can conserve scarce resources, pay its way on a continuing basis, help reduce (or at least not increase) adverse environmental impacts, and contribute to the evolution of viable urban forms including sustainable land use patterns. Questions related to changes in VMT as a result of AHS will also be examined in these contexts. Through this task, we will seek a balanced focus on both mobility enhancement (flow, congestion relief, traffic efficiency) and sustainability (transportation demand management, congestion pricing, alternative non-vehicle modes of access, less pollution, alternative propulsion systems, and use of alternative fuels). As a result of these efforts, AHS can recognize its potential for improvements in the economy, in land use, and in the overall quality of life.

7. User Needs: Market Demands

AHS must meet the perceived needs and desires of its intended users and understand both its market and its marketplace (i.e., any opportunity to apply AHS technology to private passenger, transit, or commercial/trucking activities). In addition, there may be latent or unrecognized needs, such as the use of driving time for non-driving tasks. Perhaps the best way to evaluate the various potential markets for AHS is to identify what attributes of AHS are most attractive to these markets (e.g., price, mode choice, access, mobility, safety/reliability, trip predictability, etc.). The results of focus group research from the PSA studies will be a starting point for this effort. This subtask will also seek to support an ongoing dialogue with and among the potential users of AHS, planners, critical decision makers, and members of the NAHSC. Interviews and additional consumer focus groups will be convened as needed to address the following questions in terms of the developing AHS concept(s):

- What is the level of consumer awareness of existing and planned ITS technologies?
- What identifiable market demands can or should AHS meet?
- Which of these issues are influenced by transportation planners and decision makers, and what are effective means by which AHS can enhance market acceptance through discussions with these officials?
- What new markets are created by AHS, and to what extent should AHS take an active role in supporting (or discouraging?) those markets?

8. The Human in the System: Societal Considerations

Assuring a very high degree of safety and driver confidence will be critical to AHS success. Such assurance is complex to achieve in aviation, where operators (pilots) must have hours of training and pass certification and licensing tests. It will be much more difficult in a highway environment, where vehicle operators are likely to include anyone with a valid driver's license. Studies are needed to better understand driver performance under circumstances of automated control, and the acceptability of hands off movement at high speed. In addition, research is needed to identify the special requirements of specific driver groups, such as the learning disabled, elderly drivers, non-English speaking operators, and teenage drivers. Liability and insurance demands may be closely tied to such issues.

9. Institutional and Societal Issues Relative to AHS Transit Operations

Transit can help resolve such highway transportation problem areas as congestion, safety, air pollution, and fuel consumption. It may also help resolve some of the social equity and land use considerations raised by AHS by extending AHS to serve the needs of people and markets other than automobile owners and drivers. Transit applications, particularly in early deployments, also offer the opportunity to demonstrate AHS technologies with a cadre of trained drivers and users. Although many technical issues associated with fully integrating transit vehicles into an AHS concept are not yet resolved, institutional and societal issues that can be addressed in the early phases of the AHS effort include:

- acceptability of proposed AHS related technological changes to the transit industry
- changes in the role of the driver, e.g. changes in driver training, salaries, work rules, insurance, liability, and management/labor relationship associated with automated transit
- requirements for government involvement, i.e. what would make automated transit a viable alternative for regional transportation investment
- assessment of advantages to transit operations offered by AHS, e.g.. improved service levels, increased ridership, enhanced throughput of people

10. Social Equity Considerations for AHS

How do we design an AHS so that current highway users have access to it? Will it be possible through AHS to increase the mobility of people who currently have difficulty using the highway system? Factors requiring consideration include funding, facility siting, access or user charges, usage priorities, transit and commercial vehicle access, and intermodal integration. What user groups do these issues impact? What are the associated equity issues? How can these concerns be considered in the design or deployment process?

11. Institutional and Societal Costs, Benefits, Tradeoffs

In order to provide a framework for other groups within the NAHSC and outside agencies to evaluate AHS in a comprehensive and consistent manner, it will be important to:

- Explore the relationship between the NAHSC's Measures of Effectiveness for the AHS and cost/benefit measures
- Provide input into and review tools for cost benefit estimation, throughput and other transportation related tools.
- Identify the components of benefits and costs that are of interest and relevance to different stakeholders and other interested parties.
- Establish criteria for the evaluation of methods to analyze monetary and non-monetary, and quantifiable and non-quantifiable costs and benefits.
- Identify and evaluate methods and frameworks for cost benefit analysis based on the criteria established.

The result of this task will be a framework for the comprehensive and consistent analysis of institutional, societal and engineering costs associated with AHS. Where possible, parametric estimates of cost and benefits that are sensitive to different system characteristics will be developed. The framework will be applied to specific concepts and application scenarios.

We welcome your questions and comments on this work:

⇒ Please fax your comments to A. Lubliner at 212-465-5584 or J. Blanchard at 415-768-0503

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SOCIETAL AND INSTITUTIONAL ISSUES

Market Demand



What is the issue?

AHS must meet the needs of its intended users, and like any consumer product, if it does not, the project will have failed. Understanding the market and the consumer, therefore, is a prime requirement for the success of an AHS. But the market for an AHS consists of a range of potential users, including the private automobile driver, public transit, commercial trucking, and state or federal governments who might have to provide infrastructure. Perhaps the best way to evaluate the various potential markets for AHS is to identify the various marketable services and service packages that are most attractive to these potential users and determine the prices that these users might be willing to pay for these services.

The issue then is -- what is the potential market for AHS services? What are the marketable services and service packages of AHS? Who are the potential users of the various services? How much of these services will be demanded and at what price? What trade-offs will the consumer make between the various services at different price levels. What are the factors, apart from price, that will influence the acceptability of AHS, such as location, mode choice, access, mobility, safety, reliability, and trip time and predictability? What is the consumer preference for an "evolutionary/slow" or "revolutionary/fast" approach to AHS development? And how will the demand for these AHS services grow over time?

Why is this an issue?

Assessment of the market demand for AHS services is a major issue because it is a significant factor in assessing the potential utility of AHS, and in helping determine the allocation of resources for the development of AHS services and packages, consistent with consumer demand -- in essence, determining the character of AHS. In the absence of an assessment of market demand, we risk the possibility of developing AHS services and packages that nobody wants, or are too expensive for all but a few consumers.

What is the process used to research this issue?

The process used to research the market demand for AHS services includes:

- reviewing the literature on AHS market demand in the US and in other countries (where interest in AHS is beginning to gather momentum)
- identifying appropriate study methods (e.g., workshops, focus groups, interviews, surveys, etc.)
- interviewing potential AHS users, transportation professionals, and other stakeholders, to help identify key market factors likely to influence AHS utility
- surveying potential AHS users through internet surveys, mail surveys, consumer clinics, and information acceleration, with a view to answering the questions raised above
- deriving from the analysis of interview and survey results a set of recommendations for the successful marketing of AHS services and service packages to potential users and other stakeholders

What are the results to date?

- An internet survey was completed and the results have been publicized.
- A preliminary version of an AHS Information Accelerator model is in test phase. The Information Accelerator is a computer-based market analysis tool that allows consumers to conceptualize a product -- in this case AHS services -- that has not yet been developed, before responding to what they like or dislike about it and whether or not it meets their needs. It will provide the ability to survey potential users of AHS services and stakeholders, to determine relative utilities of AHS market packages and optimal marketing strategies. Additionally, it will be possible to use this model for carrying out surveys in various locations

currently and in the future.

Where to next?

- Complete the development of the Information Accelerator model.
- Use the model to carry out a comprehensive survey of potential AHS users and other stakeholders with respect to the utility of AHS

services and market packages, and quantify the demand for these services and the consumer's willingness to pay.

- Using the model, carry out similar surveys on a regional or metropolitan basis to identify region specific issues and conditions that might facilitate or hinder the successful marketing of AHS services and market packages.

SOCIETAL AND INSTITUTIONAL ISSUES

Integrating Automation Into The Transportation Policy, Planning, And Decision Making Process



Introduction

Based on the results of the Automated Highway Systems (AHS) Precursor Study Analysis (PSA), one of the topics the Societal and Institutional Viability Team selected for study was: the transportation planning and decision making process and how to integrate automation (i.e., new technologies) into that process.

Interviews were the primary means used to gather information; workshops, focus groups, and NAHSC stakeholder forums provided additional information. Members of the team talked to officials at local, regional, and state levels in many parts of the country including New York, Boston, Pittsburgh, Michigan, Minnesota, Houston, Denver, Seattle, and California.

Much of the early research on this topic took place at a time when Consortium efforts were focused on developing an end-state automated highway system, with an emphasis on congested urban freeways. In part because of the research on this topic, as well as other NAHSC stakeholder involvement, the current focus of the NAHSC program is more on safety and near-term deployments.

Findings

Among the more frequently-raised questions, issues, concerns, opinions and recommendations during the discussions with local, regional and state agency officials were the following:

Incremental Deployment and Flexible Design/Regional Tailorability. Officials wanted NAHSC to explain a logical deployment path, evolving from current and currently-planned infrastructure and technology improvements. The deployment path should be flexible, allowing for local choice of direction to meet local needs, as well as some choice of technologies along any one path. The AHS program

must show state and local institutions how pieces that they might be able to implement incrementally could fit together eventually into the longer-range AHS system vision.

Local Goals. Even in some large urban areas, convenience and comfort, rather than congestion relief, would be important, desirable arguments for AHS. Safety is a primary concern and argument for AHS in several others: Fewer incidents/accidents as a result of the safety advantages of AHS may be the most important argument in its favor -- a reduction in incidents/accidents alone may have the greatest beneficial effect on capacity. Special and early applications for automation might be for specialized government vehicles where safety and accidents are a particular concern, such as snow plows or maintenance vehicles in general. Run-off-the-road accidents that might be prevented through automation are a top priority in rural and some more urbanized areas.

Interface with Non-AHS Roads, Effect on Local Streets. Where entry/exit ramps are located and how they are designed was a concern raised in most locations, including the traffic effects on access roads and parallel arterials (the latter probably beneficial), and particularly the effect on local streets at exit ramp locations.

Funding Constraints and Priorities. Funding constraints are one of the primary difficulties in implementing advanced technologies like AHSs. For most transportation agencies, the operation and maintenance of existing infrastructure takes precedent over the development and implementation of new technologies. To the extent that AHS will reduce capital expenditures for more/bigger roads, it should be thought of as a Transportation Systems Management technique.

AHS and Transit Operations. AHS provides the increases in capacity/throughput that can keep HOV/busways free-flowing as traffic increases in

coming years. Automated transit offers the opportunity to increase transit vehicle throughput in places with constrained rights-of-way, and to overcome the safety-related difficulties of merging vehicles at geometrically-constrained sites. Safety and accident-related costs, particularly the problem of transit vehicles being rear-ended by other vehicles, is something that automation can do something about. Automation of maintenance operations also would be particularly attractive to some transit systems.

Liability. Although AHS is expected to reduce accidents and accident costs, and, thus, to reduce the cost to society as a whole, there remains concern about shifts in the share of liability responsibility, now predominantly borne by the driver, to vehicle and vehicle electronics manufacturers and to infrastructure operators. The degree of concern about liability varies greatly among state transportation agencies, depending on differences in liability exposure under different state laws.

Public/Consumer Acceptance. The incorporation of AHS into the transportation system relies on acceptance from the marketplace (whether consumers will find the technology valuable enough to purchase AHS-equipped vehicles) as well as institutions (government agencies who are willing to facilitate the construction and operation of such a system). Although the discussions focused on institutional issues, a number of comments reflected the concerns of individual consumers and society as a whole. This is because 1) each participant saw himself/herself as a potential consumer of the technology, and 2) each of their agencies must operate in a milieu where community/societal acceptance is essential for their

operations.

Conclusion

The future of automated highway systems rests on the development of a strategy that will facilitate its adoption and incorporation into transportation planning processes at the state and local levels. The research revealed a number of ways in which the program strategy should be designed to respond to specific issues and concerns.

Future Research

Plans for future research may include case studies to look at mechanisms to incorporate AHS into long range planning documents by working with officials in locations that see a future for automation within their region -- to develop real world project descriptions (or at least placeholders) that can be incorporated into those documents. A second type of case study may take the market packages developed by the Consortium to agency officials in order to elicit feedback from them as to how effectively we now can begin to answer the "what is it?", "what does it do?", and "how much does it cost?" questions that arose throughout the interview process.

The research also has been summarized in a paper written for the Society of Automotive Engineers Future Transportation Technologies Conference, August 1997, held in conjunction with Demo '97 in San Diego, California. The paper is titled "Fitting into the Process: Institutional Issues Affecting Development and Deployment of Automated Highway Systems."

SOCIETAL AND INSTITUTIONAL ISSUES

Cost Benefit Trade-off Analysis



What is the issue?

Societal and institutional costs, benefits and tradeoffs associated with the implementation of an Automated Highway System come in many different forms. Assessing (both qualitatively and quantitatively) and comparing the costs, benefit and trade-offs is a central component of evaluation of an AHS. Developing a rational, consistent way to compare alternatives and identify appropriate locations requires the identification of the components, suitable metrics and systems for comparison. It also requires agreement on an appropriate method of assessment of costs and consequences that recognizes different stakeholder perspectives.

Why is it an issue?

The issue of differentiating among different types of customers and stakeholders is important as it influences the point of view from which the analysis of alternatives is carried out and how many of which type of customers will experience particular benefits and costs, as different customers will value costs and benefits differently.

What is the process used to research this issue?

The objective of this task is to assemble tools and data from other tasks to facilitate a rigorous and complete analysis of cost, benefits and tradeoffs. This task also provides a framework for other groups within the NAHSC and outside agencies to evaluate AHS in a comprehensive and consistent manner. The process includes:

- documentation of the issues
- development of a computer based cost benefit analysis tool
- exploration of alternative methods for comparing competing objectives.

What are the results to date?

- A preliminary version of the cost benefit tool has been developed.
- Many of the issues have been documented. For example, the tables on back of this sheet identify various components of costs and benefits and which stakeholder group directly perceives the measure as a cost or benefit. The tables also show which components have been included in the cost benefit tool.
- Using the tool has reinforced the idea that evaluation is very location dependent and at this stage fraught with uncertainty.

Where to next?

- Development of some location specific analyses
- Quantification and assessment of non-monetary variables such as regional economic growth and employment.
- Analysis of some scenarios for incremental deployment including mixed traffic.

Examples of Benefits Attributed to Different Stakeholders

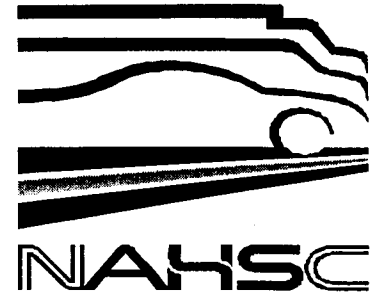
Stakeholder / Benefit	Society	Users	Govt Orgs	Included in Cost - Benefit Tool
Performance improvement				
Time savings	✓	✓		✓
Reduced vehicle O&M costs	✓	✓		✓
Safety				
Reduced accident costs	✓	✓	✓	✓
Improved safety for highway workers	✓	✓	✓	✓
Improved response to incidents	✓	✓	✓	✓
Reliability, comfort and convenience				
Improved trip time reliability	✓	✓		
Reduced driver stress	✓			
Higher quality of service	✓	✓	✓	
Greater comfort/ convenience	✓	✓		
Improved mobility	✓	✓		
Environmental				
Reduced noise pollution	✓	✓	✓	
Reduced air pollution	✓	✓	✓	✓
Fuel savings	✓	✓		✓
Economic and technology				
Job creation	✓			
Spin off technology	✓		✓	
Economic stimulus	✓		✓	

Examples of Costs Attributed to Different Stakeholders

Stakeholder / Cost	Society	Users	Govt Orgs	Included in Cost - Benefit Tool
One-time costs				
Infrastructure design and construction	✓		✓	✓
Construction related disruption	✓		✓	
Maintenance of traffic during construction	✓		✓	
Land and ROW acquisition	✓		✓	✓
Vehicle design and production	✓			
Environmental damage mitigation	✓		✓	
Infrequent costs				
Infrastructure rehabilitation	✓		✓	
Vehicle purchase	✓	✓		✓
Recurring costs				
Infrastructure O&M	✓		✓	✓
Licensing		✓	✓	
Inspection	✓	✓	✓	
Noise	✓			
Tax		✓	✓	
Education	✓	✓		
Vehicle O&M	✓	✓		✓
Tolls		✓	✓	

National Automated Highway Systems Consortium

CASE STUDIES



OVERVIEW

The NAHSC is moving towards a flexible framework that defines automation in both rural and urban settings that supports, incremental adoption of AHSs features, that can accommodate specific local options, and has the capacity to accommodate freight, transit, personal, and special (i.e., maintenance) vehicles.

Case studies are the primary mechanism by which the NAHSC will evaluate the technical and institutional impacts Automated Highway Systems (AHSs) will have on regional transportation systems including: safety, traffic congestion, air quality and energy conservation. AHSs are being studied and developed as a suite of tools that a region can use to solve local transportation problems

Case Studies are planning activities designed to look at possible AHSs system configurations within a specified region using actual data to determine: what an AHS will look like in a real world context, what effect that implementation will have on the rest of the system and how we could deploy it, what are the benefits and costs, and how does AHS compare to other possible transportation alternatives. In addition case studies are used to evaluate the institutional factors that surround the implementation and deployment and to establish regional consensus by engaging participants at the state and local levels. In order to gain a perspective on what automation means at a national level, case studies will examine everything from specific corridors to entire transportation networks in rural, suburban, and urban settings.

CASE STUDY LOCATIONS

Case studies are expected to be multiple-phase and multiple-year contracts and will parallel the AHSs market package development process. The NAHSC has initiated five new case studies this fiscal year in addition to the two case studies already underway.

Partner	Location	Classification	Status
Houston Metro	Katy Freeway HOV/Transit Lanes	Transit/HOV	Phase I complete
Western Transportation Institute	Greater Yellowstone Rural ITS Priority Corridor	Rural	Phase I nearly finished
Southern California	Southern California ITS Priority Corridor	Large Urban System	Just Starting
Virginia Tech/ Virginia DOT	I-81 Corridor Virginia	Intercity / Rural CVO	Just Starting
GCM Corridor	I-90 Gary-Chicago-Milwaukee ITS Priority Corridor	Urban CVO	Just Starting
Minnesota DOT	Minnesota	Medium Urban System	Just Starting
Michigan DOT	Michigan	Intercity / CVO and Transit	Just Starting

HOUSTON METRO

Since 1979 Houston Metro has dealt with the increasing transportation and mobility problems of the Houston - Galveston region and is the fourth largest metropolitan area in the United States and one of the nationally designated ITS priority corridors.

The Houston Metro AHS study examines how automation might increase the capacity of their dedicated transit/high occupancy vehicle (HOV) lanes. The study focuses on vehicle entry into the system, merging with other vehicles, and reducing the spacing between vehicles to increase capacity.

Preliminary results indicate that in order to meet the future increases (anticipated by Houston Metro) in the number of buses and other transit vehicles, automation (i.e., vehicle to vehicle and vehicle to roadside communication and cooperation) is necessary. The next phase of the case study includes defining the specific concepts that will help and identifying potential applications and sites for demonstration and testing.

WESTERN TRANSPORTATION INSTITUTE

The Western Transportation Institute (WTI) established by Montana State University and Montana and California Departments of Transportation in 1994 is a national and international center for rural transportation research. WTI's primary focus is the Greater Yellowstone Rural ITS Priority Corridor (GYRITS), an 800-mile rural corridor situated between Bozeman, Montana; Idaho Falls, Idaho; and Jackson, Wyoming. It includes parts of: Montana, Idaho, and Wyoming, and includes Yellowstone and Grand Teton National Parks.

The emphasis of the case study being studied here is on enhancing the safety of rural two lane highways. Preliminary investigation suggests that over 80% of the accidents in the corridor can be addressed by automation.

Through accident analysis on selected highways in the corridor, we have identified (1) near term solutions such as driver aids (infrastructure based); (2) short term solutions like warning systems (integrating infrastructure and/or smart vehicles); (5) intermediate term solutions that mix automated and manual control (more smart vehicle based); and (6) long term solutions including full automation.

The next step in the case study includes further development of corridor concepts and identification of sites suitable for field operational tests and demonstrations potentially leading to implementation and deployment.

FOR MORE INFORMATION

For further information on NAHSC Case Studies and/or becoming involved in a case studies contact:

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SOCIETAL AND INSTITUTIONAL ISSUES

AHS and Transit Operations



Background

AHS is a component of the overall research and development under investigation in the area of Intelligent Transportation System (ITS) technologies. The ITS user services group of transit management systems, or Advanced Public Transportation System (APTS) technologies are also a subset, only specifically tied to more immediate transit improvements.

What is the issue?

The successful integration of automated highway systems with transit operations have the potential to have significant benefits on such roadway transportation problem areas as congestion, safety, air quality and fuel consumption, and in addressing social equity, land use, and environmental considerations regarding AHS. Transit provides the opportunity for AHS to serve the needs of people and markets other than automobile owners/drivers. Transit applications, particularly in early deployments, also offer the opportunity to demonstrate AHS technologies with a cadre of trained drivers/users.

Process

Conceptual options for integrating transit operations with AHS are being studied and an automated electronic guidance system has been suggested as a means to integrate AHS for transit operations.

Another part of the investigation into integrating AHS with transit operation involves assessing the issues and concerns of the transit industry and subsequently making recommendations to resolve such issues. Examples of such issues are (1) determining the optimum settings for transit applications of AHS such as urban and/or rural applications, and for public and/or private sector transit operators, (2) insuring that AHS will convey to the transit industry's degree of acceptance of technological changes associated with an AHS, (3) associated with an automated transit industry could potentially be the changing role of the

driver with the potential for changes in driver training, salaries, work rules, insurance, liability, and management/labor relationship, (4) government involvement, e.g. what is needed for AHS transit application to be considered as a credible alternative for regional transportation investment, and (5) what real advantage would AHS offer to transit level of service and to what extent could it help attract more transit users.

Conclusions to date

Integrating transit operations could free transit from mechanically guided systems and the very high cost and rigid architecture inherent in such systems. If transit now operated an automated, electronically guided vehicle system, a less costly and more flexible line haul and feeder system could be planned. It is also a logical extension of the direction transit is already headed in the APTS part of ITS. Visually, these may look like an automated rubber tired tram system; it could have the features of light rail without the need for rails to guide the vehicles or the need to mechanically couple those vehicles into train sets. Passenger access and egress stations could either be off the mainline so it could better serve as a transportation hub or "on-line" like conventional rail systems. Such a "bus rapid transit system" would have the performance features of rail transit at substantially less cost with a design approach being one of flexibility. Transit improvements are made to fit the community being served, that than force fitting as it develops to the architecture of the transit system. Such a system is for a typical city with a beltway around the urban area and interstate highways along radial routes skirting the downtown core and may operate on automate highway lanes in the median of those radial interstate highways.

Through the identification and resolution of these and other issues associate with integrating transit operations with AHS, the consortium will build a positive on-going relationship with a very important stakeholder group.

The preliminary investigation of transit issues draws

the following conclusions:

- Automated highway systems that include the use of dedicated the use of dedicated lane for use of automated vehicles only may have very positive application and benefits in the context of bus transit operations.
- The design for an automated highway system in order to maximize its utility for bus transit operations must accommodate needs of all vehicle occupants, i.e. driver and passengers, especially, passenger loadings which differ from the case of a light-duty-passenger-vehicle.
- Increasing vehicle throughput on a busway or mixed busway/HOV facility could likely be accomplished without degrading transit service.
- The transit industry is used to at least some form of centralized control by means of an operations management center and would continue to favor this means as well as through other infrastructure elements (roadway facilities) to provide at least some of the information, i.e. the intelligence, to the buses.

- Predictable, reliable, safe and convenient travel are very important attributes of an AHS for the transit industry
- Another potential benefit: reduction in maintenance costs associated with decrease in variability in driver capabilities
- Privacy is not an issue in transit industry
- Automated bus transit can provide comparable benefits to rail transit to communities where density cannot justify the cost of rail transit, as well as a service flexibility that is not possible with rail transit.

Spin-off benefits of automation for the majority of bus travel -- which is on surface streets, not limited access highways -- include such possible technological applications as automated lateral docking for loading at high level platforms (leaving less gap between the platform and the bus door than is currently possible with human driving/maneuvering).

SOCIETAL AND INSTITUTIONAL ISSUES

Operations and Maintenance



What is the issue?

Safe and efficient operation and maintenance of an AHS will require changes in the staffing and processes of current operating agencies, and changes in the organizational structure of those agencies, if not the creation of new operating entities.

Strategically, important issues are:

- Potentially, both existing and new operating agency structures, and the operational impacts of a multi-jurisdictional framework need to be evaluated.
- Current levels of expertise and staffing available at existing operating agencies must be compared with the requirements to support an AHS.

Tactically, important issues are:

- Integration of AHS traffic control management with the non-AHS roadway network.
- Although AHS is intended to reduce the occurrence of incidents, ensure that incidents that do occur, do not have a catastrophic effect on traffic operations.
- Developing appropriate maintenance planning and equipment.
- Developing policing and enforcement tactics that reflect the different vehicle control options for AHS.

What is the process used to research this issue?

The primary objectives are to evaluate the management and operational requirements of an AHS from the perspective of day to day facility operations. From that focus, three categories of generic operational elements for a typical AHS configuration have been identified:

1. Organizational structure
 - operating entity/jurisdictions
 - staffing skills/levels
2. Operations

- traffic flow management
 - incident management and response
 - policing and enforcement
3. Maintenance
 - infrastructure maintenance
 - vehicle maintenance

Interviews and focus groups are used to obtain expert judgment and reactions to alternatives. Procedures and recommendations are being developed.

The experiences on SR 91 in California area also being studied.

What are the results to date?

- The shared responsibility that is effective in the maintenance and operation of highways today in terms of liability, responsibility for maintenance, and safe and efficient operation should be the basis of any new procedures developed.
- Organizations are likely to have to make major transformations to accommodate AHS facilities.
- Inter-jurisdictional issues must be resolved and communication remain effective.
- Training of the existing workforce is a critical component of evolutionary deployment of AHS.
- Preventative maintenance of the existing infrastructure is even more critical than it is today.

Where to next?

- Interview enforcement and emergency response experts.
- Document and evaluate state vehicle inspection procedures.
- Develop procedures and methods to support the safe and efficient operation and maintenance of AHS facilities.

SOCIETAL AND INSTITUTIONAL ISSUES

Human Factors Issues and the Role of the Driver in the Automated Highway System



What is the issue?

Despite the introduction of a higher level of automation, the driver will still have a role in the Automated Highway System (AHS). The level of interaction required from the driver in order for the AHS to work efficiently will affect safety, usability and driver acceptance. Driver roles will have to be clearly defined for all potential situations, and those roles will most likely change at various stages of deployment due to technology improvements. Human Factors issues and criteria must be considered throughout the design process in conjunction with other issues related to AHS design, such as cost and reliability. Trade-off analysis of various design elements will be required to optimize the system as a whole. The comfort and well being of the driver must not be ignored at any stage of AHS deployment.

What is the process?

Dr. Thomas Dingus, a Human Factors expert from Virginia Tech, was contacted by the NAHSC in 1996, to assess the state of relevant human factors knowledge with respect to automated highways, and to identify key issues requiring further study. High Priority Issues identified by Dr. Dingus (and under present or future investigation by the Consortium) include:

Issue 1: Understanding the Driver's Role

- What are the driver roles for the possible combinations of technologies and infrastructure being considered for AHS deployment? Are there possibilities for roles confusion, cognitive overload, or other sources of error introduced by the new technologies?

Issue 2: Situation Anomalies

- What role should the driver have in the event of a malfunction? How will driver alertness

Issue 3: Vigilance

- How will less than full driving participation affect the driver's readiness for critical situations that require quick driver intervention?

Issue 4: Driver Intervention

- Under what circumstances should the driver intervene in the functioning of an AHS subsystem?

Issue 5: Carry-over Effects

- What changes will occur in driver behavior on non-automated roadways as a result of driving on an AHS?

Issue 6: Driver Population Characteristics

- Who will be the driving public on the AHS?
- What are their attributes and driving characteristics?

Issue 7: Driver Comfort and Acceptance

- What are acceptable driving speeds? Vehicle separation?

What are the results?

There is a substantial knowledge base of human factors principals and guidelines that can be brought to bear on the human factors issues associated with the AHS. This knowledge base can be used to make significant trade-off decisions with respect to broad level system attributes. The participation of human factors experts in all phases of the design process is one of the more critical aspects of the AHS system design to ensure that an AHS system is safe, usable and acceptable. With the incorporation of human factors during all stages of design, the relevant human factors issues of the AHS can be specified, and a plan can be developed to address those issues on an individual basis before they become major impediments to system deployment.

SOCIETAL AND INSTITUTIONAL ISSUES



Liability

Why an Issue/What is it?

According to the California Bar Association, liability is 'in its broadest legal sense, . . . any obligation one may be under by reason of some rule of law. It includes debt, duty, and responsibility.' Under the present highway system, a number of entities assume liability for the safe operation of the system: vehicle manufacturers must make cars that can reasonably be expected to operate safely on the roadway, highway departments must provide an operating surface on which vehicles can reasonably expect to operate safely, and drivers must act in ways that generally conform to the expectations of other drivers so as not to endanger other people on the system. However, many of these assumptions of liability are implicit because drivers rarely sign contracts with highway departments or vehicle manufacturers explicitly spelling out who will assume what liability. And, presently, much of the liability for the safe operation of the system falls directly on the individual driver.

AHS proposes to change that equation by taking some of the control of the vehicle away from the driver. Because a fundamental objective of AHS is to improve overall traffic safety, there may be an overall reduction in liability costs. And liability questions may also vary depending on the design of the AHS system that is implemented, particularly if local AHS system designs differ significantly to meet distinct needs of different communities. The NAHSC is still several years away from completing the basic system design and the recommended specifications for any AHS system implemented in the US. But it realizes the serious nature of questions associated with these changes in liability, because the answers to those questions may ultimately determine how the system must be designed in order to be accepted by the general public, the institutions responsible for maintaining the system, as well as those who would build and sell the equipment that makes the system work.

Process

Contracted with North Carolina Central University School of Law to perform a study to assess the current state of highway liability codes and estimate how AHS designs (as reflected by concept distinguishing issues) might alter those statutes. A final report from this effort has been published.

Held conference on AHS Liability Issues in February 1997 at the Washington DC Holiday Inn Capitol, jointly sponsored with ITS America and AASHTO. Participation was at capacity with representatives of insurance industries, state departments of transportation, vehicle & equipment manufacturers, and the NAHSC. A final report from this effort is expected out in summer 1997.

Conclusions

Liability in and of itself is not a showstopper for AHS, as long as the effort to understand the implications of the design choices continues. Affected parties range from state departments of transportation to equipment manufacturers to private & commercial drivers. The liability concerns of each of these parties differ, and AHS can reasonably be expected to change the existing liability structure. In order to proceed to development, AHS designs must offer a balance of liability that is acceptable to all parties.

What Else to be Done?

As the AHS design progresses, we will be holding additional workshops to get search for synergistic design solutions that take into account the liability concerns of all affected parties.

SOCIETAL AND INSTITUTIONAL ISSUES

AHS & Land Use



Purpose

As one of its first research topics, the Societal and Institutional Viability task team selected: How AHS Can Fit Local Land Use and Economic Development Goals and Plans. The purpose of this effort was to address directly concerns that have been expressed about the effects (some of them unanticipated) of the Interstate highway system and related highways on urban sprawl, and what this might mean in terms of the possible future effects of a new highway technology such as AHS. Also desired was an opportunity to examine how communities might use such a new technology consistent with local land use and economic development goals and plans.

The effort is intended to complement the development and use of an analytic land use impact modeling tool as part of the Tools development task of the NAHSC.

Methodology

The research methodology for the first year of this effort included:

- a literature search
- selection of experts in the field of transportation-land use
- relationships representing a broad cross-section of published opinion on that topic
- preparation of two background papers on transportation and land use
- preparation by the selected experts of short papers considering how AHS might affect the transportation-land use relationship
- a panel discussion among the experts before an invited audience of NAHSC, and federal and local transportation officials, at Carnegie Mellon University, in Pittsburgh, Pennsylvania

The selected experts were: Edward Beimborn, University of Wisconsin and Chicago Center for Neighborhood Technology; Anthony Downs, The Brookings Institute; Genevieve Giuliano, University

of Southern California; John D. Landis, University of California-Berkeley; and G. Scott Rutherford, University of Washington. The experts generally saw their role as a broad analysis of land use patterns in general, and not intersection-specific or land use category-specific.

The background papers were prepared by Parsons Brinckerhoff Quade & Douglas' Portland, Oregon, office under the direction of Sam Seskin; one of the papers traced the history of the transportation-land use relationship, and the other looked at how such a technology might be viewed in the different "cultures" of differing American cities.

Conclusions

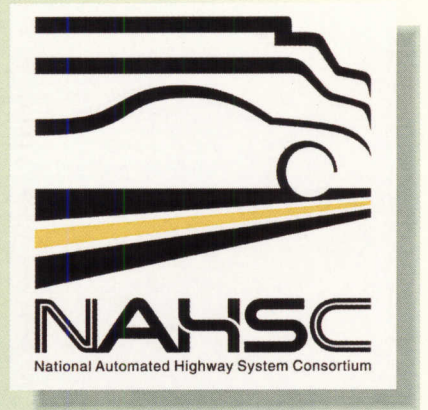
While the experts differed in their opinions of the cause/effect relationship of past transportation improvements and land use changes, as they exchanged ideas through the exchange of their papers and at the panel discussion, there was concurrence among several of them regarding the potential impacts of an AHS deployment. One of these, and perhaps the most important, was the general belief that AHS by itself would have minimal land use impacts, given the relative effects of other land use/development-influencing factors.

Some of the experts expressed the possibility that an AHS could be implemented as a tool to assist planners in improving current land use patterns, e.g. a transit/HOV application. In addition, several of them noted that technologies that serve the changing demographics of our population, specifically the increasing percentage of the elderly population, by preserving their lifestyles and mobility, would be most successful and marketable.

Next Steps

A publication with all of the papers will be available in fall 1997. The task team's statement of work calls for a geographic location-specific analysis(es) of the AHS-land use relationship, possibly with the use of the modeling tool, in the future. Because the

program's emphasis has shifted in the near term toward more short-range and safety-related implementations, such a longer-range (and primarily capacity-related topic) is likely to follow after societal and institutional research of more immediate, shorter-range concern.



Deployment Roadmap

From Warning and Control to Full AHS

National Automated Highway System Consortium

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The Automated Highway System will grow from technologies being developed or currently on the road. The Federal Highway Administration (FHWA), the National Highway Transportation Safety Administration (NHTSA), the Office of Motor Carriers (OMC), the Federal Transit Administration (FTA) and many vehicle makers are all doing research or developing products. These products will provide three levels of automated driver assistance leading towards full automation of throttle, brake and steering.

Warning and Advice The first level of driver assistance is **on-board warning systems**. A **collision warning system** for trucks has been available since 1994. Other on-board warning systems will be developed as the industry gains human factors experience with warning systems. For example, a **lane departure warning** product will detect the lane boundaries and alert the driver if the vehicle drifts out of the lane.

As computers and communications become more capable and less costly, the next generation of warning products will incorporate electronic information from the roadside or other vehicles. Because they share information, these systems are called **cooperative warning systems**. They will grow into highly sophisticated **advanced situational awareness** systems that keep the driver apprised of the overall driving situation. They will fuse information from sensors, from other vehicles and from the roadside to warn the driver of potential problems and to improve driving efficiency.

Temporary Emergency Control These not only detect potential problems, but automatically react to them. They take advantage of the reliable, fast and precise reactions of automated systems, but allow the driver full control of ordinary driving actions. The earliest will be **on-board brake and throttle partial control systems**, which will slow or stop the vehicle in emergencies, but do not control steering. For example, **forward collision avoidance** looks ahead of the vehicle and brakes if a collision is imminent.

As in the warning systems, the next generation will incorporate communications to give **cooperative partial control systems**. An example is **cooperative collision avoidance**, in which the vehicles inform each other of their actions, giving a faster, more precise response. The most sophisticated emergency systems will be **integrated partial control systems**, which control steering as well as brakes and throttle in an emergency. For example, **lane change collision avoidance** will automatically abort an unsafe lane change.

Automated Control of Normal Driving Actions These products will introduce full time control of the vehicle. Today's cruise control automatically controls speed. The next generation of **full time brake and throttle control systems**, called **adaptive cruise control**, now under development, will maintain a safe distance from the vehicle ahead. The first vehicles to include automatic steering will provide **automated throttle, brake and steering on a protected lane**. Protected lanes have barriers to help keep out obstacles and vehicles from other lanes. These protected lanes would also be used by conventional vehicles during the early years of automation.

The protected lanes will evolve into **full automation in dedicated lanes** for the exclusive use of AHS vehicles, when there are enough automated vehicles to make this practical. Operating only automated vehicles in dedicated lanes will allow doubling or tripling the lane capacity. As automation technology matures, **full automation in ordinary traffic** eventually will be possible.

Also, the AHS will grow geographically from **expansion of dedicated lanes where desired by local communities**. The map shows a community that started with automation on one heavily congested highway, from Suburbia to downtown Centerville, and later extended automation to other areas.

The **National Automated Highway System Consortium (NAHSC)** was formed in 1994 by a cooperative agreement between the FHWA and a partnership of government, university and industry to bring automation to America's highways. The Consortium's **Demo97** is currently showing a range of automated vehicles on an HOV lane. By 2002, the Consortium will build an automated highway **prototype**. This will be followed by **further operational tests** of automated highway systems.

To **enable and support** deployment of automated highway systems, the Consortium will provide demos, prototypes, operational tests, standards, specifications and deployment plans. One example is **communications standards**, which define how vehicles communicate with each other and with the roadside for seamless implementation across the country.

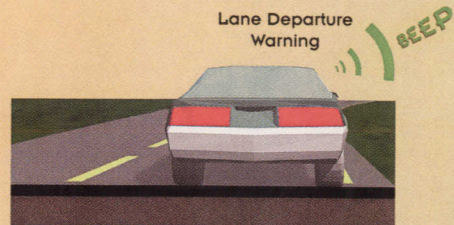
This **Deployment Roadmap** shows that the Automated Highway System is a range of technologies and products to meet many driving needs. Some products are available now, some in a few years, and all lead to safer, more efficient and more comfortable highway travel for everyone.

Improving Human Factors With Experience

Warning and Advice



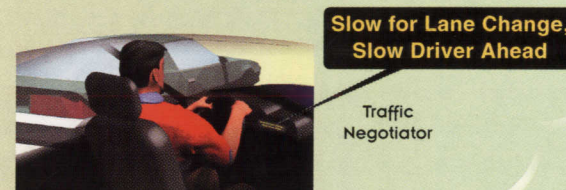
On-Board Warning Systems



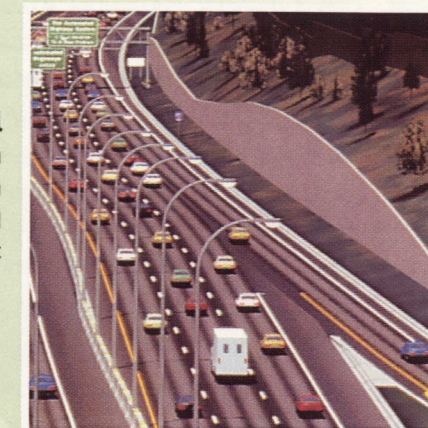
Cooperative Warning Systems



Advanced Situational Awareness

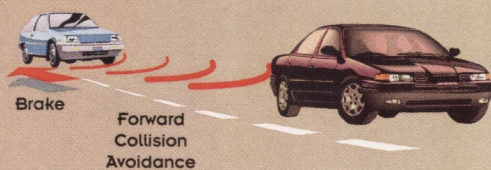


Full Automation In Ordinary Traffic

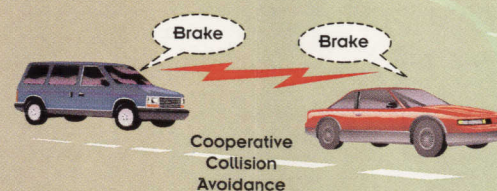


Temporary Emergency Control

On-Board Brake and Throttle Partial Control Systems



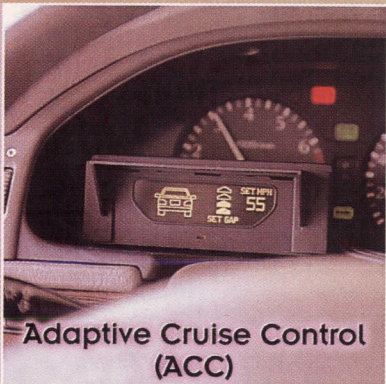
Cooperative Partial Control Systems



Integrated Partial Control Systems

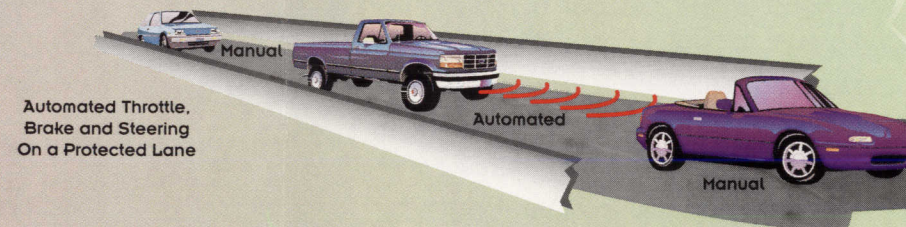


Automated Control of Normal Driving Actions

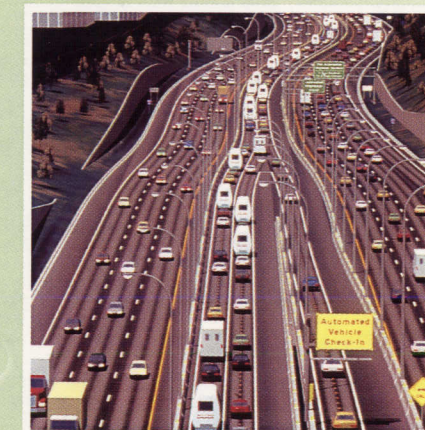


Full Time Brake and Throttle Control Systems

Full Time Integrated Control Systems

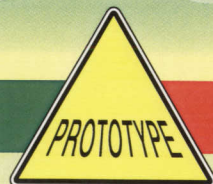
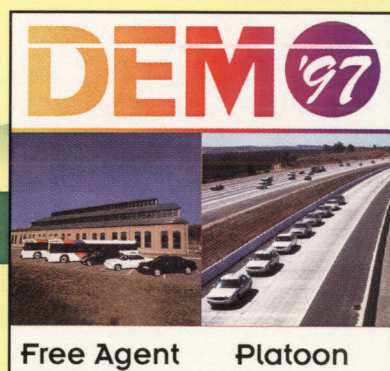


Full Automation On Dedicated Lanes



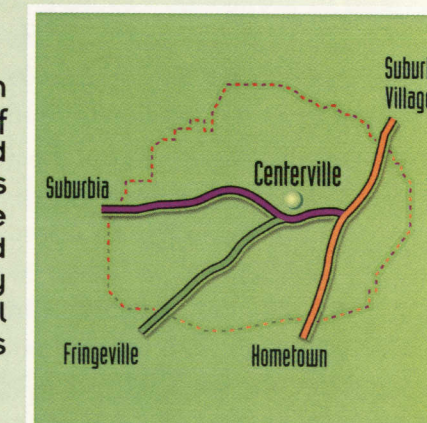
Improving Sensors, Computers & Other Technology

Enable and Support



Further Operational Tests

Expansion of Dedicated Lanes Where Desired By Local Communities



1997

2002

2010