APPENDIX C

SUMMARY OF THE INTERIM RESULTS WORKSHOP DISCUSSIONS AND FINDINGS

This appendix summarizes the major systems-oriented findings from PSA Interim Results Workshop held in Chantilly, Virginia in April, 1994. Information for this appendix is drawn from the US DOT document FHWA-RD-94-101, *Automated Highway Systems Precursor Systems Analyses Interim Results Workshop.*, or MITRE Working Paper WP 94W0000114, by the same name. The materials, which have been edited only to summarize the findings, are included in this report for the convenience of the reader. Separate sections are provided for each below. Contents include the following:

C.1 SYSTEM-ORIENTED ISSUES OVERVIEW

This section focuses on those aspects of an AHS that are cross-cutting and will impact all facets of an AHS.

C.1.1 System Malfunction

One of the major concerns for AHS is its robustness. To this end, one of the PSA activities was to identify the potential malfunctions of the system, and postulate strategies for reducing and/or managing them.

Six of the PSA contractors are conducting this activity; each has a somewhat different approach:

- Battelle - Identifying the types of malfunctions that may occur for each of their RSCs
- Calspan - Researching and analyzing hazards and fault statistics and correlating them to AHS
- Delco - Focusing of relevant automotive systems and their implications for AHS
- Honeywell - Correlating system check-in and check-out to identification of AHS malfunctions

- Rockwell - Using a software tool to simulate both vehicle and communications malfunctions

- Raytheon - Classifying AHS malfunctions by their level of severity in order to determine type of malfunction management that is appropriate

System Safety

This aspect of the system design addresses the safety of the vehicle occupants as well as the system operators. It includes the likelihood of injury or death in cases of system malfunction, but it also goes into the other aspects of the system dealing with personal safety. For example, the design of roadways so that vehicle occupants can get out in case of a fire, the ability to minimize personal injuries in cases of natural disasters, personal security, etc.

Four of the contractors addressed system safety:

- Battelle - Characterizing AHS operation under varying operating rules, including platooning; the intent is to derive safety issues and risks

- Calspan - Analyzing national highway safety database statistics, and characterize accidents and the implications for AHS

- Delco - Identifying hazards, and the operations required under various hazardous conditions

- Raytheon - Examining safety of AHS versus safety on future non-AHS roadways; also looking at the safety implications of taking the human out of the control loop

Transit

Transit is an important aspect of any SIP; it is viewed as one of the most likely approaches for reducing VMT. Transit bus ridership, however, has steadily declined. Part of the reason for this is that buses often must suffer from the same highway congestion and unpredictable travel times as automobiles.

These companies are specifically addressing the application of AHS to the movement of multiple-passenger vehicles:

- BDM - Evaluating current automated transit use and research in Europe and the US; they are also examining past research on the dual-mode bus in the US from lessons learned.
- Calspan - Examining potential for automated bus operations in the Lincoln tunnel.
- Raytheon - Reporting on the automated bus operation in Germany

Commercial Freight

The AHS technology can be applied to heavy trucks used in commercial shipping. These vehicles could be inter-mixed on the AHS roadways with light vehicle traffic, or they could be segregated from the light vehicular traffic, either by separate platoons or on dedicated lanes. These companies are specifically addressing the application of AHS to freight movement:

- BDM - Evaluating current automated transit use and research in Europe and the US; they are also examining past research on the dual-mode bus in the US from lessons learned.
- Calspan - Examining potential for automated bus operations in the Lincoln tunnel.
- Raytheon - Reporting on the automated bus operation in Germany

Alternative Propulsion Systems

An AHS must have the ability to accommodate the vehicles that will be operating on the nation's highways over the next 50 years. Given the nation's concern for pollution and its impact on the environment, the impact of alternate propulsion vehicles on AHS was examined.

This subject is being address by these researchers:

- Calspan - They have dedicated one RSC to RPEVs, in this way, this approach will be examined in all of the PSA activity areas

- Delco - They are conducting a review of internal combustion engine baseline characteristics, and (1) comparing these characteristics to various APS; (2) predicting likely availability of each APS; and (3) determining the likely impact o AHS design

- TRW - They are assessing the characteristics of alternative APS and assessing their impact on AHS design

Comparable Systems Analyses

This activity examines various system implementations and operations in the past, and attempts to derive lessons-learned form those system efforts for AHS.

Researchers addressing this area are as follows:

- Calspan - They began with a potential list of f38 possible systems; this list has been narrowed to a handful that will be analyzed

- Delco - Their focus is on automobile safety systems (in particular, the air bag), vehicle navigation systems (TravTek), and rapid transit systems (BART)

- Honeywell - They have selected a single system for comparison--air traffic management

C.1.2 Systems-Oriented Briefings

This session had seven briefings as follows:

- AHS System Functional Decomposition, Raytheon
- AHS Fault Trees and Malfunctions, Calspan
- AHS Accident Analyses, Calspan
- Check-in/Check-out Role in Malfunction Management, Honeywell
- Impacts of Commercial and Transit, Calspan
- Impacts of Alternate Propulsion Systems, TRW
- Comparable Systems: Air Traffic Management

C.1.3 Breakout Group Summary

After each plenary session, each attendee participated in one of ten breakout groups where issues were assigned for discussion. In addition, the groups could choose to also address other issues that they felt were relevant. The notes from the breakout groups that followed the Systems-Oriented Issues plenary session are given in Appendix B.

Generally, it was felt that there are no "show-stoppers"; however, there are many areas in which careful attention must be paid. Below, the comments and discussions relevant to the system-oriented topics are summarized.

Robustness

Discussions in the breakout groups relevant to system robustness focused on the public's perception of AHS if there are frequent system breakdowns. The feeling was that AHS must be very reliable--more than today's highway system--to the extent that users accept its reliable operation as a given. This has implications for the system design, including redundancy and built-in malfunction management capabilities to handle the different kinds of malfunctions that may occur:

- Warning level - The vehicle is moved to exit at the next available exit when one of these malfunctions occur. Causes could include low-on-fuel indication, engine overheating, etc.

- Serious level - The vehicle is slowed down in traffic, and it is moved into the first available breakdown lane, hopefully before it becomes inoperable. This could be caused by a flat tire, partial failure of either lateral or longitudinal control (e.g., the primary control failed and the backup is operational, but at a lesser degree of accuracy), or the engine stopped running and the car is coasting (should the driver be given control to restart the engine?).

- Critical - The vehicle is brought to an immediate, controlled stop in the lane possibly with hard braking. Potential causes could include total loss of lateral or longitudinal control, stuck throttle or loss of steering. it could also result from an on-board "panic button" that the driver has pushed. crashes could occur for these malfunctions depending on the type of failure.

- Imminent crash - The vehicle is given emergency maneuvers that may include full braking and/or evasive steering. This would be caused by detection of an obstacle in the roadway whose movement is slow enough that a crash is likely, perhaps even if immediate action is taken. Causes could be a system breach by an animal or by vandals, or instrument failure or loss of control by an adjacent vehicle.

Safety

As with system robustness, safety was a topic of considerable concern in the breakout groups. For AHS to gain public acceptance, it must be safe; that is, it was felt that the AHS must be viewed by the public as being safe enough that it is not thought about. For example, when people climb on a train, most do not think about the train having an accident--the same should be true for AHS.

It was also generally agreed that this perception of safety could be undermined early in the implementation of AHS if: (1) the system was not much safer than the non-AHS roadways (how much is enough was discussed, and estimated ranged from 50% better to order-of-magnitude better); (2) the system was designed so that a mega-accident could occur (i.e., 20 cars smash into a piano that fell off the back of a truck, and several people were killed); and/or (3) the frequency of low-velocity accidents is high enough that everyone knows someone who was in one of these minor fender-benders.

Discussions also focused on the factor that affect system safety; it was generally agreed that they are different in urban areas (accidents from non-AHS vehicles impinging on the AHS lanes) versus rural areas (animals breaching the system).

It was felt that attempts to drastically reduce the likelihood of serious accidents may actually raise the number of less severe accidents, thus lowering overall system safety.

Transit

AHS use for transit (i.e., multiple passengers per vehicle) was a topic of considerable interest. It was felt that an AHS-based transit system, particularly one that incorporates dedicated lanes in high-congestion areas, may have many advantages:

- Attractive per-passenger costs
- Predictable, and probably faster, travel times
- Provides an additional option to regional planning agencies; e.g., the agency may choose to offer multiple passenger vehicles priority on AHS during rush hour, or establish dedicated lanes where justified
- Transit may offer meaningful early winners to the AHS program; e.g., Lincoln Tunnel (high benefits, low infrastructure costs)

On the freeways, transit will realize the same benefits from AHS as passenger vehicles

AHS has the potential to substantially improve transit operations in urban and central business districts by allowing operation on narrow, close-tolerance guideways, much as rapid transit vehicles do; however, then operate on regular freeway lanes in less dense areas to eliminate the need for high-cost infrastructure with relatively low utilization.

Unmanned transit uses such as airport shuttles or special intra-urban transit systems also appeared to offer promise for AHS technology

There was some sentiment to consider making transit part of the 1997 demonstration

Freight

Freight is an important market pull for AHS; but, its a very segmented market and cannot be easily discussed as a single entity. Some factors to consider in examining potential AHS use in commercial shipping include:

- Long-haul (over 500 miles) is often competitively served by intermodal (rail); this is because of driver availability and cost; but there is still substantial long-haul trucking that is not intermodal because of the nature of the shipment or the OD locations
- AHS may allow truck operation without drivers (at least partially, gradually);
  - Very desirable economically for long-haul operation, but
  - Raises many perceptual and engineering problems

- Better opportunities may exist for short-haul (under 1,000 miles) where shipments are smaller (less-than carload), and the demand for time-sensitive delivery is growing (just-in-time delivery)
- The trucks used for this short-haul market (usually not semi-trailers) are somewhat more compatible with light vehicles
- Many trucking companies are already investing in IVHS; the incremental cost of AHS electronics for a truck is much smaller than the incremental cost for a light vehicle (because of its high initial cost)--also, trucking companies will invest if they believe there is a positive cost/benefit ratio

Mixing of heavy vehicles with light vehicles creates many problems:

- In a single lane AHS, system performance (acceleration, speed, etc.) would degrade to the performance characteristics of the truck
- People may feel uncomfortable being closer to heavy vehicles, even though safety factors are being maintained
- At the least;
  - Heavy vehicles in urban areas should be separated from light vehicles, either in dedicated lanes or in separate platoons with passing lanes to allow faster traffic to pass
  - Heavy vehicles in rural areas should have dedicated lanes; however, because of the cost, they may need to share the same lane with light vehicles--this means that there must be frequent passing lanes

Trucks can (and may want to) operate at times other than commuter rush hours; thus, trucks may not require separate lanes since they can use the HOV lanes in off-hours--**kills two birds with one stone**--supports HOV and rush hour transit with separate lanes, **and** support trucks in separate lanes in non-rush hours.

Alternate Propulsion Impact Analyses

AHS will need to accommodate the APS of the twenty-first century. If the performance characteristics of those vehicles are similar to today's predictions of some APS, then they will probably negatively impact the operational efficiency of the system unless a special lane is provided for them. A special APS lane within the next twenty years or so is unlikely based on predictions of APS market penetration.

Most of the discussions fell on EVs. It was generally felt that based on known technology, the problems are difficult; however, it was felt that we must keep looking.

AHS seemingly provides a stronger basis for feasibility of roadway-powered EVs. Power could be provided to the EVs periodically or on steep hills. This could significantly extend the EV's range and perhaps ease some of its operational restrictions (e.g., if it climbs a long, steep hill at a reasonable speed, then it quickly drains the battery). The AHS lanes would need to be designed to safely accommodate both RPEV and regular AHS vehicles.

The public perception is that EVs are non-polluting. However, given a recent report regarding the pollution that would be caused in the northeast by coal-fired power plants producing power for RPEVs, a further examination of RPEV impact on pollution may be warranted.

Operational Observations

Eventually there will be a need for a single functional breakdown for AHS . This will be the task of the consortium; the alternative breakdowns developed as strawman breakdowns by the PSA contractors, will be used by the consortium as input

It was generally felt that an evolutionary AHS is very important; the end-goal is achieved by evolving along a step-wise feasible path that contains several intermediate successes. This means that each step taken must show some benefits. What those steps are and which path is to be followed needs further examination. There may be a risk in tying the AHS to intermediate steps that may not be popular with the public.

Major safety benefits will probably not be realized until there are dedicated AHS lanes. major efficiency and capacity benefits may not be realized until AHS is proven and the public has trust in it; intermediate goals need to established with this in mind.

In moving from AHS goals to operational requirements, a balance will need to be struck between conflicting goals. Also, an air of reasonableness will need to be maintained; for example, requirements for AHS operation in adverse weather must be achievable.

Automation has a tendency to evolve to a "lowest-common-denominator" operational mode that degrades system performances; until the system expands to the point where there are multiple AHS lanes and lane changing is possible, this could be the case. This means that initial AHS design must avoid an approach in which AHS performance is lower than what some humans would choose or decide to do.

C.1.4 Reporter Summary

This summarizes the materials presented by the systems-oriented Working Group at the final Plenary session of the Workshop.

Transit

- Transit must be taken seriously; an automobile-only AHS may be a show-stopper.
- The program must have more transit stakeholder involvement, both operators and agencies.
- An automobile-only AHS segment may decrease transit usage.
- Advantages may include:
  - Attractive passenger costs
  - Predictable travel times
  - A regional planning agency may choose to give transit (i.e., multiple passengers per vehicle) priority on AHS
  - Transit can offer substantial early winners to AHS program; e.g., Lincoln Tunnel (high benefits, low institutional costs, highly politically correct)
  - Consider making transit part of the 1997 demonstration?

Freight

- Freight is an important market pull for AHS; but, its a very segmented market:
  - Long-haul may be competitively served by intermodal (rail)
  - Better opportunities may exist for short-haul where smaller, time-sensitive demand is growing
  - This short-haul market is more compatible with light vehicle AHS

- Taking the driver out of the freight-AHS (at least partially, gradually) is:
  - Economically desirable
  - Raises many perceptual problems

- Trucks can and want to operate at times other than commuter rush hours; thus, trucks may not require separate lanes--use the HOV lanes in off-hours--**kills two birds with one stone**--supports HOV and rush hour transit with separate lanes, and support trucks in separate lanes in non-rush hours.

Alternative Propulsion

- Electric is difficult; need to keep looking
- Seems like an unnecessary complication; will EVs really be less polluting by the year 2010?
- Perceptually, has many social benefits
- Becomes more realistic if AHS speeds are modest, and there is roadway-provided power--implications for urban versus rural use need to be further examined

Operational Issues

- Evolution is very important; the end-goal is achieved by evolving along a step-wise feasible path that contains **several intermediate successes**. This means that each step taken must show some benefits. Is there a risk in tying the AHS to intermediate steps that may not be popular with the public? Need to keep this in mind.

- Requirements for AHS operation in adverse weather must be reasonable

- Large capacity benefits will probably not be realized until AHS is very successful and the public has trust in it; intermediate goals need to established with this in mind.

- Automation has a tendency to evolve to a "lowest-common-denominator" operational mode that degrades system performances; until the system expands to the point where there are multiple AHS lanes and lane changing is possible, this will be the case. The problem is that initially, AHS performance may be <u>lower</u> than what some humans would choose/decide to do.

Safety

- Safety is a "minimum operational standard" (a floor, a necessary condition, etc.)
- Mega-disasters cannot be allowed since this will cause perceived safety to be less than actual safety
- Attempts to drastically reduce the likelihood of serious accidents may actually raise the number of less severe accidents, thus lowering overall system safety.
- Be careful to readily accept a system in which there are low-velocity collisions; these will worsen the public's perception of AHS safety.
- MOEs are multi-dimensional

Human-in-the-Loop

- There will need to be some involvement by the human in AHS, including option selection, display of what is going on, etc. This may evolve with increasingly more functions being assumed by the system.

Overall Summary

- There are no obvious show stoppers that can't be circumvented. Lots of optimism, but there are areas where (1) there is much work needed; and (2) we must be careful.

C.2 VEHICLE-ORIENTED ISSUES OVERVIEW

This section focuses on issues related to all aspects of operating a vehicle on AHS. These issues include vehicle functionality, reliability, maintainability, and vehicle evolution.

C.2.1 Vehicle-Oriented Activities

Automated Check-In

The automated check-in activity area focuses on identifying the issues related to certifying that a vehicle and its driver are functioning properly for AHS operation. The check-in function is performed prior to entry on the AHS and should be conducted in such a manner as to provide a smooth flow onto the AHS system. Effective pre-check of the vehicle and driver is necessary for safe and reliable AHS operation. The check-in function could incorporate periodic (remote) inspections, verification when entering the AHS, and continuous checks of the vehicle (and possibly its driver) as it moves on the AHS lane.

Five of the contractors are addressing automated check-in. Their focus areas and some of their unique features are as follows:

- Calspan - Assessing on "on-the-fly" check-in, that is, performing the check-in function without requiring the vehicle to stop or significantly slow down.
- Delco - Focusing on implications of having to stop the vehicle during check-in. Also, looking at remote check-in and check-in of special service vehicles (e.g., fire, police, ambulance).
- Honeywell - Focusing on an integrated "health management" system for the roadside, vehicle, and the driver. This combines the activity areas of automated check-in, automated check-out, and malfunction management.
- Northrop - Incorporating knowledge and experience from flight-test instrumentation approaches.
- Raytheon (University of Southern California [USC]) - Examining evolutionary aspects of the role of the driver and the levels of automation. Coordinating the automated check-in activity closely with the automated check-out activity.

Automated Check-Out

The automated check-out activity area focuses on identifying the issues related to transitioning control to the human driver and certifying that the vehicle equipment is functioning properly for manual operation. This function takes place while the vehicle and driver are operating on the AHS. The primary focus area for this task is on the issues associated with checking that the driver is ready to assume manual control of the vehicle. The issues associated with the transition of the vehicle from automated to manual control appear less problematic given that the vehicle was operating properly on the AHS.

Four of the contractors are addressing automated check-out. Their focus areas and some of their unique features are as follows:

- Calspan - Building on the Honeywell Human Factors Study. This includes the applicability of cognitive and physiological measurement technology to driver readiness testing.

- Delco - Focusing on an overall systems approach.

- Honeywell - Focusing on an integrated "health management" system for the roadside, vehicle, and the driver. This combines the activity areas of automated check-in, automated check-out, and malfunction management.

- Raytheon (USC) - Focusing on evolutionary aspects with respect to the role of the driver and the levels of automation. Coordinating the automated check-out activity closely with the automated check-in activity.

Lateral and Longitudinal Control Analysis

This activity area focuses on identifying the issues related to automated vehicle control. Analyses of issues related to various control options are being performed.

Six of the contractors are addressing lateral and longitudinal control analysis. Their focus areas and some of their unique features are as follows:

- Calspan - Analyzing control with different vehicle spacing requirements. Incorporating vehicle dynamics modeling in their analyses.

- Delco - Addressing asynchronous vehicle behavior. Addressing the differences in characteristics and benefits of automated versus manual control.

- Martin Marietta - Incorporating experience from DOD autonomous land-vehicle programs. Producing sensor and maneuver taxonomies.

- Raytheon (USC) - Focusing on system control and its evolution from human to AHS lateral and longitudinal control.

- Rockwell - Conducting a high-level systems operational control study. Investigating the tradeoffs of safety versus capacity and traffic-stream stability given different control options.

- SRI - Taking a unique look at GPS carrier phase technology for AHS control applications.

Vehicle Operational Analysis

The vehicle operational analysis activity area focuses on identifying the issues related to the operation of an AHS vehicle. This includes issues such as functionality, reliability, and trends in future vehicles. Issues related to the retrofitting of future vehicles for AHS operation are also being studied.

Four of the contractors are addressing vehicle operational analysis. Their focus areas and some of their unique features are as follows:

- Calspan (Farradyne) - Focusing on the current status of vehicle components and AHS requirements for vehicle-based components. Special attention is being given to vehicle interfaces.

- Delco - Focusing on the automobile industry experience in developing, marketing, and fielding of vehicle features.

- Raytheon (USC) - Focusing on the evolutionary deployment of vehicle systems and their corresponding reliability, maintainability, and safety.

- Rockwell - Conducting an overall functional breakdown of an AHS vehicle. Focusing on self diagnosis and interaction with malfunction management strategies.

C.2.2 Vehicle-Oriented Issues Briefings

The following briefings were presented during the Vehicle-Oriented Issues session:

- Vehicle Functional Requirements Decomposition, *Rockwell.*
- Analysis of Automated Vehicle Control Evolution, *Raytheon/USC.*
- Vehicle Check-In Information Acquisition Approaches, *Northrop.*
- Analysis of Platooning Characteristics, *Rockwell.*
- Sensor Requirements and Trade Study Results, *Martin Marietta.*
- Vehicle Design Trends Impacting AHS, *Delco.*

C.2.3 Vehicle-Oriented Issues Breakout Group Summary

After the Vehicle-Oriented Issues plenary session, each attendee participated in 1 of 10 breakout groups where issues were assigned for discussion. In addition, the groups could choose to also address other issues that they felt were relevant. The notes from the breakout groups that followed the Vehicle-Oriented Issues plenary session are given in appendix C.

Below, the comments and discussions relevant to the vehicle-oriented topics are summarized. These thoughts and exchanges of ideas are being made available to the PSA researchers for their consideration as they complete their study efforts. These materials will also be provided to the national AHS consortium for consideration as they begin their AHS concept selection activities.

Vehicle Evolution

The general thought was that an evolutionary path to AHS (i.e., full vehicle control) is a desirable approach. It was felt that the vehicle evolutionary paths presented at this IRW will not happen without government participation. AHS could occur by natural evolution, but this would take a much longer time without a focused AHS program. Some of the Advanced Vehicle Control Systems (AVCS) technologies will be driven by market forces and will evolve independently of AHS. Vehicle control evolution must work in parallel with the evolution of the roadway system.

Mixed-Mode Traffic

Mixed-mode traffic involves partially automated and manual vehicles operating together on the same roadway. Mixed-mode traffic was seen by the participants as a possible evolutionary step to AHS. However, mixed-mode traffic was seen as adding complexity (and cost) to the vehicle system, while at the same time reducing gains in safety and efficiency because of the continued presence of human control in the system. A concern that was raised was whether accidents and perceived safety degradation would be blamed on the introduction of the automated vehicles. There could be other major concerns with mixed-mode traffic if commercial vehicles are the first to incorporate automated vehicle features.

A possible mixed-mode scenario was that of automated vehicles operating together with manual vehicles on HOV lanes. Road pricing could be used for the automated vehicles operating on the HOV lanes.

A question is whether the world market will be mixed-mode-oriented. If so, the partially automated vehicle systems that are suitable for mixed-mode traffic, may have a broader worldwide market.

Research is needed to determine what level of market penetration for partially automated services is required to justify a dedicated lane.

Driver Role

The issue of the role of the driver during AHS operation was discussed in the breakout session. Some felt that if the driver is to have any role, it should be meaningful. Does the driver need to be given a role in order to stay alert to retake control? The issue of the driver in the loop was thought to be a potential influence on cost for AHS. Some felt that the driver would not be taken totally out of the loop, but would be a part of the system for a long time. The inclusion of the driver in the control loop would add randomness to the AHS system and degrade its safety and performance.

Vehicle Design

The issue of smart versus dumb vehicles was discussed in the breakout. This issue was determined to be a major costing factor (e.g., who pays; impact on maintenance and installation; driver versus government responsibilities). The smart/dumb vehicle discussions also raised the issue of reliability impacts. Reliability of equipment, especially communications equipment, could be increased in a centralized (dumb vehicle) system. On the other hand, concern was raised that the continued addition of sensors to the vehicle would make the vehicle less reliable. It was recognized that AHS will likely be a combination of vehicle and infrastructure "smarts" and this allocation should be determined through good systems engineering efforts. The issues of good systems engineering and "needs driving the requirements" were reinforced when the vehicle functional decomposition was discussed.

With respect to comparable systems in the automotive industry, the participants brought up many good points. They felt that the first system will be a baseline that will evolve over time. As proven by the airbag system, the perception that safety cannot be sold is changing. It was discussed that drivers and the government already share full economic cost of driving. Public education was highlighted as an essential ingredient to acceptance of the AHS concept. The participants were asked to discuss design trends (other than the ones briefed) that could positively or negatively influence AHS. Standardized interfaces were discussed as a trend that is essential for AHS. It was pointed out that since IVHS functions are more imminent, many functions will already be standardized. Some of the trend towards more vehicle electronics (other than Anti-lock Braking Systems [ABS] electronics, airbag collision detectors, etc.) was viewed as convenience-oriented as opposed to vital. The trend for smarter vehicles was seen as lacking a corresponding trend in the increased education of the driver.

With respect to vehicle-related costs, the participants indicated that the requirements (accuracy, range, etc.) would influence the costs. Safety and redundancy requirements were seen as having a big influence on cost. It was mentioned that the first production costs would be high and that as volume increased, the costs would come down.

An area for further research was to determine consumer willingness to pay for AHS features as a percentage of the total vehicle cost.

Vehicle Reliability

The breakout groups were asked to discuss the tradeoff between a highly reliable system and the impacts of a less reliable system with respect to non-safety-critical system performance. These non-safety-critical system performance measures were thought to include throughput, travel time predictability, and communication links. It was noted that non-safety-critical performance reliability will most likely vary, depending on the regional/local application of AHS. For example, efficiency may be more important in one geographical deployment than another. Reliability of vehicle systems must be high enough so as not to annoy the users. People will pay for reliability; reliability is market-driven.

Roadway-Powered Electric Vehicles

Several issues were raised when discussing the impacts of RPEVs for AHS. Implementation of RPEVs could also be used for vehicle control, and thus simplify the vehicle-control hardware. There may need to be some way of monitoring electric power usage (pricing). RPEVs could lead to more electromagnetic interference (EMI) problems. A thought was that RPEVs could be more appropriate for transit vehicles that travel along a fixed route.

Automated Check-In

The participants discussed issues related to the automated check-in process. Some felt that it was necessary to put as much responsibility as possible on the vehicle owner/driver. This would require a certain amount of preventative maintenance requirements. BIT should be used as much as possible and the system should be most thorough for safety-critical-systems (e.g., brakes, sensors, steering). The question of whether a driver would need special training or certification was raised, and if so, how different would this be from today's certification.

Some of the automated check-in cost influences included checking of mechanical subsystem status (e.g., brakes). Electronic subsystems can be monitored fairly inexpensively with vehicle diagnostics. In general, the cost depends on the thoroughness of the tests. Costs of off-line maintenance and testing could be influenced by the level of education required for the maintenance personnel.

Technologies

The topic of maturity of technology was discussed in the breakout groups. The participants felt that the maturity of sensor technology is a function of the application for which it is being used. For example, radar is a mature technology for ACC, but not necessarily for full longitudinal control. It was felt that mature technologies for lateral control have not yet been selected.

Some of the areas where the participants felt that more technology and/or engineering development and research was needed include:

- Obstacle detection (vision system not yet mature).
- ACC.
- Lateral/longitudinal control.
- Communications (vehicle-to-vehicle and vehicle-to-infrastructure).
- True ground-speed indicator (for accurate measurement).
- Standardization of vehicles to add sophisticated electronics for AHS.
- Sensors need more work to reach the levels needed.
- Software control algorithms—for exception control (some disagreed).
- Computer power and bandwidth for in-vehicle systems.
- Technology for lane changes (needed for road-follower technology solutions, i.e., magnetic nails).
- Predictive diagnostic systems.
- Electronic steering.
- Localized road-surface detection (ice, environment, etc.).

Vehicle Operation

The participants discussed issues associated with establishing a safe gap between vehicles operating on the AHS. Their discussions indicated that safe gap is a major area for further research. Other areas that need further definition/research include: reliability of vehicles (malfunctions that will cause accidents); acceptable change in velocity (delta V) or impact; vehicle performance variability (acceleration, braking); road condition (for dynamic/adaptive gap size); human factors; and public acceptance.

One of the major public acceptance questions is determining willingness for a large number of very small delta-V collisions versus a very small number of higher delta-V collisions. The participants also recommended research into events that cause a lead vehicle to decelerate significantly greater than the trailing vehicle. What are the probabilities of these occurrences?

The need for platooning was discussed by the participants. The question was raised whether AHS needs the kind of capacity that can potentially be provided by platoons. The overall design goal should be based on moving people, not vehicles. Another concern was related to incident management for small delta-V platoon collisions. Will incident management be slow due to the multiple vehicles involved in the collision? It was felt that platoons must be made as safe as trains (e.g., linkage of functions such as braking).

Operation under adverse weather and road conditions was discussed by the participants. It was agreed that operating conditions should be adjusted for weather conditions; this includes gap spacing, operating speed, and sensor management. The AHS should be designed so that weather conditions will not be show stoppers. It was suggested that the interaction of reduced lane width and weather conditions be considered in the design of AHS.

C.2.4 Reporter Summary

This summarizes the materials presented by the vehicle-oriented Working Group at the final Plenary session of the Workshop.

Vehicle Evolution

- Mixed-mode traffic evolutionary stage likely, full automation is goal.

Vehicle-Control Evolution

- Market-driven by safety needs.
- Need government participation.
- Vehicle/roadway evolve together.
- Consistent with current design trends.

Mixed-Mode Traffic Implications

- May cause real or perceived safety degradation.
- Fosters evolutionary development.
- Limits AHS performance gains.
- Complex, costly vehicle manufacturing.
- Research: Breakout to dedicated lane.

Impact of Shared Driver/Vehicle Role

- If driver has a role, it must be meaningful.
- Driver's role may keep driver alert.
- May add randomness to system.
- Driver may initially be part of the system.

Non-Safety-Critical Reliability Tradeoff

- Cannot afford to annoy the user.
- Tradeoffs are market-driven.
- Non-critical performance needs clarification.
- Regional variation.

Smart/Dumb Vehicle Design Tradeoff

- Smart vehicle simplifies implementation.
- Vehicles already becoming smart.
- Smart trends support AHS.
- Drive-by-wire will evolve.
- Smart-car trend requires driver education.
- Research: Cost benefit to government, consumer, and auto manufacturer.

Vehicle Design Comparable Systems

- The first system will be baseline.
- Safety can be sold.
- Government, driver share driving cost.
- AHS acceptance depends upon public education.
- Development of control will take time.
- Perceived success of initial AHS will have major impact on AHS acceptance.

AVCS Evolution

- AHS requires long-term planning.
- AVCS driven by market forces.
- Jerry Ward's evolutionary strategy.
- Private venture may create AHS.

Time frame

- Affected by automated lane acquisition.
- Advanced-feature time frame shorter than AHS.
- Government funding driven by AHS advancement.
- Retrofit driven by standardized interface.

Vehicle Designs

- Design varies with cost.
- Inadequate redundancy for AHS.
- Trend toward more electronics.
- More sensors.

Contradiction

- Overly complex.
- Reliability from simplicity.

Technology Development Programs

- Lane-change technology.
- Advanced communications.
- Lateral/longitudinal control.
- Electronic steering.
- Road-surface detection.
- Lateral sensor.

Vehicle Functional Decomposition

- Add check-out.
- Change pause?
- Add operations and maintenance.
- Some functions specific, some broad.
- Change incident management.
- Needs should drive requirements.
- Placement of communication operation unclear.

Roadway-Powered EVs

- Monitor electric power usage (pricing).
- Modular pavement design.
- Transit vehicles first.
- More electromagnetic interference.
- Potential for improved control.
- Continuous power supply required.
- Simpler instrumentation.

Check-In Requirements (* indicates mentioned more than once)

- *Responsibility on vehicle owner/driver.
- BIT for safety-critical systems.
- Periodicity impacts test quality.
- *Equal emphasis on vehicle and roadside.
- Combination of maneuver and on-board diagnostics to:
  - Check vehicle performance characteristics.
  - Driver characteristics.
  - Fuel, tire pressure.
  - Sensors.
- *Institutional responsibility for results.
- *Possible need for training.
- *Queues lead to negative trip quality.
- Diagnostics should "learn."

- Check-in is system configuration dependent.
- *Standardization between systems.

Check-In Cost Drivers (* indicates mentioned more than once)

- Mechanical system test, on-/off-board.
- BIT designed now for electronics.
- Coverage.
- *Location - off-line, during check-in.
- *On-board/off-board.
- *Improved sensor technology.

Check-In System Issues (* indicates mentioned more than once)

- Many sensors versus driver involvement.
- *Human in loop with panic button.
- On-board versus remote via communication.
- *No sensors for:
  - Obstacle detection.
  - Driver monitor.

Mature Technology—Sensors (* indicates mentioned more than once)

- Application-dependent:
  - Sensor performance - RADAR, etc.
  - Algorithm development.
- Video, scanning systems.
- Certification tags.
- *No sensors for:
  - Obstacle detection.
  - Driver monitor.
- Research:
  - Traction sensing, many cost tradeoffs.
  - Platooning, more human factors.
  - Obstacle detection.

Gap Distances (* indicates mentioned more than once)

- Trade - driver acceptance:
  - Large number of low delta-V collisions.
  - Small number of high delta-V collisions.
- Varies - urban versus rural.
- *Platooning the right answer?

- *Depends on system reliability.
- Depends on vehicle performance.
- Adaptive to road conditions.
- Platoon group dynamics.

Weather Impact (* indicates mentioned more than once)

- Manage gap and speed.
- *Sensor limitations.
- Slow to driver-capable operation.
- Lane-width requirements.
- Roadside versus in-vehicle.

Evolution of Platoon/Close Headway (* indicates mentioned more than once)

- *Is it needed? Throughput study needed.
- Safe as trains.
- *How is low delta-V collision quantified for damage.

Subsystem Cost Drivers (* indicates mentioned more than once)

- First production high.
- *High accuracy, high reliability.
- Technology development status.
- Good dynamic performance.
- Research:
  - Manufacturing trades, retrofit.
  - Drive-by-wire concepts.
  - *Level of public willingness to pay.
  - More market surveys.

Conclusions

- Evolutionary approach important.
- Bullets on summary sheets did not do justice to discussion.
- "Leap to Auto Lane Hold":
  - Reliability and safety.
  - Cost.
  - Evolutionary problems.
  - Human interface.
- Discussions were good exchanges of ideas and concerns.
- Provided a level of education due to the mix.

C.3 ROADWAY-ORIENTED ISSUES OVERVIEW

The roadway issues investigation focuses on issues that relate AHS impacts to existing infrastructure, the different operational environments such as urban and rural, AHS configuration impacts to the environment, and AHS facility operations. The research has been divided into five PSA activity areas:

- Urban and Rural AHS Comparison.
- AHS Roadway Deployment Analysis.
- Impacts of AHS on Surrounding Non-AHS Roadways.
- AHS Entry/Exit Implementation.
- AHS Roadway Operational Analysis.

C.3.1 Urban and Rural AHS Comparison

The urban and rural activity area focuses on identifying and analyzing the technical and operational requirements of AHS in both urban and rural environments. Issues and risks relating to deployment of AHS in both environments and the transition between environments are being identified. Each of the contractors researching this activity area are using different methodologies to identify the operational environment as explained below:

- **Battelle (BRW)** - Utilizing Minnesota DOT roadway inventory statistics to identify roadway characteristics that are common or unique to urban, rural, and fringe area operating environments. These characteristics will then be evaluated against the analyses of the team to identify the AHS issues and risks.

- **Calspan** - Identifying the important parameters that characterize the operating environment by categories, such as infrastructure, traffic, safety, and power availability.

- **Delco (Hughes)** - Categorizing the urban/rural issues and risks that they identify as functional, operational, or environmental.

- **PATH (CalPoly)** - Constructing a matrix that contrasts the characteristics of each operating environment to the operating demands of that environment.

C.3.2 AHS Roadway Deployment Analysis

The focus of the roadway deployment activity is to identify issues and risks related to deployment of AHS in both urban and rural environments, from the perspective of impacts on roadway infrastructure and the surrounding environment. Below is an explanation of each contractor's unique methodology being used to identify these issues and risks:

- **Battelle (BRW)** - Incorporating comments and input for various State DOT's on their initial set of issues and risks.

- **Calspan (Dunn Engineering)** - Analyzing the trade-offs between alternative roadway cross-sections for each AHS concept.

- **Delco (DMJM)** - Incorporating the needs of a range of vehicle types in their AHS configurations to determine the impacts of providing for vehicles such as trucks.

- **PATH** - Utilizing the California DOT's (Caltrans) video log to identify roadway characteristics; assess the impact of these characteristics on AHS; and derive the frequencies of occurrence for these characteristics and their implications for AHS. Using the frequency and impact information, they have located a couple of the most issue-intensive roadway segments in California in which to assume AHS deployment. These issue-intensive segments are now being used in the last part of this analysis in order to analyze the specific deployment impacts an AHS configuration would encounter on these segments.

C.3.3 Impact of AHS on Surrounding Non-AHS Roadways

An important aspect to the deployment of AHS is what impacts will an AHS facility have on the surrounding roadway system and how will these impacts affect the surrounding community. This research activity is designed to investigate, identify, and analyze the impacts that may arise due to deployment of AHS in a community. The following is a summary of each contractor's research efforts in this activity:

- **Battelle (BRW)** - Investigating AHS impact on roadway segments located in Minnesota using a transportation planning model. The investigation includes examination of traffic's sensitivity to changes in frequency and position of entry/exit points, and the demand on the AHS facility due to changes in market penetration.

- **Calspan (Dunn Engineering)** - Utilizing a planning model for AHS on the LIE. They are looking at entry/exit placement, market penetration, and the relationship of AHS facility capacity to the capacity of the roadways from which AHS traffic enters and to which it exits.

- **Delco (DMJM)** - Using a corridor class model to study the roadway areas that border an AHS facility. This border area can be described as the first parallel, non-AHS roadways on each side of the AHS facility and the cross streets that connect these parallel roadways. Also, due to this corridor model's capability, they are also investigating specific lane impacts between the AHS and non-AHS lanes that reside on the same right-of-way.

C.3.4 AHS Entry/Exit Implementation

This research activity consists of a detailed investigation of the issues and risks associated with the access to and egress from an AHS facility. This research entails identifying various entry/exit strategies, identifying the MOE's that can be used to evaluate and optimize the various strategies, and analyzing each strategy's deployment impacts. Below is an explanation of each contractor's area of interest regarding entry/exit:

- **Battelle** - Analyzing the impacts that each of their entry/exit configurations may have on roadways of the urban, suburban, and rural operating environments.

- **Calspan** - Identifying the service rate of various configurations and how to service the entrance of packs of vehicles.

- **Delco (DMJM)** - Also analyzing service rate, however, they are converting the service rate into a level of driver comfort. They are also investigating possible queuing impacts by each configuration to indicate the amount of entry and exit plaza storage that may be necessary.

- **PATH** - Investigating the characteristics and operations of an AHS transition lane or area for the PATH platoon concept using computer simulation. They are identifying the issues and risks of transition area/lane operations, and the interaction between automated and non-automated vehicles.

- **Raytheon (Ga. Tech)** - With input from the urban and rural analysis task, Raytheon is developing specific entry/exit strategies customized to the specific operating environments, both urban and rural.

C.3.5 AHS Roadway Operational Analysis

The roadway operational analysis entails the identification and analysis of issues and risks that may be involved in undertaking the responsibility of operating and maintaining an AHS facility. The analyses address organizational structure, operational functions, and maintenance activities. The analysis areas covered by the contractors include a wide range of AHS operational aspects. Each contractor's specific area of emphasis is described below:

- **Battelle** - Identifying the possible daily tasks and functions an AHS facility will have to perform or support. Examples of these daily tasks could include traffic monitoring and sensor maintenance.

- **Calspan** - Analyzing and evaluating possible organizational structures for an AHS facility based on the administrative and operational tasks that it may be required to perform or support.

- **Delco (DMJM)** - Identifying the issues and risks that may arise in the evolutionary process of converting already-established Freeway Management Systems to an AHS facility.

- **UC Davis** - Investigating the unique possibility of automating some of the AHS construction and maintenance activities.

C.3.6 Roadway-Oriented Issues Briefings

The following briefings were presented during the Roadway-Oriented Issues session:

- Influence of Urban/Rural Characteristics on AHS, *Battelle/BRW.*
- Potential AHS Roadway Characteristics and Configurations, *Battelle/BRW.*
- Alternate Approaches for AHS Entry/Exit, *Raytheon/Ga. Tech.*
- Effect of AHS on Surrounding Non-AHS Roadways, *Delco/DMJM.*
- Issues of AHS Roadway Operations, *Calspan/Parsons Brinkerhoff.*
- Comparable Systems: HOV Lanes, Ramp Metering, *Calspan.*

C.3.7 Roadway-Oriented Issues Breakout Group Summary

After the Roadway-Oriented Issues plenary session, each attendee participated in 1 of 10 breakout groups where issues were assigned for discussion. In addition, the groups could choose to also address other issues that they felt were relevant. The notes from the breakout groups that followed the Roadway-Oriented Issues plenary session are given in appendix D. Below, the comments and discussions relevant to the roadway-oriented topics are summarized. These thoughts and exchanges of ideas are being made available to the PSA researchers for their consideration as they complete their study efforts. These materials will also be provided to the national AHS consortium for consideration as they begin their AHS concept selection activities.

Urban and Rural AHS Analysis

A summary of breakout discussion comments pertaining to operational environment influencing AHS design and operation related the influence to some general urban and rural characteristics. For the urban operational area, the participants considered entry/exit spacing, capacity impacts, and right-of-way (ROW) availability as being the major factors affecting AHS urban design and operations. The participants also identified safety, higher speed, lane conversion, commercial vehicle operations, and maintenance as the factors that would affect AHS in a rural operating environment.

Roadway Deployment

The participants in the breakout sessions concerning roadway deployment stressed the need for the development of a strategic plan for AHS deployment. To develop this strategic plan, they cited the need to involve the State agencies very early in the development stage. The content of the strategic plan should consider issues related to market growth and what comes first, the vehicle capability or the infrastructure. The plan should also identify the possible benefits envisioned from each stage of the development. Besides the strategic plan, the participants also considered lane conversion and the combination of HOV and AHS-equipped Single-Occupancy Vehicles (SOVs) on the same lanes. More work is needed to identify the operational issues and how these issues may impact the drivers' potential uses, which will vary from region to region and from State to State.

Participants discussed various deployment strategies. Issues surfaced concerning a transition strategy that involves operating partially automated vehicles with manual traffic. With mixed or segregated traffic, what would happen at the merge points? What impacts are there to traffic flow when automated and non-automated vehicles interact? Would driver training be needed? Could the confusion and cost of a mixed system cause increased consideration of an "exclusively trucks" system first?

Narrow lanes were another topic of discussion. Most participants identified both good and bad issues concerning the use of narrow-lane AHS configurations. The narrow lane has potential in those limited ROW situations. However, how would narrow lanes fit into an evolutionary deployment sequence? Would the public accept these narrow lanes? How would trucks be handled? How would narrow lanes affect activities such as snow removal?

In any deployment situation, all participants agreed that rapid response to incidents is essential. To implement this ability to respond rapidly to an incident, the following were essential: automatic incident detection, special emergency equipment and staging locations, and vehicle mayday capability.

Impact of AHS on Surrounding Non-AHS Roadways

The major concern of participants was the problem of the non-AHS roadway being inundated by the volume of traffic exiting the AHS facility. Many of the participants expressed concerns about the ability of States or local jurisdictions to update or expand the capacity of their local streets to accommodate an AHS facility. For this reason, AHS must be part of an integrated, balanced transportation plan.

Participants discussed what they believed would be some characteristics of AHS traffic. Some thought that AHS would be characterized by long-distance commuting. This long-distance commuting might contribute to more urban sprawl. Channel growth along corridors may develop due to AHS. AHS may compete with other modes. The participants stated that not having AHS will not reduce the demand for new capacity, however, AHS and the additional capacity it could supply must be incorporated into the regional transportation and land-use policies so that its impact is to reduce congestion, not induce new traffic growth.

AHS Entry/Exit Implementation

The discussion participants identified a few additional MOEs which could be developed to evaluate entry/exit strategies. A good indication of an entry/exit strategy would be to measure the impacts of automated lanes on the manual lanes (e.g., reduced congestion, higher average speed). A measure should also be developed to contrast user delay against system safety and efficiency. The last measure, which would be used to rate strategies that compared well under the first two measures, is to measure efficiency as related to cost of the configuration infrastructure that would be needed to implement the entry/exit strategy.

The participants also discussed aspects of some of the entry/exit strategies presented. They considered the issues and risks related to a mixed-flow or dedicated-transition lane. Is a mixed-flow lane viable with the interaction of automated and non-automated vehicles? The major parameter in the development of the entry/exit configuration is how check-in will be performed and how long it will take. To mitigate the effect of the check-in procedure on entry/exit strategy and configuration, participants suggested that parts of the check-in be done at locations on local streets or maybe after the vehicle has entered the facility. Other factors that must be considered in entry/exit strategies are the need for high-capacity ramps or the use of multiple channels to and from the feeder streets.

The discussion of transition lanes raised many concerns about how to design them to maximize safety and minimize land use. A few suggested that there may not be a need for transition lanes—that accepted AHS vehicles could be pulled directly from the manual lane into the AHS lane. However, returning exiting vehicles directly to manual traffic lanes could be a problem—a buffer lane might be needed in those cases.
Participants wondered how rejected or unauthorized vehicles should be handled, and noted that an AHS must be designed to assume that a certain number of manual vehicles will breach the system, even if there are physical barriers. Most felt that TM strategies on the AHS lanes could isolate the manual vehicle so that safety is not threatened, only the efficiency of the system is reduced. Some suggested that to increase public acceptance there would need to be some sort of appeal process if a driver feels the vehicle has mistakenly been rejected.

Roadway Operational Analysis

A primary portion of the breakout session discussion concerning roadways focused on the advantages and disadvantages of privately operated AHS facilities. The participants cited the following major advantages of a privately operated AHS:

- Access to capital.
- Organizational focus.
- Competitive salaries to attract competent staff.
- Avoids equity concerns regarding the use of public funds.

However, the participants also cited these disadvantages:

- Difficulty in obtaining ROW acquisition.
- The high startup cost.
- Liability concerns.
- Profitability concerns.
- Possibility, due to cost, of limiting access to a small portion of the population.

With these advantages and disadvantages, most thought that an AHS facility would need the cooperation of both a private entity and a public entity; however, the relationship between these private and public entities may differ across the country.

C.3.8 Reporter Summary

This summarizes the materials presented by the roadway-oriented Working Group at the final Plenary session of the Workshop.

Urban/Rural Influence on AHS Design and Operations

Urban

- Entry/exit spacing.
- Capacity impacts (time of day).
- Constrained right-of-way availability.

Rural

- Safety priority.
- Higher speeds.
- Potential for lane conversion.
- Commercial vehicle operations.
- Distances for maintenance/emergency services.

Rural AHS Users

- Heavy trucks.
- Long-distance commuters.
- Tourists/recreational.
- Emergency vehicles.

Benefits:

- Safety.
- Convenience.
- Speed.
- User comfort.
- Productivity.

Transportation Agency AHS Issues

Attractive Aspects:

- Increased safety.
- Increased capacity.
- Cost-effectiveness as a capacity enhancement.
- Potential source of revenue (tolls).
- Improved mobility for older drivers.

Unattractive Aspects:

- Maintenance complexity.
  - Computers.
  - Software.
  - Access.
  - Incident severity.
- New skills.

AHS and HOV

Complementary

- Learn from HOV experiences.
- Institutional challenges.
- Restricted access.
- Potential to migrate from HOV to AHS.

AHS and Induced Traffic

- Long-distance commuting encouraged—potential for urban sprawl.
- Potential for channel growth in corridors.
- Potential competition for other modes.
- Need to couple AHS deployment with regional transportation and land-use policies.
- "... not having AHS will not reduce demand for capacity."

AHS Sites

Promising Sites
- Long-distance corridors.
- Good metering locations.
- High demand, long trip distances (I-94 Minnesota, I-95).
- Vacation travel corridors (I-15 [Los Angeles to Las Vegas], I-75 [Michigan to Florida]).
- Monotonous rural highways (I-70 through Kansas).
- Commercial truck corridors (I-80 Chicago, I-81 Virginia).
- Others: US-101 Los Angeles, I-35 Dallas-San Antonio, I-10 Los Angeles -East.

Bad Sites
- Difficult access points.
- Snow and ice areas??

AHS Entry/Exit

MOE's
- Impacts on manual versus automated lanes.
- User delay versus system safety and efficiency.
- Efficiency versus infrastructure cost.

Strategies/Configurations
- Transition lane - dedicated or mixed flow.
- Check-in location:
  - Local streets.
  - After entry (first "x" number of miles).
- Multiple channels to and from urban street grid.
- Exclusive ramps for high capacity.
- Rejected vehicle storage.
- Appeal process for potential conflicts.
- Unauthorized vehicle access
  - Self-policing?
  - Fines for violators?
  - Accommodate violators?

AHS Operating Strategies

- Different for urban and rural.
- Heavy vehicles:
  - Incompatible with light vehicles.
  - Limited grade ability.

- Don't mix heavy and light.
- No trucks in platoons.
- Time-of-day restrictions on trucks in urban areas.
- Separate lanes complicate entry/exit.

- Expel vehicles that degrade AHS performance.

Deployment Issues

- State agencies must be brought on board.
- Rate depends on market growth.
- Consider conversion of existing lanes?
- Work is needed on operational issues for diverse applications.
- Need strategic plan for deployment.
- "Chicken-and-egg" problem.
- Need to show benefits at each stage.
- Consider incentives such as HOV lane access for AHS-equipped SOV's?

AHS Narrow Lanes

- Potential for efficient use of limited right-of-way.
- How to fit in evolutionary deployment sequence?
- Would depend on exclusive AHS lanes.
- Human factors concerns (proximity).
- Public perception/acceptance?
- How to accommodate heavy trucks?
- Snow removal?

Deployment Practicality

- Concerns about passing, merging—mixed traffic, heavy trucks.
- Exclusive truck system first?
- Concerns about merging through openings in barriers.
- Driver training needs?
- Interactions between automated and manual traffic flows?
- Need minimum standards for vehicle performance.

Special Transit AHS Access Points

- Desirable, but difficult to implement:
  - Vehicle performance limitations.
  - Concern about spacing between access points.
- Helps:
  - Schedule reliability.
  - Bus priority.

Incident Management

- Rapid response essential.
- Automatic incident detection and management.
- Special emergency vehicle locations.
- Vehicles call for help (mayday/probes).
- Needs more sophisticated strategies and service providers than today.
- Special equipment for emergency access?

Flexibility Needs

- Geographic/environmental constraints (weather, curves, grades).
- Local financing/jurisdictional/policy issues.
- Following distances for heavy vehicles.

Standards Needs

- Lane width.
- Training requirements.
- Entry/exit protocols.
- Safety, compatibility...

Privately Operated AHS Facilities

Advantages
- Access to capital.
- Organizational focus.
- Staffing and salaries.
- Avoids equity concerns about use of public funds.

Disadvantages
- Right-of-way acquisition.
- High startup investment.
- Need public shield from liability.
- Liability detracts from profitability.
- Possible limited access for lower income travelers.

Throughput Issues

- Measure people/hour, not vehicles/hour.
- Measure percent gain over existing operations.
- What throughput level is needed for each application?

- Must consider effects on throughput of:
  - Accidents.
  - Weaving.
- Consider effects on entire system, not just trunk-line throughput.

C.4 INSTITUTIONAL AND SOCIETAL OVERVIEW

This session focused on the institutional and societal issues that could potentially affect an AHS deployment. They can also impact design characteristics of an AHS system. This area encompasses a broad range of non-technical issues that affect all aspects of AHS development and operation. The major categories of issues include:

- Legal/Regulatory.
  - Tort/Product Liability.
  - Anti-Trust.
  - Intellectual Property.
  - Privacy.
- Environmental.
- User/Public Acceptance.
- Organizational.
- Jurisdictional.
- Societal Impacts.
- Financial Architecture.

C.4.1 Contractors and Areas of Research

There were five PSA contractors working on this area. The research intentionally overlapped to help ensure that critical issues were not overlooked. However, each team had a slightly different approach and there were some teams that narrowed their research to a few areas in order to obtain more depth for the issues in those categories. The research focuses were:

- **Battelle** - Identifying critical societal and environmental issues, including focus groups for public perception and user acceptance, applying a methodology for prioritizing critical issues.

- **BDM (George Mason University)** - Using focus groups to assess public acceptance; also addressing commercial operator regulations.

- **Calspan (Parsons Brinkerhoff)** - Identifying a broad spectrum of issues and their impacts on the other Calspan analyses.

- **Delco (PATH)** - Conducting in-depth research on environmental issues, privacy, and the potential impacts on existing transportation facilities and agencies.

- **SAIC** - Addressing product and tort liability, applicability of existing regulatory and financial models, and impacts of current environmental legislation.

C.4.2 Institutional and Societal-Oriented Briefings

Five briefings were presented during the Institutional/Societal Issues session:

- Types of Institutional/Societal Issues, *Calspan/Parsons Brinkerhoff.*
- Prioritized Issues and Report on January Focus Group, *Battelle/BRW.*
- Potential Implementation Frameworks and Related Legal Issues, *SAIC.*
- Discussion of User Acceptance, *BDM/GMU.*
- Discussion of Environmental Issues, *Delco/PATH.*

C.4.3 Breakout Group Summary

The general discussions in the breakout groups emphasized that the issues in this area are critical and could prove to be the most difficult to resolve. The discussions raised many good issues and some of the highlights are outlined below.

Legal/Regulatory Issues

The following is a subset of institutional/societal issues that were defined as part of the breakout groups; relevant comments on each is shown:

- Liability.
  - Federal protection/limitation on damages could encourage participation.
  - Establish a mediation process that could alleviate the costs of litigation.
  - Create a risk pool.
  - Involve the insurance industry in the formulation of AHS deployment configurations.
- Anti-Trust.
  - May require regulatory organization (e.g., utility company).
  - This issue is of greater importance if the private sector owns the system.
  - The model of the US CAR program could be a good model for the AHS program.
- Intellectual Property.
  - Groups felt that this is an issue, but it is not unique to AHS and it will probably be solved by the IVHS program.

- Clean Air Act.
  - AHS can manage vehicle-to-roadway gaps to allow roadway-powered EV operation.
  - More consistent speeds and reduced congestion will greatly reduce emissions.
  - AHS should increase passenger-mile traveled (PMT)-per-VMT rather than VMT.

Perceived Safety and Strategies to be Enhanced

- First impressions are extremely important, so early systems should be overly safe.
- Outreach to the public is crucial.
- Communication, starting at the check-in process, is vital for confidence building.
- False alarms should be minimized to avoid permanent disregard and nuisance.
- Mixed-vehicle traffic could potentially make people feel less safe.
- An evolutionary approach might be more publicly acceptable, but may run risks for the fully automated AHS.

Roadblocks to Public Acceptance

The public acceptance issue is probably one of the most crucial. The public needs to trust and believe in the system from the beginning or AHS will probably never be realized. Some of the roadblocks that could hinder this are uncertain costs, reliability, safety, trust, and lack of tangible benefits. There needs to be a plan that targets the early winners and a solid demonstration that AHS meets the needs.

Societal/Quality of Life

Like most new technologies that we are accustomed to, an AHS has the potential to impact the quality of life. Some possible improvements include:

- Increased driving/riding comfort and convenience.
- Efficient use of time.
- Increased mobility.
- Increased recreational travel opportunities for lower income families.
- Improved safety.
- Economic benefits (reduced insurance, job creation, etc.).

These issues are just a sampling of the extensive thought and research currently underway. Early identification of issues is essential to finding solutions before they become obstacles. The discussions also emphasized that there could be many different solutions to an issue and that lessons learned should be highly visible so that others who may be beginning to implement systems will benefit. Although not all issues will be "show stoppers," it is still imperative that they be addressed.

C.4.4 Reporter Summary

This summarizes the materials presented by the institutional and societal Working Group at the final Plenary session of the Workshop.

Legal Issues

- Liability
  - Seek Federal protection/limitation.
  - Establish mediation process.
  - Create risk pool.
  - Involve insurance industry in formulation of AHS deployment configurations.
- Antitrust
  - May require regulatory organization (e.g., utility commission).
  - More important if owned by private sector.
  - Model US CAR program.
- Intellectual Property
  - Issues exist, but not unique to AHS.

Clean Air Act

- AHS can manage gaps to allow hybrid/EV use.
- More consistent speeds on AHS may reduce emissions.
- Increase passenger-miles traveled/vehicle-miles traveled rather than vehicle-miles traveled.

Demographic Changes

- Potential for sprawl exists (depends on how development is channeled).

Perceived Safety and Strategies to Enhance

- First impressions important.
- Outreach important.
- Communication, starting at check-in process for confidence-building.
- Minimize false alarms.
- Mixed-vehicle traffic will make people feel less safe.
- Make safety features obvious.
- Identify the risks early.
- Evolutionary approach.

Revenue Sources

- Should be distributed among those who benefit.
- Could charge users higher fees for higher priority use.

Fees for Use

- How to achieve equity.
- Complicated taxing/fees could confuse the AHS issue.

Those Negatively Affected

- Low income.
- Immediate neighbors of AHS facility and those who live on feeder routes (who are non-users).

Roadblocks to Public Acceptance

- No major funding champion.
- Perceived safety risks, lack of trust.
- Cost (especially at start)/limited funding resources.
- Too many constraints, loss of freedom.
- Solutions:
  - Evolution could reduce roadblocks.
  - Show how features of AHS benefit users and non-users.
  - Early winners.
  - Demonstrate that AHS meets needs.

Benefits by Type of User

- SOVs - reliability, predictability, time savings, reduced cost, safety.
- HOVs - increased savings above SOVs.
- Transit - same as above and potential labor savings (no driver).
- Commercial/Trucking - same as above.

Benefits to Non-Users

- Job creation.
- Reduced congestion for manual lanes.
- Commercial/shopping and tourism industry growth.

Contributions to Quality of Life

- Lower stress.
- Comfort, convenience.
- Efficient use of time.
- Increased mobility for seniors.
- Increased recreational travel opportunities for lower income families (compared to air travel).

Research Needs

- Market research.
- How to make seamless transition between urban and inter-urban systems.
- How to maximize beneficiaries.
- How to ensure participation in AHS design and deployment process by both beneficiaries and those not benefited.
- Research to demonstrate positive relationships between quality of life/land use/environment and AHS.

APPENDIX D

PSA ISSUES/RISKS DATABASE DESCRIPTION

D.1 INTRODUCTION

Calspan was tasked to development a database to integrate the key issues and risks from all of the PSA research teams. The goal of this expansion was to standardize issues and key findings formats so that the NAHSC could resolve them more easily. The completed PSA database is seen as a tool for the NAHSC and other interested AHS researchers.

A standard format was developed from input received from all PSA teams, FHWA, and MITRE. After this standard format was developed, a form was distributed to all the PSA researchers so that their key findings could be recorded. The completed forms (in both hard copy and electronic format) were sent to Calspan who entered them into the database.

D.2 DATABASE FIELD DESCRIPTIONS

Below, a description is given for each of the fields used to describe any given database item.

The data contained in the issues database describes the major results identified by the PSA researchers. The database can be searched and queried on several different descriptors so that a user can find information of interest. The major elements for each item contained in the database is described below.

- **Entry:** PSA team and researcher that captured the item.
- **Entry Date:** Date the item was entered.
- **Review:** Person on PSA team that reviewed the item.
- **Item Type:** Identifies the item type. Four possible choices:

"**Issues**" refers to items where there are reasonable questions concerning how to proceed; issues may arise as concerns are addressed; they should be posed as questions; **Issues are resolved.**

"**Risks**" are conclusions that identify potentially negative situations that, if they should happen, could result in system failure or major problems; severity of risk can be indicated (High, Medium, Low); **Risks are managed.**

"**Concerns**" is for items that may be risks or issues, but sufficient analyses have not yet been done to know for sure; **Concerns are addressed** (perhaps through further analysis).

"**Conclusions**" are supportable results of analyses; they may be resolved issues; **Conclusions reference supporting analysis.**

- **Action:** This field is for use by the consortium to pursue action based on the item.

- **Sources:** This indicates the PSA team, the reference document in which the basis for the item can be found, and the name of the PSA researcher. This could include more than one document.

- **Pertains To:** The item in the database is identified as pertaining to at least one of the following categories:

  - Safety
  - Efficiency
  - User Acceptance
  - Environment
  - Legal
  - Societal
  - Concept Selection
  - '97 Demo
  - Design/Development
  - Test/Evaluation
  - Deployment
  - Maintenance/Operation
  - Transition
  - Human Interface
  - Program
  - Management
  - Funding
  - Cost
  - Benefits

- **Short Description:** Descriptive title for the item; no more than 10 words.

- **Summary:** A summary so that the reader can understand the essence of the item. Additional references may also be entered here. No more that 200 words.

- **System Function:** Identifies those functions that are related or most closely related to the item (several may be identified):

  - ALL
  - Check-In
  - Enter/Merge

- Driver Interface
- Longitudinal Control
- Lateral Control
- Maneuver Coordination
- Check-Out
- Exit/Merge
- Incident Management
- Zone Flow Management
- Regional Management
- Environmental Sensing
- Maintenance/Operation
- Operational Mode

- **Infrastructure and Vehicle System:** Identifies those elements of AHS that the item impacts (several may be identified):

Infrastructure System:

- ALL
- Entry/Exit Configuration
- Lane Configuration
- Roadside Sensors, Communication/Processors
- Region Command Centers
- Barriers
- Surface Materials
- Bridges/Tunnels
- Roadway Maintenance Equipment

Vehicle System:

- ALL
- Steering Actions
- Braking Actions
- Throttle Control
- Power Train Control
- Lights
- Suspension
- Vehicle Electronics
- Sensors
- Chassis
- AHS Controller

Communications:

- Intra-vehicle
- Road-road
- Road-vehicle
- Vehicle-vehicle

- **Concept Impact:** Identifies those characteristics of an AHS concept that may be affected by the item (several may be identified):

Concept Impact:

- ALL

Vehicle Type:

- Light
- Heavy
- Transit
- Pallet
- Special
- Maintenance

Infrastructure Type:

- Dedicated
- Shared with Manual
- Barrier
- No Barrier

Entry/Exit Type:

- Dedicated
- Transition Lanes
  - Periodic
  - Unrestricted

Power Source:

- On-Board Internal Combustion Engine
- On-Board Alternative Propulsion System
- Roadway Powered Electric

Longitudinal Control:

- Autonomous Vehicle
- Platooned Vehicle
- Point Following

Lateral Control:

- Passive Road (e.g., magnets, paint)
- Barriers
- Active Road

Control Location:

- Mostly Vehicle
- Mostly Infrastructure
- Balanced

D.3 ACCESS TO THE PSA DATABASE

Any AHS researcher can have access to the PSA database. The database is contained on a single floppy disk in either Personal Computer (PC) or Mac format. Access to the database requires the use of the *Access* Database Management System, which is available for either the p.c. or the Mac. Detailed instructions on how to use the PSA implementation are also available. Both the database and the instructions are available from the FHWA, AHS Program Manager.

There are currently 599 items in the PSA issues database. The breakdown of items is as follows:

140	Issues
53	Risks
135	Concerns
253	Conclusions
18	Unknown

599	TOTAL