Automated Highway System (AHS)

System Objectives and Characteristics

November 3, 1995

NAHSC

National Automated Highway System Consortium
3001 West Big Beaver Road, Suite 500
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MISSION STATEMENT

The National Automated Highway System Consortium (NAHSC) will specify, develop, and demonstrate a prototype Automated highway System (AHS). The specification will provide for an evolutionary deployment that can be tailored to meet regional and local transportation needs. The consortium will seek opportunities for early introduction of vehicle and highway automation technologies to achieve benefits for all surface transportation users. The NAHSC will incorporate public and private stakeholder views to ensure that an AHS is economically, technically, and socially viable.

INVITATION

The AHS is being designed to meet the future highway needs of all stakeholder groups including:

- Vehicle industry
- Government agencies
- Highway design industry
- Vehicle electronics industry
- Environmental interests
- Trucking operators
- Transit operators
- Transportation users
- Insurance industry

The NAHSC invites you to participate in developing the next generation of the National Highway System to ensure it meets your needs for the next century. For more information about how to participate, please contact:

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FOREWORD

This document was prepared by the National Automated Highway System Consortium (NAHSC) for the United States of America Department of Transportation under cooperative agreement DTFH61-94-X-00001. It was developed with the help of AHS stakeholders. The NAHSC is soliciting comments, inputs, suggestions, and feedback on the objectives and characteristics of an AHS described herein. The resulting objectives and characteristics will be used to guide the definition of the Automated Highway System.

Please submit your comments by sending them to the:

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Revisions:

1st Draft	First public version prepared for the 1st AHS workshop, April 12,13, 1995, in Ft Lauderdale	4/3/95
2nd Draft	This version incorporates the stakeholder feedback from the first workshop	5/22/95
3rd Draft	This version incorporates extensive stakeholder feedback from focus meetings, surveys, and mailings.	9/15/95
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1.0 INTRODUCTION

Recent research in automated highways has clearly indicated that automated vehicle control technology offers major improvements in the safety and efficiency of existing highways. With this in mind, Congress directed the Secretary of Transportation to enhance and focus the nation's research into fully automated intelligent vehicle-highway systems. The Automated Highway System (AHS) program is a government-industry-academia collaboration to apply automated control technology to the U.S. vehicle-highway system to greatly improve the safety, mobility, and quality of highway travel. The efficiency of the automated vehicle-highway system is expected to help conserve energy resources to make more efficient use of existing transportation facilities and to contribute to a sustainable future transportation system. The deployment of AHS is intended to support community economic development and land use planning goals and to be compatible with urban air quality goals. Wherever possible, these improvements will be made using the existing highway infrastructure.

The Secretary [of Transportation] shall develop an automated highway and vehicle prototype from which future fully automated intelligent vehicle-highway systems can be developed.[1]

1.1 Automated Highway System/Intelligent Transportation System Architecture Relationship

The AHS program has been established to be the stepping stone to automated vehicle-highway transportation in the 21st century. The program focuses on a planned evolution from today's vehicle-highway system. This transition will be simplified because some of the basic automated vehicle controls needed for an AHS are starting to appear in today's vehicles. Use of this technology is expected to increase during the next decade. Drivers will be offered Intelligent Transportation System (ITS) services such as adaptive cruise control, which is a cruise control system that maintains a safe following distance from the vehicle in front of it; collision warning and avoidance to help prevent both rear-end and side-swipe crashes; and automated lane keeping, which will hold a vehicle safely in its lane. Similarly, ITS technologies such as infrastructure-to-vehicle communications for traveler information services and advanced

[1] Section 6054 (b) in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991

traffic management systems will be deployed in the coming years. The AHS program will build upon and integrate with the evolution

of these ITS services to ensure overall compatibility. To this end, current AHS activities are fully coordinated with the ongoing development of a National ITS Architecture Program. With nationwide planning and infrastructure integration, AHS will become both a logical and major evolutionary step in our highway transportation system.

"Why is the Department of Transportation pursuing this development of AHS so vigorously? Let me share with you my sense of the need for the Automated Highway System and the potential benefits created by the future deployment of this system. Our current highway transportation system, as effective and elegant as it is, is at a critical crossroads in its evolution and has started to plateau in its ability to provide significant new operating performance in its present form.[2]

Automation is one of the most promising approaches for improving vehicle-highway system performance. The ITS program is investing substantial resources to improve the performance of our current transport systems. ITS is focused on such areas as improved information flow among vehicles, travelers, and the infrastructure, the enhancement of safety and security, and the dismantling of institutional barriers. During the next decade or so, deployment of the ITS services within a coherent national architecture will result in gains in safety and transportation efficiency. Vehicle-highway automation is the natural evolution of these technology investments, integrating crash avoidance enhancements on vehicles and communication capabilities in our highway systems. Therefore, the promise of AHS is an expansion of the collision avoidance safety benefits and a major performance gain in flow capacity for a given land area compared to today's systems based on manually driven vehicles.

In fact, AHS is capable of providing a level of performance and service that is a generation beyond other ITS services. An AHS can double or triple the efficiency of today's most congested highway lanes while significantly increasing safety and trip quality. An AHS would serve all highway users, opening up new opportunities for transit bus operation, enhancing the safety and productivity of heavy trucks, and offering improved security and dependability to the traveling public. Its efficiency can help reduce both fuel consumption and individual vehicle emissions, and will ensure maximum use of our existing highway infrastructure investment.

1.2 Document Purpose

The National Automated Highway System Consortium has prepared this document to introduce the current objectives and

[2] Administrator Slater's speech on the AHS Program, October 21, 1993

characteristics expected of a fully automated highway system, with the goal of balancing the needs of users and other stakeholders. These objectives and characteristics are goals and measurable targets used to guide requirements, system specifications, constraints, and criteria for AHS design concepts, prototype testing and deployment of the system. This document is useful as a point-of-departure to stimulate discussions with stakeholders and interested parties.

1.3 Document Scope

This document provides an initial description and reference concept for an AHS that will be built for operational test and evaluation beginning in the early part of the next decade. It defines the AHS objectives and characteristics independent of concept, design, or physical architecture. The reader should note that the objectives and characteristics specified herein are goals that may not be attainable, but serve as a target for the system designers.

2.0 AHS OVERVIEW

2.1 The Need for an AHS

Today's vehicle-highway system functions surprisingly well with its more than 6 million kilometers of streets, roads, and highways and its 190 million vehicles. However, it cannot keep pace with society's increasing transportation needs. Driven by population growth, the demand for mobility as a fundamental economic need is in direct conflict with our ability to fund new conventional highways and maintain a clean environment. The total vehicle kilometers traveled in the nation is predicted to nearly double by the year 2020, and our population will grow 50 percent by the middle of the twenty-first century.[4] We will need to make more efficient use of existing transportation facilities.

There are approximately 40,000 lives lost annually on the nation's roads and highways, and there are over 1,700,000 serious disabling injuries. The annual cost to the nation is estimated at over $156 billion.[3]

Although traffic fatalities have decreased significantly in recent years, there are still more than 40,000 lives lost annually on the nation's highways, and there are more than 1,700,000 serious disabling injuries. The annual cost to the nation in dollars is estimated at more than $156 billion.

Traffic volume has increased anywhere from 38 and 54 percent for each of the last three decades. Because system capacity has not kept pace with peak demand, 70 percent of all urban interstate peak-hour traffic is congested, and this figure is predicted to grow to 80 percent by the year 2000.[5] A large portion of this congestion is caused by incidents on our highways (e.g., crashes, breakdowns, obstacles in the lane). Congestion is projected to worsen by 300 to 400 percent over the next 15 years unless significant changes are made in the surface transportation system.[6] In many areas, the traditional solution of building more lanes is becoming less viable because of limited rights-of-way, cost, citizens' concerns about the impact on the quality of life in their communities, and environmental requirements.

Our nation's economic growth, competitiveness and productivity is limited by the inability of our current vehicle highway system to meet the mobility demands for people and goods of our growing population.

[3]Focus on Environment: An IVHS New York Forum, v1, #1, 1994.

[4]ITS America Energy and Environment Committee

[5]U.S. DOT, Federal Highway Administration

[6]General Accounting Office

Today, congestion alone costs the nation an estimated $100 billion in lost productivity annually.[7] It also increases driver frustration and discomfort as congestion becomes worse and travel times become less predictable. Also, some drivers, including the elderly, are intimidated or frightened by highway travel. Moreover, fuel consumption will rise as trip times increase due to either length of the trip or time delays. In addition, predictability of delivery times will become less reliable, thereby increasing the frustration of customers of the shipping industry.

As traffic volume and congestion continue to increase, methods to reduce exhaust emissions will be necessary to maintain air quality. The key emissions produced by individual vehicles have decreased between 70 percent (oxides of nitrogen) and 100 percent (lead) since 1970. Nevertheless, the vehicle-highway system is still one of the largest contributors to air pollution in urban areas as a result of increases in the vehicle kilometers traveled, vehicles idling in congestion, and the driving habits of the vehicle operators. The nation's concern is reflected in the Clean Air Act, which has established emission guidelines that must be accommodated in transportation planning. Therefore, the vehicle-highway system must continuously strive to meet this demand. In particular, the system must improve in the areas of safety, congestion, air quality, and trip quality.

The AHS program addresses fundamental human limitations to improving the vehicle-highway system, such as driver reaction times and fatigue. These factors are major contributors to accidents and congestion on our nation's highways. "Automated vehicle control" directly addresses these issues. It is because of human limitations that automation is essential for improving our vehicle-highway system. To illustrate, the most common form of crash is the rear-end collision. Ten percent of all cars and 25% of all trucks experience a crash of this type during the vehicle's lifetime.[8] Single vehicle roadway departure and lane change/merge crashes represent about 32% of all accidents.[9] Often times secondary accidents occur with each primary accident as a result of gawking, intrusion, and obstacles associated with the primary incident. The fatality rate is sharply higher at night: the night fatality rate is twice as high in urban and three times as high in rural areas compared with the day rate.[10] More than 40% of the fatal

[7] IVHS Strategic Plan, Report to Congress, U.S. DOT, Dec. 1992pg 32.

[8] National Highway Traffic Safety Administration Analysis

[9] Fatal Accident Reporting Database

[10] National Safety Council, 1993.

crashes involve impaired drivers (drivers under the influence of alcohol, or experiencing drowsiness and fatigue). In addition, about 25% of crashes that result in fatalities occur on wet or icy roads. Finally, a lane volume of 2,200 vehicles per hour may be close to what humans can safely manage, and in many cases this rate is not achieved because of weaving or distractions such as stalls, collisions, or incidents in other lanes.

2.2 Building Solutions

Improvements in highway design, traffic management, vehicle safety design, and improvements in driving under the influence, safety, and speed enforcement programs have allowed modern highways to sustain passenger vehicle flow rates of up to 2,200 vehicles per lane per hour, while decreasing the number of fatalities per 100 million kilometers traveled by 30 percent. These benefits should be delivered with due care for natural resources and the environment.

Automation is one of the most promising approaches for improving vehicle-highway system performance.

The results of a significant body of research suggest that a fully operational AHS can dramatically affect our nation's vehicle-highway transportation system by improving the safety and efficiency of highway travel for a broad spectrum of vehicle types, including passenger, commercial, and transit vehicles. These improvements may also reduce vehicle emissions through reductions in stop and start traffic. Projections indicate that AHS lanes will double or triple the safety and efficiency of existing highway lanes.[11] In sheer economic terms, if the AHS even approaches these kinds of benefits, this program will represent one of the most productive transportation investments ever made.[12]

With all vehicles under full automatic control, the system will provide significant benefits in enhanced safety, increased throughput, and shorter and more predictable trip times.

2.3 AHS Concept

The NAHSC has established the fundamental guidelines and capabilities for the AHS concept.[13] An AHS will safely operate properly equipped vehicles under automated control on properly equipped lanes. Human errors and inefficiencies will be virtually

The AHS will support a broad range of vehicle types (passenger cars, trucks, and buses) in a widely varied array of highway configurations.

[11]AHS Precursor Systems Analysis Studies byCalspan, PATH and Delco, December 1994.

[12]Administrator Rodney Slater, Federal Highway Administration, October 7, 1994.

[13]The NAHSC working with the Federal Highway Administration (FHWA) and based on the AHS Precursor System Analysis contract work.

eliminated when all vehicles in the lane are fully automated. It is currently assumed that AHS lanes will be adjacent to, and similar in structure to, the other highway lanes. Entry to the AHS may be similar to entry to some of today's high occupancy vehicle (HOV) lanes or through dedicated entry stations.

With nationwide planning and vehicle and infrastructure integration, AHS will result from logical progressive steps over time.

The fully automated AHS will be developed through a planned progression from today's vehicle-highway system. This transition will be simplified because some of the basic services needed for an AHS are starting to appear in today's vehicles and highway systems. Use of these services is expected to increase during the next decade. Metropolitan areas are already upgrading their highway infrastructure with such services as electronic toll systems for nonstop toll collection, and automated incident detection for faster responses to crashes and other incidents. All have the potential to improve the efficiency of highway systems. The AHS will build on and guide this progression to ensure vehicle and infrastructure compatibility. With nationwide planning and vehicle and infrastructure integration, AHS will result from logical progressive steps over time.

An AHS will use modern electronics to safely and efficiently move AHS equipped vehicles along instrumented, dedicated highway lanes under fully automated vehicle control with no driver involvement required. Manually driven vehicles will be denied access to the AHS lanes. AHS-equipped vehicles will be able to operate under manual control on conventional lanes. On conventional lanes, the driver may choose to use partial automated vehicle control capabilities (e.g., adaptive cruise control). This mode of operation known as "partial-AHS" will offer some increase in safety and reduced driving strain compared to completely manual operation while on highway lanes used by all vehicles.

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

The AHS primary system control may require interaction between the vehicle and the roadway. This interaction will be a non-contact electronics-based design as opposed to a mechanical, physical contact design.

The AHS will consist of at least two major subsystems: the vehicles and an infrastructure. The vehicle subsystem will contain the portion of the system that actually moves along an AHS. The vehicle subsystem includes sensors, data processing, actuator, linkage, and communications equipment. The AHS will automate the following driver functions to control vehicle movement.

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

AHS Entry — The system will enter vehicles onto the automated highway with simultaneous speed adjustment between several vehicles to successfully merge vehicles.

AHS Exit — The system will move vehicles from the AHS lane and will return control of the vehicle to the driver after ensuring that the driver is prepared to safely operate the vehicle.

Object Detection and Collision Warning/Avoidance — The system will detect moving and stationary objects on the automated lanes and will avoid collisions with these objects.

Longitudinal Vehicle Control — The system will adjust the vehicle speed, both to maintain a safe overall speed (as influenced by environmental conditions), and the appropriate longitudinal distance between vehicles.

Lateral Vehicle Control — The system will steer the vehicle by sensing the lane boundaries or lane centers of the automated lane and control vehicle steering to keep the vehicle in the lane, coordinating lane changes and entry/exit maneuvers.

Navigation — The system will track the vehicle's position on the highway network to ensure that the vehicle leaves the system at the driver's desired exit or guide the vehicle to another exit of the desired exit becomes unavailable.

Maneuver Coordination — Using the vehicle's absolute or relative position on the highway with communication between vehicles, the system will coordinate vehicle maneuvers.

The infrastructure subsystem will contain all other aspects of the AHS not found in the vehicle. This includes, but is not limited to, communications equipment, roadways, control centers, sensors, and operations and maintenance facilities.

The AHS will not be a standalone system. It will be developed and integrated with other transportation systems. It will supplement existing vehicle-highway systems for state and Metropolitan Planning Organization (MPO) transportation planners and other policy makers. It will allow safer, more efficient, and cost-effective highways to be designed while still meeting a region's environmental guidelines and societal goals.

The AHS can be tailored to meet the needs of the individual states and regions that choose to implement the system.

An AHS will support varying modes of transportation, including, but not limited to, local and trunk line transit services, commercial truck and taxi services, and shuttle services to major trip generators such as airports and commercial centers. All of the improved conveniences in the flow of information as a result of ITS technologies will be incorporated. In addition, AHS will provide faster transit and more reliable guideways on which to operate. Users will not only be better informed of available service, but more attracted to faster, more reliable, and more direct service. Travelers as well as commercial users will find many new important ways to facilitate their activities. Typical of the early stages of any important innovation, it is impossible to anticipate all the entrepreneurial responses that will serve the user needs.

An AHS will support varying modes of transportation including, but not limited to, transit systems, trucking including intermodal terminal shuttles, and airport and downtown shuttle systems.

There will be common standards so that an AHS-equipped vehicle from one region of the country will be able to travel on an AHS in any other part of the country. Local vehicle size and performance restrictions may be different not to allow, for example, AHS-equipped heavy trucks to operate in high-congestion central business districts at certain times of the day.

The AHS will be adaptable to the local needs. This flexibility and tailoring of AHS includes, but is not limited to the applications listed in Table 2-1.

Table 2-1 The AHS concept is flexible to accept local tailored needs like these examples.

Highway Networks in Highly Congested Megalopolises
AHS lanes could be implemented throughout the highway networks of our largest and most congested metropolitan areas, where they would help alleviate the daily congestion that plagues these regions. The primary focus of such an AHS implementation would be on maximizing throughput to relieve congestion and air quality problems, diverting traffic from arterials and other highways. Examples could include Los Angeles and New York metropolitan areas.
Highway Corridors in Large, Congested Metropolitan Areas
AHS lanes could be implemented on the most heavily traveled portions of the highway networks in many large, congested metropolitan areas, where they would help relieve congestion bottlenecks, enabling the entire road network to function more efficiently. The emphasis in these applications would be on achieving high enough throughput to relieve the bottleneck problems, and reducing congestion and pollutant emissions. Examples include cities such as Boston, Washington, D.C., San Francisco, and Houston.
Exclusive Transit and HOV Lanes
In order to encourage use of transit and HOVs, giving them advantages in average travel time, travel time predictability and safety over SOVs, priority could be given to the implementation of AHS on special lanes reserved for use of transit vehicles and HOVs. These could provide express services for relatively long-distance suburban and urban commuters, from park-and-ride facilities to transit terminals or major activity centers. Examples include the Houston Metro HOV network, the Shirley Highway in Virginia, the El Monte Busway in Los Angeles and the Lincoln Tunnel contra-flow busway in New York.
Heavily Traveled Intercity Highways
AHS could be implemented for intercity travel in high-density corridors, where long-distance traffic is combined with urban and suburban commuter traffic to produce both congestion and safety problems. In this setting, AHS could substantially improve the comfort and convenience of travel for a wide range of users, both personal and commercial, while reducing fatigue and safety problems in particular for the long-distance travelers. Examples of such applications include the I-95 corridor between Boston and Washington, I-94 between Detroit and Chicago, and I-5 between Los Angeles and San Diego.
Exclusive Commercial Vehicle Lanes
In areas having very heavy truck traffic, separate AHS lanes could be established to provide safe, efficient movement of goods with greatly enhanced trip time reliability, as well as reduced average trip time. Such services should be very beneficial to trucking operators and their shippers, especially those involved with just in time delivery. It should help improve the productivity of truck fleets and drivers, reduce their number of incidence of crashes, and reduce the impacts that heavy truck traffic have on the rest of the highway network. This could be particularly beneficial in areas with multi-modal terminals and major ports, such as the northern portion of the New jersey Turnpike or the Alameda Corridor between Los Angeles and San Pedro.
. . . . continued on next page.

Table 2-1 The AHS concept is flexible to accept local tailored needs like these examples. (cont)

Sparse Rural Areas
AHS-equipped rural roadways could be designed to operate intermixed with conventional vehicles to help prevent the two major causes of rural accidents - accidents with animals and single vehicle road departure. The AHS equipment would maintain a safe distance from the vehicle in front and help detect obstacles on the road. It would also help the driver keep the equipped vehicle in its lane and avoid road departure accidents. The driver could choose to turn the AHS services on or off as needed.
Long Distance Interstate Highways
AHS could make long-distance travel significantly safer and more comfortable and convenient for both personal and commercial goods travel. By relieving the monotony and fatigue associated with long-distance highway travel, AHS should be beneficial to a broad range of travelers. This kind of application would probably begin on the most heavily traveled Interstates such as I-95 along the east coast, I-5 along the west coast, I-75 from Michigan to Florida, or I-80 from coast to coast.
Roadway Powered Electric Vehicles (RPEV)
Roadway powered electric vehicles use opportunity roadway-based charging to supplement the vehicle's battery supply, thereby extending the vehicle's range and capability. An integration of AHS and RPEV would enable the vehicles, for example, to lane-keep directly over the charging elements. A region could stimulate the electric vehicle market by supplying power from the roadway to keep the vehicle moving without draining (and possibly charging) the vehicle's batteries. The vehicle would continue off the highway via battery power. The integration of AHS and RPEV may be particularly beneficial for transit vehicles.

2.4 AHS Benefits

A prime goal of the NAHSC is that AHS be viewed as a desirable option for vehicle-highway system enhancement by all stakeholders; users, communities, state and regional transportation agencies, environmental organizations, and industry, who have a stake in the design and implementation of an AHS. "The Automated Highway System offers the potential for dramatic changes in the driving experience, such that safety would be vastly increased and drivers would be free from the stress of driving in heavy, congested traffic. The expected ability of an Automated Highway System to handle large volumes of traffic also creates benefits for the entire road network, relieving stress on the surrounding highway, thereby benefiting all users."[14] AHS will attempt to balance the inherent tradeoffs among safety, environment, congestion, speed, and community liability, and the goals of each stakeholder group.

Benefits for AHS Users

The AHS will provide users with the following benefits:

- Safer travel.
- More efficient travel.
- More predictable trip times.
- Environmental benefits.
- Additional mobility to an increasingly aged population.
- Reduced insurance rates due to reduced numbers/severity of crashes.

Specific safety goals include the following:

- Significantly reduced driver error by providing for increasing degrees of automated assistance, from partial control in conventional lanes, up to full control of the vehicle while in AHS lanes.

[14] Administrator Rodney Slater's speech on the AHS Program, Oct. 21, 1993.

- Less frequent and lower severity crashes.

- No collisions in the absence of AHS malfunctions.

- In the event of malfunctions, the use of fail-soft and fail-safe designs. Fail-soft and fail-safe designs have been used successfully in the defense, aerospace, transit, and vehicle industry to minimize the effects of failures in the system. AHS will be designed to minimize both the number of crashes that occur and their severity.

The AHS will make highway travel less stressful and more enjoyable for all travelers, including transit and other multiple occupant vehicles. Specific comfort and convenience goals include the following:

- Reduce travel time and stress of travel for commuters.

- Enhance personal mobility for the elderly or other drivers with special needs in performing the driving task.

- Increase the comfort of traveling as a result of increased safety and less frustration resulting from the decrease in congestion and unpredictable travel times.

- Reduce the strain of driving on crowded, high-speed highways.

AHS users can expect shorter and more predictable trip times. As a result of reduced congestion, smoother flow, and higher average speeds, average trip times on the AHS will be shorter.

Benefits to Society

For the U.S. Department of Transportation and the public to fully support the AHS, the long-range AHS effort must also provide benefits that consider the nation's societal needs. The following have been identified as societal needs that the AHS can help to achieve:

- Provision of increased, equitable access to transportation by all segments of society

- Reduced highway congestion and increased safety and security.

- Reduced overall fossil fuel consumption and emissions.

- Support for response to national emergencies, both civil and national defense.

- Support for enhancing the nation's robustness and vitality with a sustainable transportation system.

- Transportation system that increases mobility of people and goods, which can potentially increase productivity, enhance competitiveness, and result in economic growth.

Benefits to State and Regional Transportation Agencies

AHS should be seen as a desirable, cost-effective investment alternative that can be tailored to meet the state and regional transportation needs. The AHS will provide the following benefits to the state and regional transportation agencies:

- Remove or reduce traffic from conventional streets and highways.

- Move traffic more safely and quickly through urban areas.

- Serve as a long-term supplement for major highways that in many cases uses existing infrastructure to increase safety and throughput.

- Favorable return on investment when compared with other transportation alternatives in many deployment environments.

- Increased service to citizen users and higher customer satisfaction.

- Improved productivity, safety and reliability will benefit transit operators using AHS. Steady vehicle speeds, automated operations and controlled guideway access will reduce transit trip times, reduce driver error, and ensure on-time performance.

- Integration with other ITS services, including travel demand management approaches.

Benefits to Communities

The AHS will represent an attractive alternative for handling community transportation needs and issues. It will provide communities with the following benefits:

- Enhanced quality of life and environmental sustainability in communities. This includes improved personal security due to improved communications and reduced response time of emergency vehicles.

- Better support for community policies to reduce demand for new land use for highway rights-of-way by allowing increases in traffic demand to be handled on existing rights-of-way.

- More efficient support for community policies to reduce air pollution.

- More efficient use of scarce resources in ways that minimize environmental impacts and are compatible with local land use plans.

- Less need for emergency services (e.g., fire, rescue, emergency room treatment) because of fewer crashes on the highway. Better response time from these services (including law enforcement) when they are needed in the community as a result of the increased efficiency of the transportation system and system notification of emergency personnel.

Benefits to U.S. Industry

The AHS offers major benefits to industry and U.S. competitiveness in the world market.

- New business opportunities are created by public-private partnerships in support of AHS.

- Many vehicle manufacturers, highway construction firms, and vehicle electronics companies will see substantial, long-range market opportunities because of the open architectures and interoperability standards used by the system.

- Trucking firms will benefit from safer highways and more efficient roadway operations, particularly shorter, more predictable, and reliable point-to-point travel times that will translate into realistic just-in-time delivery inventory control and lower operating costs. In addition, reduced driver workload will translate into the potential for higher productivity.

- Industry in general will benefit from increased transportation reliability, mobility, and flexibility that should translate into faster market response times and reduced operating costs.

- Industry will benefit from the new business opportunities from spin-off products from AHS technologies.

- Defense and aerospace firms can use their expertise in this civilian application providing dual-use technology and products.

"...the Automated Highway System offers the potential for dramatic changes in the driving experience, such that safety would be vastly increased and drivers would be free from the stress of driving in heavy, congested traffic. The expected ability of an Automated Highway System to handle large volumes of traffic also creates benefits for the entire road network, relieving stress on the surrounding highway, thereby benefiting all users."[15]

[15] Administrator Rodney Slater's speech on the AHS Program, Oct. 21, 1993.

3.0 AHS PERFORMANCE OBJECTIVES

This section describes the performance objectives of the AHS. These objectives were derived from the original Request for Application to establish a National AHS Consortium,[16] and revised based on the results from the AHS Precursor System Analyses and the ongoing NAHSC System Definition efforts including stakeholder feedback provided at the first Workshop.[17]

The following sections (3.1 through 3.5) describe the AHS performance objectives. The objectives are the fundamental reasons for developing and deploying AHS, representing the purpose of the program. They define the reasons for investing resources to develop and deploy the AHS. Appendix B defines a preliminary set of measures for assessing the of AHS designs meet the objectives.

3.1 Improve Safety

The AHS will be collision-free in the absence of AHS malfunctions and will include malfunction and incident management capabilities that minimize the number and severity of collisions that occur, as well as reducing the amount of time needed to respond to incidents that do occur.

The AHS will provide substantially increased safety to vehicle-highway users. Automated control will greatly eliminate driver-generated errors attributable to poor judgment, fatigue, unpredictable behavior, and personal impairments. Up to 93% of highway crashes are attributed to driver error.[18] By transferring driver control to the AHS vehicles while on AHS highways, the automated system will reduce vehicle mishaps per highway kilometer by as much as 50 to 80 percent. The AHS will interact positively with on-board vehicle monitoring systems so that defective and manually controlled vehicles are excluded from automated control lanes.

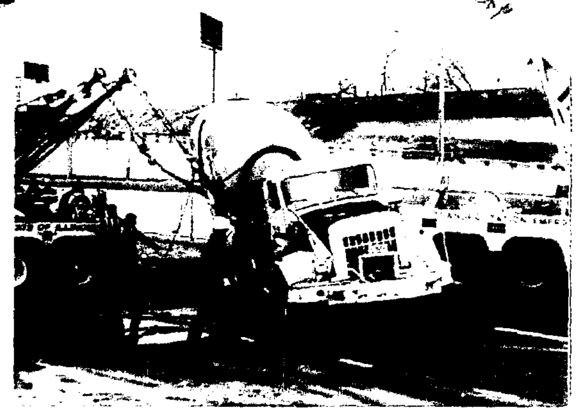
The AHS will be significantly safer than today's highways.

- ***Reduce vehicle crashes per highway kilometer by as much as 50 to 80 percent.***
- ***Reduce fatal and major injury crashes at least one half the current rate.***
- ***May allow reduction in insurance costs***

[16] Request for Application To Establish a National AHS Consortium, U.S. DOT, DTFH61-94-X-00001, December 15, 1993.

[17] AHS System Requirements Workshop, NAHSC, Ft. Lauderdale, FL, April 12-13, 1995.

[18] IVHS Strategic Plan, Report to Congress, U.S. DOT, Dec. 1992,pg 32.



Up to 93% of highway crashes are attributed to driver error

The AHS will show a reduction in the occurrence rate per highway kilometer of fatalities, severe injuries, and property damage for AHS vehicles under automated control of at least one half the current rate for highway traffic. This reduction will be accompanied by an ability to decrease the rate of mishaps resulting in minor injury or property damage on similar types of highways. The AHS will be designed to ensure that the safety of manually operated vehicles will not be degraded by AHS.

In normal operating conditions, the driver will transfer vehicle control to the automated system as a condition of entry into the automated lanes. The AHS will control the vehicle while it is in the system. Control will be returned to the driver upon exiting the automated system. This will help ensure that driver errors, both personal and those by drivers in nearby vehicles, will not result in a mishap. The automated system will take appropriate measures to ensure that the driver is ready to take control from the automated system before control transfer. To help increase safety in case of unexpected events, the system will enable the driver to signal an emergency and bring the system to a halted condition or other fail safe state of operation. This is similar to the emergency signaling provided on public buses and trains.

The AHS should result in lower insurance costs to drivers and shippers as a result of a significantly lower rate of loss due to crashes. The AHS system will provide safe operation under degraded service in the presence of multiple concurrent failures of AHS components. Individual failures may occur periodically and the AHS will be designed to ensure continued safety during and after the failure. Any individual failures occurring within system facilities or equipment will be transparent to the motoring public. The AHS will be designed so that multiple failure occurrences result in decreased levels of service while maintaining safety standards. Individual failures in individual vehicles will result in the vehicle being removed from the system in a safe and efficient manner. This may include a concept that has the failed vehicles removed at the nearest available exit, stopped in a breakdown lane, or stopped in the lane of travel if continued operation compromises safety.

To ensure the safety of its users, the AHS will be resistant to outside interference and tampering. The AHS will use protocols and techniques in its communications services that prevent unauthorized access or interference. The AHS will be designed to respond to intrusion by pedestrians, animals, environmental conditions (rock and snow), and vehicles in adjacent lanes.

3.2 Increase Efficiency

The AHS will significantly increase the throughput of all accommodated vehicle types in the United States. As much as a 300% increase may be possible.[19] Throughput improvement varies depending on weather conditions, traffic conditions at egress points, and vehicle types accommodated on a specific AHS. Throughput gains will be obtained through significant reduction of incidents and crashes. The net per-lane throughput of an automobile-only AHS will be at least double and perhaps triple the per-lane throughput of a conventional highway under dry and good weather conditions, barring reductions due to specific site conditions. The throughput gains of those AHS lanes accommodating heavy vehicles intermixed with automobiles will be lower.

The AHS will enable significant increase in vehicles-per-hour per-lane flow through increased density at free-flow speeds, stable traffic flow, and possible increase in speed.

Throughput refers to predicted achievable flow in a particular lane given the physical configuration (e.g., frequency of entry or exit points), demand pattern and operating policy (e.g., ramp metering or speed limits). Total conventional roadway capacity refers to the

[19] IVHS Strategic Plan, Report to Congress, U.S. Dot, Dec. 1992pg 33.

The total vehicle kilometers traveled in the nation is predicted to nearly double by the year 2020

maximum rate of flow at which persons or vehicles can be reasonably expected to traverse a point or uniform segment of a lane or roadway during a specified time period under prevailing roadway, traffic, and control conditions. Dedicated automated lanes on an urban/suburban AHS may require additional supporting space, e.g., shoulder (breakdown lane), transition lane, and areas required at the interface with conventional roadways (including possible check-in or check-out facilities).

In calculating the capacity increase of the roadway as a whole (e.g., roadway capacity), the additional amount of supporting space required must be considered. Because the AHS lane width may be narrower than today's standards, it should also be considered in the capacity calculations. Roadway capacity measures for AHS must include those measuring maximum possible flow for the most critical of the following:

- Check-in (the process of determining if the vehicle and driver have the necessary certification, training, and equipment; verifying the operability of the vehicle; and processing the vehicle into the system);

- Entry to automated traffic, with or without physical segregation from manual traffic;

- Longitudinal flow;

- Lateral flow, with or without barriers/openings between automated lanes;

- Merging at on-ramps, lane merges and highway-to-highway interchanges;

- Exiting from automated traffic, with or without physical segregation from manual traffic;

- Check-out (the process of verifying the readiness of the driver, processing the vehicle out of the system, and returning the vehicle to manual control).

These basic capacity measures, including physical configuration and operating policy determine the roadway capacity. Speed regulation is a key performance characteristics of the AHS in achieving increased throughput. For high-demand urban highways, the AHS will regulate the speed of all vehicles to achieve the optimum speed to ensure maximum AHS lane throughput. The AHS will give local highway operators the ability to set the normal operating speed of a roadway segment to meet local needs, including any desire for shorter trip times. The maximum design speed of the AHS must be able to provide a desirable service level on intercity highways, where dedicated AHS lanes are an affordable option and high speeds can be accommodated by the existing right-of-way. Also, the maximum design speed must accommodate and provide an acceptable safety margin for the expected range of operating vehicle designs. For example, a state DOT may plan to operate the AHS initially at 90 kph, then advance to a speed of 140 kph, and may ultimately consider a maximum design speed of 200 kph.

3.3 Enhance Mobility and Access

More efficient use of the nation's highways will increase mobility and access. This is one of the major premises of the AHS program. Motor vehicles and highways are the most used, most flexible, and most intrusive transportation system we have.

The AHS will provide more rapid movement of people and freight by reducing highway congestion caused by increasing demand and by driver errors resulting in incidents. More rapid movement will translate into noticeably shorter trip times and into the ability to move people and freight to more locations in the time available. This has significant implications for private, commercial, and transit vehicle users and operators.

The AHS will provide shorter and more predictable trip times resulting from increased throughput and the ability to maintain free flowing speeds at high levels of throughput. People will be able to plan trips with much less uncertainty about the possibility of delay caused by congestion or crashes. Transit service providers will have increased ability to maintain their published schedules. Implementation of an AHS may encourage people to use alternative modes of transportation instead of single occupancy vehicles. Predictable trip times will increase the feasibility of just-in-time deliveries for commercial trucking companies.

AHS will integrate with and support various ITS services, such as pre-trip planning to avoid areas of congestion and possible delay. In addition, the AHS will integrate with services to monitor and track the movement of individual trucks or transit vehicles.

AHS will enhance the nation's ability to effectively and predictably move people and freight using the highway system

The AHS will provide vehicles — private automobiles, transit vehicles, or trucks with seamless highway transportation. To assess the ability of an AHS to enhance mobility and access, measures can be developed to estimate differences in: trip times for selected origination/destination pairs in typical or actual locations before and after an AHS installation; variation in trip times with an AHS for varying traffic conditions; and the ability to achieve on-time transit service in varying traffic conditions with and without an AHS.

Increase travel reliability
- ***Reliable point-to-point travel times***
- ***Dependable service***
- ***Graceful accommodation of service interruptions***

AHS will be a system that requires less skill and concentration than is needed on current highways. Its goal is to extend the diversity and range of driving opportunities for all drivers, including senior citizens, the drivers who are fearful of highway driving, and the less experienced driver. For those people who may normally avoid highway driving, automation will reduce driving stress and should permit them to gain, or regain, access to the highway after it has been automated. The driver interface for AHS must accommodate the capabilities and limitations of people whenever possible. However, drivers will have to drive on conventional roadways to reach the AHS. It is not the intent of the AHS to encourage individuals who are temporarily impaired due to alcohol or drugs, to drive.

3.4 Provide More Convenient and Comfortable Highway Traveling

One of the expected major benefits of the AHS will be to increase the convenience of motor vehicle travel by relieving the driver of the driving task while on the AHS. After entering the automated highway, the driver will be free to relax and engage in non-driving tasks, thus improving personal productivity. Under normal circumstances, the driver will not be required to resume any driving tasks until the requested exit is approached.

AHS will substantially increase the quality of traveling by motor vehicle, will substantially reduce the stress of driving, and will make highway driving more accessible to the aged and less experienced.

To achieve this improvement in trip quality, the AHS will reduce the stress associated with manual driving and must not induce stress during automated driving. There will be less stress on the driver because he or she does not need to control the vehicle or concentrate on traffic conditions while on the AHS. The driver must feel secure while on the AHS — confident of their own well-being and of the system's ability. The driver should have less fear from other errant, inattentive, or overaggressive drivers. The drivers also should have less fear of the consequences of their own driving mistakes. The driver should also suffer less frustration due to congestion and/or unreliable travel. The driver should have a feeling of increased safety because far fewer crashes will occur on the AHS. The ride must be as smooth as good manual driving, with no sudden changes in speed or direction under normal circumstances. AHS must not permit sudden jerky motions of the vehicle. Automated maneuvers will be consistent and occur the same way when the conditions are the same.

3.5 Reduce Environmental Impact

The AHS will be consistent with and help satisfy the nation's long-term air quality and energy usage goals as exemplified in national legislation.[20] The AHS, when coupled with policies that are aimed at limiting growth of vehicle kilometer traveled (VKT), will help meet the nation's long-term air quality goals. It will be used by environmental and transportation professionals to (1) reduce emissions per VKT and (2) enhance the operation of other pollution-reducing transportation approaches. Reduced trip time, improved reliability, and more direct non-transfer service available to transit with AHS are highly valued by potential transit users. As AHS guideways become more available for transit vehicle use throughout a metropolitan area, these positive service attributes will be available to more residents, further reducing VKT.

AHS will improve fuel economy and reduce emissions per vehicle kilometers traveled through smoother flow and compatibility with future vehicle propulsion and fuel designs

The AHS is expected to reduce fuel consumption and tailpipe emissions per VKT for internal combustion engines through smoother vehicle operation (fewer accelerations and decelerations), and reduced congestion. AHS operations at very close spacings can dramatically reduce aerodynamic drag on vehicles, thereby substantially reducing fuel consumption and tailpipe emissions. Also, traffic formerly on surface streets will be attracted to use AHS. However, the increased AHS capacity may attract additional traffic. Further, the environmental impact of much larger volumes of vehicles traveling in concentrated corridors must be understood and accounted for. Approaches such as encouraging more passengers per vehicle, and policies for ensuring that this added capacity ultimately results in reduced congestion with no substantial environmental impact must be developed.

[20] Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and Clean Air Act Amendments of 1990 (CAAA).

Air quality continues to be a major problem in most cities.

AHS will also support the environment by utilizing existing highways and right-of-ways, reducing the demand for building new highways that have a detrimental impact on the land.

The AHS will support and enhance the deployment and operation of known alternative propulsion systems. In addition AHS will provide a base on which roadway-powered electric vehicle systems might feasibly be developed.

An ongoing trade-off and issue is that the increased throughput enabled by AHS may negate the positive benefits on emissions. All of these objectives will need to be balanced to find the best solution for each community.

4.0 AHS USER SERVICE OBJECTIVES

The AHS performance objectives described in section 3.0 are common needs for all users; however, the users of an AHS are a diverse group including: transit, trucking, commuters, and vacationers. Each of these groups have unique needs that the AHS must service. Many of these user service objectives can be implemented differently depending on local needs or uses, as shown in Table 4-1. The following sections (4.1-4.7) describe the unique top-level service objectives for AHS users.

Table 4-1 AHS User Service Objectives

User Service Objectives	Section Number	Implementation Locally Determined
Disengage the Driver from Driving	4.1	
Facilitate Intermodal and Multimodal Transportation	4.2	✓
Enhance Operations for Freight Carriers	4.3	✓
Support Automated Transit Operations	4.4	✓
Apply to Rural Highway	4.5	✓
Support Travel Demand Management and Travel System Management Policies	4.6	✓
Support Sustainable Transportation Policies	4.7	✓

4.1 Disengage the Driver from Driving

Full automatic control "hands-off and feet-off driving" is a service to be provided to all drivers on the AHS. Full automatic control will be a learned condition for the driver brought about by trust in the reliability, safety, and convenience of the AHS. After the driver gains that level of trust in the AHS, the stress associated with driving will be greatly reduced. The driver will become a passenger in the fully automated AHS and may sleep, read, or work and will not be required to attend to any driving-related tasks.

During the full automatic vehicle operation in the AHS, the system will effectively and safely control the vehicle, requiring no support from the driver.

Some drivers may want to remain alert to passing vehicles, progress on the AHS, and the existence of hazards. If the driver detects a mishap, debris, or potential incident, the driver will be able to communicate that condition to the system. However the system will not rely on driver detection of these hazards. The system will respond to these conditions, but will retain vehicle control unless the situation warrants and allows a safe return to driver control.

In addition, the system will attempt to make the driver aware of situations where the driver must again become engaged. Until a driver responds to these alerts and demonstrates to the system that manual control can be reassumed, the system will retain control even to the point of exiting and stopping the vehicle in a safe and effective manner. The return to safe manual control with short notice during emergency situations requires a strategy of notification to the driver that encompasses all levels of driver capabilities, including the aged, impaired, hard of hearing, and inexperienced driver. It also requires a strategy for dealing with drivers who do not respond to this notification.

One ongoing issue being studied is whether to allow a driver to resume manual control of a vehicle while in an automated lane. In some situations, driver response times and capabilities may be inferior to the capabilities provided by the AHS, and permitting the driver to resume control may present a serious hazard to the system.

4.2 Facilitate Intermodal and Multimodal Transportation

The AHS will support an intermodal and multimodal surface transportation systems.

The highway system of the United States today supports a wide variety of transportation modes, including the personal automobile, public and private transit vehicles, and trucks for transportation of freight. A commuter may carpool to a park'n ride and take a bus to work. The AHS will support all these transportation modes and services in combination and separately. AHS will interface with parking and transit operators to connect with other mode stations (e.g., rail, airports). Local planners will be able to use AHS capabilities to build transportation systems that meet the needs of their locality and region.[21]

[21] See sections; 4.16 Enhanced Operations for Freight Carriers and 4.17 Support of Automated Transit Operations