# Precursor Systems Analyses of Automated Highway Systems

RESOURCE MATERIALS

## AHS Roadway Analysis: Final Report Vol. III

U.S. Department of Transportation
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## FOREWORD

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

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

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

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

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

## NOTICE

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16. Abstract

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

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

The 17 task reports (A through P plus Representative Systems Configurations) are organized into 8 volumes. This volume, which describes roadway analyses, covers four tasks in three chapters. Urban and Rural AHS Analysis (Task A) was supervised by Joseph A. Elias of Calspan and supported by Richard Naish of Parsons Brinckerhoff. AHS Roadway Deployment Analysis (Task H) was supervised by Robert Gordon of Dunn Engineering and supported by Robert A. Reiss, Egan Smith, and Victor Yang, also of Dunn Engineering. The detailed physical layout was supervised by Habib Shamskhou of Parsons Brinckerhoff and supported by Olaf Kongshaut, also of Parsons Brinckerhoff. Impact of Non-AHS Roads (Task I) was supervised by Ronald Hill of Dunn Engineering and supported by Robert Gordon, Egan Smith, and Victor Yang, also of Dunn Engineering. AHS Roadway Operation Analysis (Task K) was supervised by Joseph Setteducato of Parsons Brinckerhoff and supported by Kerri Collins, June Kahng, and Robert Conte, also of Parsons Brinckerhoff.

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VOLUME III— AHS ROADWAY ANALYSIS

CHAPTER 1: URBAN AND RURAL AHS ANALYSIS

## 1.0 EXECUTIVE SUMMARY

The target for Automated Highway System (AHS) deployment is our national freeways, the backbone for worker commuter, inter- and intracity travel and the major roadway choice of America. Freeways, pressured to carry more traffic, are experiencing crippling and prolonged congestion. The remedy for congested freeways is not to build more of them but to make them work more efficiently. AHS analysis is based on this premise.

Experienced transportation engineers recognize the fact that freeway problems are not the same for urban, suburban and rural environments. They were not built for the same purposes, were not engineered the same, and do not operate the same (AASHO Blue Book, 1954, Red Book, 1957). Rural freeways were built before urban freeways, with the primary purpose of connecting cities. Urban freeways were built to 80.5 km/hr (50 mph) design standards within tight right-of-way (ROW); rural freeways used 112.7 km/hr (70 mph) design standards with ample ROW. However, many freeways that were created as rural freeways are now surrounded with spreading suburbs, which generate significant traffic. This evolution from rural to suburban leaves only open country freeways to free flow. This freeway evolution to three different environments has gradually evolved over the half century existence of the interstate highway system.

AHS deployment may be easy to envision in a final form, where all vehicles and roadways are AHS equipped. This would be a complete replacement for the manual interstate highway system. If this is a potential long-term goal, then the near-term process is one of converting manual freeways to automated freeways, to begin the market driven process towards the final level of automation. Solving this near term deployment problem is the immediate challenge for AHS designers.

The urban and rural analysis task is the initial task, under the Precursor Systems Analysis (PSA) research effort, that concentrates on the roadway aspect of AHS. A very general analysis approach was adopted for this task. This general approach will provide the overall insights necessary for use in other task research. Each of the three interstate environments: urban, suburban, and rural were characterized in terms of the following five attributes: Trip Characteristics, Incident Impacts, Roadway Restraints, Potential Market, and Societal Impacts. These attributes were chosen because of their effectiveness in characterizing freeway environments and their relevance to AHS design.

The following are conclusions from the analysis performed under this task:

- The daily user of urban and suburban freeways wants travel time savings as a performance improvement. Acceptance of AHS equipment and traffic management costs will be based on the performance gain. A target goal for this savings is one minute per 1.61 travel kilometers (one travel mile); totaling at least ten minutes on the freeway portion of the trip. This objective can, most likely, be accomplished by providing preferential lane and exit/entry provisions for AHS users, since automated control can regulate speeds above the current congested level.

- Major sources of urban and suburban freeway congestion are incidents (non-recurring), bottlenecks at entry/exit points (recurring), and scheduled maintenance (non-recurring). AHS vehicle instrumentation and Traffic Management (TM) are tools to eliminate congestion, provided poor roadway geometry is corrected.

- Worker commuter users of urban and suburban freeways are effective targets for early deployment of AHS. These individual users have a vested interest in making AHS a success as they gain time, reliability, and safer trips. As a daily user, they should be willing to equip their vehicles and pay for the service. High Occupancy Vehicle (HOV) users and Transit are prime customers for AHS since they are currently part of the solution for urban and suburban congestion.

- Optimize operational improvements on urban and suburban freeways along with introduction of AHS, as it a part of a Traffic Management (TM) package not a stand alone service. Traffic Management includes; surveillance and control systems, ramp metering, incident management, motorist information systems, HOV facilities, and low-cost geometric improvements. These TM techniques are required to supplement AHS full automation.

- During early year deployments, AHS performance may not be ideal in terms of congestion relief, due to mix of manual and automated vehicles. Working with existing freeways to gain initial automation benefits, provides a wider and more immediately visible return than attempting to build new AHS guideways to serve a select few.

- Understand and respect the social issues of AHS deployment. AHS deployment is not just a technical installation exercise to provide a service. Impacts on land use planning, air/noise pollution and public/political acceptance may be more important than solving mechanical/electronic/concrete problems.

- Consider separated AHS lanes a high priority for suburban freeway deployment, provided equal provisions can be made for entry and exiting. A major infrastructure design issue for AHS deployment is solutions to the traffic mixing, weaving, entry and exit with non-AHS vehicles especially heavy trucks.

- Assume that AHS on rural freeways will initially operate in mixed traffic lanes. When AHS use increases, and higher performance is needed, the minimum lane requirements appear to be one AHS lane and two general use lanes. This requirement will impact most of the dual two-lane freeways (outer suburban and rural). Although traffic volumes may show only a need for a single general (manual) lane, entrance/exit, passing, incidents plus operation during maintenance will probably require a minimum of two general lanes.

- AHS can increase throughput during peak hours provided the supporting interchanges, feeder roads and city streets can accept this increase. At the proposed high flow rates, urban and suburban facilities now regularly fail. Only rural freeway feeders have the capacity required.

- Research into AHS technology is important as this defines the "How". Equally important is research in the market to identify size and needs as this defines the "Customer". The "How" should be driven by the "Customers' Needs".

- Envisioning AHS as a national system requires flexibility of design to accommodate urban, suburban, and rural needs. The urban, suburban, and rural environments cover a spectrum of needs. Therefore, a variety of configurations are required to meet each of the needs. Suburban would be more I3 driven and rural would be more I1 driven.

## 2.0 INTRODUCTION

### 2.1 TASK OBJECTIVE

The existing transportation system in this country serves urban, suburban and rural environments. The central component of this system is our existing freeway system consisting of Interstate Highways, Parkways, Expressways and Toll Roads comprising approximately 80,500 kilometers (50,000 miles) (1%) of the national 6.1 million kilometers (3.8 million miles) of roads. To demonstrate their key role, freeways, which are only 3% of the total urban/suburban arterial mileage, carry approximately 30% of the total traffic. Cars and personal light trucks are the major freeway users (98%). Their use pattern and operational characteristics vary widely between urban, suburban and rural lengths of freeways.

It is not the environmental locations that account for these differences. Urban, suburban, and rural freeways were not built the same nor expected to operate the same [AASHO Blue Book, 1954, Red Book, 1957]. AHS should, therefore, not be expected to be deployed or operate the same in each environment. The major freeway transportation concern is the growing congestion and associated degradation of travel quality (e.g., travel time, trip reliability, increased driver stress). The focus of the major IVHS initiatives currently underway is to improve travel operations rather than build more highways. The identification and documentation of operational characteristics of the three freeway environments is a useful first step in the process of finding a way for AHS to be part of the solution for these problems.

### 2.2 TASK APPROACH

It has been suggested that the Automatic Highway System has the potential to compliment the existing freeway system, through the use of automated vehicle control and highway management, to provide:

- Increased Capacity
- Smoother Traffic Flow
- Higher Average Speeds
- Higher Level of Safety

The purpose of this task is to examine the three environments (urban, suburban, rural) to assist in the development of AHS design requirements and evaluate potential benefits.

This task is divided into three subtasks. One for each of the freeway environments to be analyzed. Within each subtask, the specific freeway environment will be characterized by five freeway attributes that relate to potential AHS design and benefits evaluation. The five attributes are:

- User Trip Patterns
- Incident Impacts
- Roadway Restraints
- Potential Market
- Societal Impacts

Analysis of derived benefits from AHS deployment will be compared to existing operational characteristics, which are well represented by this set of five attributes. AHS costs will also be required for deployment feasibility analysis but are not addressed here.

The data source for the analysis presented in this chapter is national statistics and expert opinion. Categorization of typical segments of freeways into the three environments is subject to many interpretations but, when viewed in the context of general deployment, minor differences have little significance. The guidelines presented in this task are intended to be general. AHS deployment should be designed to be site or area specific and site specific aspects are presented in Chapter 2 of this volume.

In order to do the site-specific analysis, four specific roadway scenarios were selected to represent urban, suburban, and rural environments. These four scenarios will be identified within this chapter (Section 3.4) for the sake of completeness. However, detailed discussions of their characteristics are presented within Roadway Deployment (Chapter 2 of this Volume), since that task generated the results.

Other more in-depth aspects of urban, suburban, and rural freeways are discussed in the various task reports. For example, the safety statistics associated with urban, suburban, and rural travel on interstates is detailed in Chapter 2 of Volume V.

## 2.3 GUIDING ASSUMPTIONS

This task emphasizes the early deployment of AHS, where issues of environmental considerations have significant meaning. Two other assumptions underlying the analysis are:

- Existing freeway infrastructures should be used with minimal construction impact

- AHS designs, structured to work within freeway design limitations, should provide improved operations on all lanes, not just AHS lanes.

# 3.0 TECHNICAL DISCUSSIONS

## 3.1 URBAN ENVIRONMENT

### 3.1.1 Trip Characteristics

The urban freeway can be described as the conduit into and out of the Central Business District (CBD). Fewer than 25% of all trips on urban freeways are through trips. During worker commuter travel periods nearly all trips are inbound in the AM and outbound in the PM. Travel volumes remain relatively constant from 7:00 AM to 9:00 PM with peak hours extending one to three hours. Travel speed, during peak hours, are below 48.3 km/hr (30 mph) and experience severe according action (slowing and accelerating) due to lane changing, and exit and entry movement. The local streets feeding and receiving freeway traffic are usually traffic signal controlled to favor freeway traffic. The length of trips on the urban sections are usually less than 16.1 kilometers (10 miles) or the radial distance from the suburban boundary. Most drivers on urban freeways understand the description "freeway crawl" and accept it as long as traffic keeps moving.

The urban freeway users want improvement through travel time savings. A suggested target is one minute for each 1.61 kilometers (one mile) traveled, totaling 10 minutes. An overall increase of 32.2 km/hr (20 mph) in travel speed is an analogous target. Using typical commuter trips as an example, a 16.1 kilometers (10 mile) trip on the freeway under normal conditions of 32.2 to 48.3 km/hr (20 to 30 mph) takes approximately 20 minutes. This time is programmed into the commuter's overall home-to-work trip. Designed AHS operation of 88.6 km/hr (55 mph) on the freeway would reduce the trip time by 10 minutes. These guidelines were developed for HOV deployment which should apply for AHS (See Volume II). The time savings must include exit or entry into the AHS lane.

### 3.1.2 Incident Impacts

The major operational problem on urban freeways is congestion, both recurring, which occurs regularly at known locations and time periods and non-recurring, caused by incidents. Both types of congestion results in user dissatisfaction. While recurring congestion can be planned into a user trip the non-recurring delay is unpredictable. Predictability is very important to all freeway users since, after entering, they can not just turn right at the next street to find an alternative. Non-recurring congestion caused by incidents accounts for more than half of all urban freeway congestion problems. A single lane blockage on a three lane freeway reduces capacity by 50% even though the physical reduction is only 33%. A disabled vehicle on the shoulder causes a 33% reduction with no physical reduction of travel lanes. The majority of incidents are minor. They are caused by drivers operating beyond safe speeds and/or headway which leaves the driver one second short in reaction time.

The impact of incidents on freeway travel time can be illustrated using the same 16.1 kilometer (10 mile), 20 minute commuter trip. Incident reductions in capacity equates directly to increased travel time. Thus a 33% reduction in capacity (67% available) increases the normal 20 minutes to 30 minutes (20 min/.67), a 50% lane blockage doubles 20 minutes to 40 minutes. Incidents recur statistically approximately 15 times per 1.61 million kilometers (one million miles) of travel which equates for a high volume 3-lane freeway to an incident every three weeks in a peak hour or an incident every week in the AM and the PM three hour peak periods. Hopefully, AHS can eliminate most of the driver caused incidents. Incident management, or the lack of it, sets the duration of delay time. Stopped at the end of a queue, the typical motorist is often left to wonder — is the breakdown just ahead or am I at the end of a 16.1 kilometer (ten mile) queue?

Intelligent cruise control equipment , including collision avoidance can reduce much of the incident congestion but, may not be effective due to driver abuse. Recurring congestion correction is more a traffic management task and the fixing of poor geometry.

### 3.1.3 Roadway Restraints

The urban freeway cross section is dual three or four lanes separated by a median barrier with partial inside (left) and full outside (right) shoulders. Their alignments penetrate into the CBD on elevated viaducts, high embankments and/or depressed below street levels in walled corridors. The alignment is constructed within tight right-of-way with compact diamond type interchanges spaced on less than one to three mile intervals. Possibility of expansion to increase the number of lanes and provisions for direct ramp connections from local streets to a separated AHS lane would be difficult, if not impossible. The design choice should be to tailor the operations to fit the infrastructure not make the infrastructure fit the operations.

Preferential use of existing travel lanes and shoulders can be accomplished with minimal construction using any of the following arrangements.

- No separation between AHS and general lanes with only a designation of the left lane for exclusive (initially mixed) AHS use. This retains use of all travel lanes.
- Left lane designated as the AHS lane with the lane adjacent serving as the common shoulder or buffer. AHS transition lane and the right shoulder converted to a general use travel lane. This retains use of all travel lanes.

The above conversions will provide left lane AHS continuity. Solutions for entry/exit problems may be the use of prioritized mainline and ramp metering.

### 3.1.4 Potential Market

The worker commuter traffic accounts for 25% of all freeway Daily Vehicle Miles Traveled (DVMT) with their highest concentration during peak hours. As they have the greatest concern for uniform and predictable travel they logically can be expected to equip their vehicles for AHS or at the least have intelligent cruise control. The next highest users are the commercial service traffic which fills the off-peak periods. They are high volume users but not as forced flow as the commuter rush. They would also be expected to equip their vehicles.

There is a ready market for some form of AHS on the urban freeways beginning with Intelligent Cruse Control. However, it will be difficult to measure improvement unless strong traffic management is also introduced. The individual user, if they are allowed to use AHS lanes, may question if their costs will generate equal benefits. The other prime market, transit (HOV and Buses) operators may welcome the opportunity to use AHS to create a more predictable trip.

### 3.1.5 Societal Impacts

During the early years of designing and building the interstate highways, their placement in urban centers was in poorer sections where property acquisitions were cheaper and easier to obtain by condemnation. The justification for this was the use of underutilized city backyards. Soon after building sections of downtown freeways opposition began to grow. The highways brought high volume congestion to city streets, air and noise pollution while eliminating or dividing local communities. Most states delayed building the urban sections to build more miles of rural. In the 1960's rural interstate could be constructed for one million dollars for each 1.61 kilometers (one mile), whereas for each 1.61 urban kilometers (one mile), the cost was ten million. Planners hoped that time would overcome the opposition. They were wrong. Today, as a result of organized opposition to urban intrusion, critical urban links are missing. The lesson to be learned is to address social issues of land use planning, air and noise pollution and public/political acceptance on an equal level as the technical issues.

### 3.1.6 Summary

Urban environments are in great need of congestion relief to provide faster and more predictable work commutes. AHS can be a traffic management tool to reduce congestion. This tool will be useful to smooth traffic flow, if bottlenecks in roadway geometry are corrected, and traffic management sets operating levels of speed and gap consistent with the carrying capacity of interchange ramps and local streets.

Two aspects of urban environments that must be addressed to facilitate AHS deployment are (1) the use of traffic management as a tool to optimize all freeway traffic, and (2) the need for public/political acceptance. The severe right-of-way restrictions in urban environments are real and will continue. Conversion of manual lanes to automated lanes will be the mode in this environment.

## 3.2 SUBURBAN ENVIRONMENT

### 3.2.1 Trip Characteristics

A typical suburban freeway is the radial belt or outer radial leading to urban freeways. Their main function is traffic service between origins and destinations within the suburbs. Their peak hour users are similar to urban freeway users (i.e., commuters). Trip lengths are less than 16.1 kilometers (10 miles). Off peak speeds are high averaging 16.1 kilometers (10 miles) over posted speed limits, and characterized as unstable with sudden stops and starts. Incidents, usually accidents, produce extensive queues. The introduction of HOV lanes have been welcomed by commuters as they free them from the erratic open lane disorder.

Urban congestion is usually continuous. Suburban congestion both recurring and non-recurring is unpredictable. This could seriously affect concurrent AHS operation where it mixes with non-AHS vehicles.

### 3.2.2 Incident Impacts

Speeds are higher and accidents more serious on suburban freeways than on urban freeways. Motorist behavior is aggressive and sometimes characterized by unsafe driving. Selling AHS, to bring about short and long term improvement, will be most effective if AHS vehicles are segregated from the unsafe and unpredictable driving in the general lanes. A return to stricter enforcement, in the manual lanes, appears to be a necessary base for AHS deployment.

### 3.2.3 Roadway Restraints

The typical suburban freeway cross section is dual three or four lanes constructed within an ample right-of-way usually at surrounding ground level or slightly depressed. Interchanges connect to major arterial on 4.83 km to 8.05 km (3 to 5 mile) intervals with slip ramp connections between major interchanges. The weakest capacity link is the interchange ramps and junctions with other freeways. These interchanges were designed as a single lane to carry half to two-thirds capacity of a through lane. They are now pushed to carry double their design capacity.

The lane arrangement options for urban freeways are equally applicable for suburban freeways. The preference is to physically separate (via barrier, transition lane, shoulder) the manual and AHS lanes, since right-of-way is more available. Capacity improvements are also needed to interchanges.

### 3.2.4 Potential Market

Commuter traffic generates a series of peak hours beginning with workers destined to the CBD; followed by workers commuting within the suburbs; and lastly, suburban store workers and shoppers. Commuters all have a common investment in their personal vehicle and a wiliness to pay for individual freedom. Generally, transit options are not available.

The national mandate is to reduce DVMT and to encourage increased vehicle occupancy. If it can be demonstrated that AHS deployment will provide a more effective use of freeway lanes, with reduction of air pollution, the worker commuter may be able to retain his freedom. If these requirements are not attainable, the future of AHS may be destined for High Occupancy Vehicle (HOV) and transit use, only.

### 3.2.5 Societal Impacts

One example of past neglect for social concern is the current installation of high barrier fences along suburban freeways and arterials to provide pollution noise relief, possibly more perceived than real, for communities with these highways in their backyards. The urban and suburban concerns are intrusion and abuse. However, the probability of new or expanded highways in urban centers is becoming remote due to ROW restrictions. Suburbia not only wants protection from new intrusions and abuse, but is calling for improvements to their life style. Undesirable conditions exist along most freeways, but if no changes to the roadway are contemplated, AHS deployment may be accepted. However, the deployment of AHS will need to provide measurable improvement, not just maintain existing conditions. Ameliorative measures, such as installation of highway enclosures, (roof and side panels) have been suggested to meet environmental standards.

### 3.2.6 Summary

The suburban environment is similar to the urban environment in that its trip characteristics are dominated by peak-hour worker commuter trips. However, the suburban trips, although they are of similar length, are more diverse in roadway use due to the radial belt roadway configuration. This difference, coupled with the possible availability of right-of-way, lends itself to more varieties of roadway configurations than are possible for the urban environment.

The suburban traveler has the most to lose, in terms of personal freedom, if personal vehicle travel does not remain as part of the suburban congestion solution. AHS may provide the answer through more efficient use of the roadway.

AHS deployment in suburbs should also be viewed as a series of local solutions in regards to community acceptance. Each location and community will have unique conditions and concerns requiring individual, rather than blanket, approaches.

## 3.3 RURAL ENVIRONMENT

### 3.3.1 Trip Characteristics

Rural freeways may be high demand intercity connections or low demand open country links. They serve long trip users. Less than 25% of these inter-city trips originate or end on local interchanges. Rural freeways seldom operate at capacity. They usually operate at less than 70% of capacity with short periods of peaking.

### 3.3.2 Incident Impacts

Impaired driving — drowsiness, drugs, speeding — is the major cause of rural freeway incidents. Many result in just driving off the road. Others result in hitting obstacles or other vehicles. All of these incidents are usually at high speeds. They result in more severe consequences in terms of personal injury than urban and suburban incidents.

Long trips require the driver to perform the tedious tasks of maintaining speed and lane position, for long periods of time. Automation can relieve the driver of these monotonous tasks and provide a more reliable driving environment. Therefore, it could reduce incidents and create safer inter-city travel.

For a system intended to increase safety, AHS may, if not deployed properly, be a source of abuse and create dangerous conditions. AHS, in its early version for rural environments, will be driver controlled within mixed traffic. Finding a means to control aggressive or improper manual driving; e.g., tailgating, sudden and excessive weaving, slow travel, should be a requirement for AHS deployment in this mixed lane configuration.

### 3.3.3 Roadway Restraints

Nearly all rural freeways were constructed as dual two-lane facilities with a wide separation median designed to add a third lane in each direction. Where land development has turned farm land into suburbia, a third lane has been added. For most lengths of rural freeway there is relatively unlimited space to add lanes or improve and add interchanges, as necessary.

### 3.3.4 Potential Market

Increased safety and assistance for long trips will probably be the primary AHS benefits and selling points. Rural accidents are more severe than urban and suburban accidents, and they are usually associated with the demands put on the driver by the long trip length. However, the rural travel is more infrequent and the additional cost of the vehicle will need to be small to entice its purchase for such limited use.

### 3.3.5 Societal Impacts

One major societal issue is land use planning. Drawing lessons from the rural interstate highways experience, a typical diamond interchange was used to connect the open country highway with local, farm-to-market roads. High volume traffic was never anticipated to use these interchanges. Today, the narrow country road has become a four lane arterial serving the shopping plaza, recreation and business centers surrounding the interchange. Traffic delays are common and continuous.

AHS will certainly extend the limits of commuter travel due to its increased average speed. Outlying living will become more popular. Establishment of land use provisions to protect the newly created entry/exit points will need to have a high priority in the AHS deployment.

### 3.3.6 Summary

The rural environment is distinctively different than either urban or suburban. The trip characteristics are markedly different since they are of longer duration, more spread out throughout the daily period, and frequency of use per traveler is less. Also, existing and expected capacity is adequate for demand. ROW does exist for expansion; however, it would be very expensive due to the large number of miles involved compared to short haul routes.

The deployment of AHS on rural routes, based on the above scenario, most likely will involve manual and automated travel using the same two-lane roadway. The issues associated with this approach are more related to driver behavior enforcement than to automation technology or automated traffic flow.

## 3.4 ROADWAY DEPLOYMENT SCENARIOS

### 3.4.1 Scenario Characteristics

Four interstate segments within the nations northeastern freeways, were chosen by the Roadway Deployment Analysis Task as examples of possible AHS deployment. They are reviewed in this task to provide real examples of possible AHS use within the three environments described above. The Roadway Deployment Analysis Task concentrates on infrastructure issues. It used prediction flow modeling to illustrate potential AHS usage volumes. These interstate segments were also used for geometric studies, institutional and societal analysis, and cost and benefits analysis.

A brief description of each scenario is presented below to relate the generalized urban, suburban characteristics to the applicable scenario(s).

### 3.4.2 Urban Scenario

Boston's I-93 is a dual four-lane freeway that feeds the CBD from the south. Traffic movement is relative free flowing averaging 72.4 km/hr (45 mph) which can be typical for four-lane roadways. Ramps are closely spaced, carrying medium levels of traffic. The right lane serves as the ramps collector/distributor leaving three lanes for through movement. Freeways with fewer lanes (dual three or dual two) are usually not as free flowing as dual four lane freeways.

The configurations for the AHS scenarios, studied within this research effort, are two AHS lanes with two general lanes. The infrastructure is a combination of an I2 (HOV-like arrangement) and an I3 (direct ramp connections). Retrofitting two separately operating dual two lane configuration from a dual four lane facility, with or without major widening, may be the most typical design form, for AHS configurations on urban freeways.

There are a number of questions associated with implementing this configuration. The first question focuses on the need for widening. Is there an absolute requirement for a transition lane between AHS lanes and general lanes, if a two-lane AHS configuration is chosen? For all highways the right lane serves as the feeder, distributor, and exit collector as well as a through lane. Can the right AHS lane serve the same purpose?

Hopefully, this approach will limit the need for widening, if barriers are not needed to separate general use lanes from AHS lanes. The scenario design parameters for operation are: a maximum speed 96.6 km/hr (60 mph) and a throughput of 4500 vph/lane. This should allow the required multi-weaving in order for vehicles to reach the left AHS lane and return to exit. This scenario Illustrates the need to select operational standards consistent with the traffic handling capacity of the facility.

Results from the traffic modeling exercise, performed in the Roadway Deployment Analysis Task, reflect AHS traffic flow characteristics based on typical driver behavior to choose the route with the shortest travel time. A traffic assignment model was used that assigned all traffic, except for short trips, which had origin and destination demands consistent with the ramp placements to AHS.

### 3.4.3 Suburban Scenarios

Two suburban freeway segments are included in this scenario. They are the Long Island Expressway (LIE) in New York and the Washington DC Beltway (I-495) in Maryland. Both are high volume, suburban link roads. The LIE was reconfigured, for the purpose of this research, from a D-4 freeway to one AHS lane and two general lanes. Its first configuration is I2, with a transition lane separating the AHS lane from general lanes. The second configuration is an I3, physically separated with direct connecting ramps to the parallel service road. The Beltway, I-495, has sections of dual three, dual four, and dual five lanes which were reconfigured to one AHS lane and the remainder general use lanes. I-495 was tested for I2 and I3 configurations similar to the LIE. All scenarios used the same design parameter as I-93.

Deployment results from both freeways were similar to I-93 results, for both peak and off-peak lane usage. The design lesson from these scenarios is that both have high entrance and exit volumes due to the scenario design decision to reduce the number of exit/entrances and to increase the distance between entry/exit points. This was required to accommodate transition length requirements. This is a valid assumption and simplifies reconfiguration of the expressway for AHS but generates the following problems. Interchange spacing is usually selected to balance the entrance and exiting volume to create voids at exits and then fill them at entrances, all at a level the local streets and the mainline can handle. However, general through lanes can not store large volumes waiting to exit into AHS lanes, nor freely accept large volumes exiting AHS lanes. Balancing traffic flow across AHS and general use lanes is an important design issue for successful AHS operation.

### 3.4.4 Rural Scenario

The New York State Thruway (I-87) scenario is a dual two-lane freeway with moderate to low volumes. It serves through traffic with interchange spaced at 24.2 km/km (15 mile) intervals. Two configurations were developed, for analysis purposes. Both I2 and I3 infrastructure were created by adding one AHS lane and retaining the existing lanes as general lanes. This section of the Thruway passes through hilly terrain and, with its high level of truck traffic, lane changing and passing is needed in the manual lanes for light vehicles to maintain a uniform speed. Therefore, the I2 and I3 infrastructure were chosen.

Results from this analysis in the Roadway Deployment Task show minimal traffic flow benefit for a combined I3 and I2 configuration to justify the extensive construction costs of another lane. As expected, it will be difficult to justify any other configuration than an I1 for rural freeways. The major issues associated with this scenario concern implementation of AHS with mixed vehicles (manual and automated) in the left lane of the 2-lane freeway.

## 4.0 CONCLUSIONS

Table 1-1 provides a summary level discussion of the task findings.

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

| No. | Descriptive Title | Description/ Recommendation | RSC Impact | Where Discussed |
|---|---|---|---|---|
| UR-1 | The daily user of urban and suburban freeways wants travel time savings as a performance improvement. Acceptance of AHS equipment and traffic management costs will be based on the performance gain. | A target goal for this savings is one minute per 1.61 travel kilometers (one mile); totaling at least ten minutes on the freeway portion of the trip. This objective can, most likely, be accomplished by providing preferential lane and exit/entry provisions for AHS users, since automated control can regulate speeds above the current congested level. | I2 & I3, C2 & C3 | 3.1, 3.2 |
| UR-2 | Major sources of urban and suburban freeway congestion are incidents (non-recurring), bottlenecks at entry/exit points (recurring), and scheduled maintenance (non-recurring). | AHS vehicle instrumentation and Traffic Management (TM) are tools to eliminate congestion provided poor roadway geometry is corrected. | All | 3.1, 3.2 |
| UR-3 | Worker commuter users of urban and suburban freeways are effective targets for early deployment of AHS. | These individual users have a vested interest in making AHS a success as they gain time, reliability, and safer trips. As a daily user, they should be willing to equip their vehicles and pay for the service. High Occupancy Vehicle (HOV) users and Transit are prime customers for AHS since they are currently part of the solution for urban and suburban congestion. | All | 3.1, 3.2 |
| UR-4 | Optimize operational improvements on urban and suburban freeways along with introduction of AHS, as it a part of a TM package not a stand alone service. | Traffic Management includes; surveillance and control systems, ramp metering, incident management, motorist information systems, HOV facilities, and low-cost geometric improvements. These TM techniques are required to supplement AHS full automation. | All | 3.1, 3.2 |

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

| No. | Descriptive Title | Description/ Recommendation | RSC Impact | Where Discussed |
|---|---|---|---|---|
| UR-5 | During early year deployments, AHS performance may not be ideal in terms of congestion relief due to mix of manual and automated vehicles. | Working with existing freeways to gain initial automation benefits, provides a wider and more immediately visible return than attempting to build new AHS guideways to serve a select few. | I1 & I2, C1 & C2 | 3.3 |
| UR-6 | Understand and respect the social issues of AHS deployment. | AHS deployment is not just a technical installation exercise to provide a service. Impacts on land use planning, air/noise pollution and public/political acceptance may be more important than solving mechanical/electronic/concrete problems. | All | 3.1.5, 3.2.5, 3.3.5 |
| UR-7 | Consider separated AHS lanes a high priority for suburban freeway deployment, provided equal provisions can be made for entry and exiting. | A major infrastructure design issue for AHS deployment is solutions to the traffic mixing, weaving, entry and exit with non-AHS vehicles especially heavy trucks. | I2 | 3.2 |
| UR-8 | Assume that AHS on rural freeways will initially operate in mixed traffic lanes. When AHS use increases, and higher performance is needed, the minimum lane requirements appear to be one AHS lane and two general use lanes. | This requirement will impact most of the dual 2-lane freeways (outer suburban and rural). Although traffic volumes may show only a need for a single general (manual) lane, entrance/exit, passing, incidents plus operation during maintenance will probably require a minimum of two general lanes. | I1 & I2 | 3.3 |
| UR-9 | AHS can increase throughput during peak hours provided the supporting interchanges, feeder roads and city streets can accept this increase. | At the proposed high flow rates, urban and suburban facilities now regularly fail. Only rural freeway feeders have the capacity required. | I2 & I3 | 3.1, 3.2 |

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

| No. | Descriptive Title | Description/ Recommendation | RSC Impact | Where Discussed |
|---|---|---|---|---|
| UR-10 | Research into AHS technology is important as this defines the "How". Equally important is research in the market to identify size and needs as this defines the "Customer". | The "How" should be driven by the "Customers' Needs". | All | 3.1.4, 3.2.4, 3.3.4 |
| UR-11 | Envisioning AHS as a national system requires flexibility of design to accommodate urban, suburban, and rural needs. | The urban, suburban, and rural environments cover a spectrum of needs. Therefore, a variety of configurations are required to meet each of the needs. Suburban would be more I3 driven and rural would be more I1 driven. | All | 3.1, 3.2, 3.3 |

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