Precursor Systems Analyses of Automated Highway Systems

RESOURCE MATERIALS

AHS Comparable Systems Analysis

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

Technical Report Documentation Page

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16. Abstract

The program described by this eight-volume report 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 describes the Comparable Systems Analyses performed under Task G, supervised by Douglas J. Funke of Calspan, supported by consultant Caren Levine; Alain L. Kornhauser, Bart W. Huffman, and Eric C. Huber of Princeton; Robert Riess of Dunn; and Richard Naish of Parsons, and Kimberly Witherow of Calspan.

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VOLUME II — AHS COMPARABLE SYSTEMS ANALYSES (TASK G)

"Don't take all my experience as applicable today, but please, let's not relive history. Let's not mislead anyone as to what is reality; let's find that reality and go forward on that basis."

— Najeeb Halaby
FAA Administrator
Head, Supersonic Transport (SST) Program

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

The Automated Highway System is not the first large system that involved the introduction of new innovative technology, was intended for widespread public use, required coordination across Government and private industry, had potentially significant cultural and societal impact, and required large amounts of financial investment. Large innovative systems have come and gone. Some have been successful and changed society forever in fundamental and important ways (e.g., the automobile, computers). Many changed our world in small to moderate, yet important ways (e.g., ramp metering, electronic toll systems and traffic management systems). Others met with public and/or political resistance or technological and/or fiscal problems and ultimately failed (e.g., the supersonic transport—SST).

1.2 TASK OBJECTIVE

These analyses were completed to learn from the history of systems sharing common features with AHS. The objective was to identify and document relevant historical lessons for AHS planning and development. As recommended by Najeeb Halaby, the first FAA SST Program Manager, our goal was to define today's reality for AHS in an historical context, drawing from the lessons of past programs that share important features with AHS.

1.3 TECHNICAL APPROACH

The approach taken for this task maintained a high-level perspective. Brainstorming, review of literature, and personal contacts/interviews with experts were applied as appropriate. The effort proceeded with the following subtasks:

1. **Candidate Comparable System Selection -** A list of candidate comparable systems that could provide lessons learned for AHS was generated. These were identified through a brainstorming session held early in the program.

2. **Candidate Comparable Systems Prioritization -** Candidate comparable systems were prioritized and selected for high level study. This was accomplished using a nominal group technique supported by project task leaders.

3. **Comparable Systems Study Assignments -** Study action items were assigned. Based on their expertise, task personnel were assigned comparable systems to study.

4. **Comparable Systems Analysis -** Analyses were conducted. During this step, relevant literature was reviewed, domain experts were consulted, and lessons for AHS were identified.

5. **Internal Communication of Interim Results -** Intermediate results of the analyses were provided to other PSA of AHS Task Leaders based on relevance to their respective tasks. This was done via internal memorandum, draft interim results documentation, and informal personal contact.

6. **Integration of Final Results -** During this task, lessons learned based on the analysis of selected comparable systems were consolidated and integrated. Twenty high level conclusions were identified based on integration of the over 100 individual issues, risks, concerns, and recommendations resulting from the individual analyses.

7. **Documentation -** Conclusions were documented in a final report (this volume) and within the PSA of AHS issues database (ongoing).

1.4 OVERALL CONCLUSIONS/KEY FINDINGS

The results of the analyses are synthesized into 20 major conclusions. The following paragraphs describe each major conclusion and cite evidence from relevant comparable systems.

1. The public must perceive the overall benefits of AHS.

   In order for a new technology to successfully replace an existing technology, the new system must offer clear and obvious advantages and benefits over the older system. If these benefits are not provided or evident, potential users will likely be unwilling to give up the pre-existing trusted system for the newer system, especially if the changeover involves significant costs (e.g., money to purchase the new system, time to learn new procedures, license fees). AHS design and deployment should proceed in ways that will make the benefits obvious to all potential users.

   Evidence for this conclusion comes from several of the comparable systems studied. For example, experience with HOV implementation indicates that, when drivers can see that HOV lanes are moving more people than non-HOV lanes, they are willing to accept the dedication of a lane for this purpose, even if they do not personally choose to use the HOV lane themselves. Similar experience has been found with the implementation of ramp meters. Toll road implementation also provides support for this conclusion. When toll roads were first implemented in this country, there was great concern whether people would pay to use them when conventional roads were available free. However, experience has shown that because toll roads significantly reduced travel time, they were very successful. Other comparable systems that support this conclusion include the streetcar, commercial flight, domestic appliances, and automated teller machines (ATMs).

2. The safety and reliability of AHS must be clearly demonstrated.

Any new technology must be proven safe and reliable before the general public is willing to accept and use it. Evidence from the comparable systems studied has shown that even systems that have a reputation for good safety may face loss of users if a safety incident does occur. Systems that have a reputation of safety problems have had a very difficult time achieving public acceptance.

Evidence for this conclusion comes from the study of elevators, commercial flight, bank automated teller machines (ATMs), aircraft automation, and the Morgantown personal rapid transit system. Public concerns about health and safety have even been raised for electronic toll and traffic management (ETTM) systems. To illustrate, elevators have been around since the middle ages but, until after 1854, were limited to hauling freight because the public had serious concerns about their safety. In 1854, Elisha Otis dramatically demonstrated the safety of his "safety elevator" by having himself raised 40 feet in the air and having the elevator rope severed, demonstrating the effectiveness of the new elevator safety mechanism. From then on, elevators have been used to haul people (and, in fact, are the safest form of automated transportation in use today!). The ubiquitous use of elevators has changed the urban landscape forever.

On the negative side, when safety and reliability problems occur, acceptance of the systems involved is reduced. For example, when the Hindenburg crashed, the then thriving commercial dirigible industry completely collapsed. Similarly, when a demonstration intended to show that sonic booms from the SST would not disturb residents led to over 15,000 angry phone calls and over 5,000 damage claims, the program was severely damaged and never really recovered.

The success of AHS will require demonstration of safety and reliability before full implementation. People must believe that the system is as safe, or safer, than the traditional highway system. Further, public demonstrations of AHS that raise safety concerns may do more harm than good, and even prevent the system from ever being accepted. AHS developers should perform extensive testing before a prototype is demonstrated to the public.

3. Long-term and continuous financial support for AHS deployment must be secured.

For the long-term success of AHS, it is important to ensure that funding for the project is sufficient and guaranteed. If the funding is not sufficient, it may be difficult to raise funds at a later date. If the funds are not guaranteed, they may be cut at any time, and battles for project financing will be ongoing. Further, funding needs to be specific to the goals of AHS, and pay-as-you-go financing is preferable to borrowing.

Evidence for this conclusion comes from study of the interstate highway system, automated guideway transit systems, the railroad (i.e., interurbans and maglev), and the SST. When interstate highway funding was first made available the scope of its intended use was defined in a general way and much of the money allocated was used to fund porkbarrel projects. Subsequent attempts at interstate highway legislation were unsuccessful, because of the very large amounts of borrowing required. The interstate highway was ultimately developed successfully, but on a pay-as-you-go basis. A small gasoline tax was levied and used to develop the interstate highway network over a long period of time.

4. Support from influential persons in Government and industry is important for large programs.

The success of many large-scale projects has been facilitated through the commitment of high ranking officials from Government or industry who were willing to work hard to ensure the success of the projects. AHS will benefit from such an individual (or group) to help secure the necessary financing and support, and to help maintain enthusiasm for the project during all stages of design and implementation.

The importance of a strong proponent for large projects was evident in many of the systems studied during this program. Without one or more strong supporters, projects have often faced great difficulties. Those with strong and influential supporters have generally been more successful. For example, support from Senator Daniel Moynihan (D-NY) was a key factor in the recent formation of the Maglev Technical Advisory Committee and the National Maglev Institute, and in the ensuing interest in maglev development. Public confidence and interest in commercial flight were greatly bolstered when Franklin D. Roosevelt used an airplane to travel from New York to Chicago to accept the Democratic nomination for the presidency of the United States. Similar proponents of AHS would increase its potential for success.

5. Evolutionary development of AHS is recommended.

An evolutionary approach to the development and implementation of AHS is recommended, based on the experience of several large-scale public systems studied during this project. An evolutionary approach will provide for incremental development, allow safety and reliability to be demonstrated on a small scale before system-level integration is attempted, and provide a gradual approach to achieving public acceptance. This will also allow alternative technologies and design approaches to be compared prior to selection. Finally, U.S. industry will be more willing to invest in AHS if short-term profits are possible.

Evidence for the advantages of an evolutionary AHS development approach was found in many of the comparable systems studied, including HOV lanes, the interstate highway system, automated guideway transit, air traffic control, the railroads, office automation, domestic appliances, and ATMs. For example, the evolutionary approach taken in the development of the interstate highway system made it possible to fund the effort on an incremental basis, while the immediate provision of benefits maintained public support. HOV lanes have also been successful, in part because they build on existing highways (i.e., they are an evolutionary improvement to the existing highway system). Alternatively, when large projects have been unable to use an evolutionary development approach, they have experienced problems. The Chunnel (the tunnel connecting England and France under the English Channel) is a good example.

Cost overruns have led to serious questions about its ability to compete with less expensive ferry service, and the lack of any demonstrated benefits (no one has used the Chunnel yet) has led to waning public support for the project.

6. AHS should be designed for integration within the overall transportation system in the United States and worldwide.

   The AHS market should be defined in relation to other transportation forms. The AHS network and design should be developed based on this potential market. When AHS is included as an integral component of the U.S. transportation system, rather than as an independent competing mode, a realistic and stable user base will be encouraged, and the goals of the U.S. transportation system will be best served. AHS objectives should be developed on the basis of this integrated definition. Further, AHS components should be standardized for all AHS applications in the U.S. and worldwide and should be compatible with existing conventions. For example, AHS should be designed to be as compatible as possible with existing highway signs and procedures.

   Evidence for this conclusion was found in the study of several comparable systems, mostly from the transportation area. For example, the success of HOV treatments has been facilitated when integrated with park-and-ride lots and mass transit (e.g., preferred parking spaces reserved for HOVs). Experience in the planning of mass transit systems has also shown that realistic estimates of market size should be made in the context of the larger transportation system as a starting point. Transportation systems that have been developed without an integrated view have experienced problems. For example, the interstate highway system did not consider the effect of interstates on urban traffic patterns and the result has been excessive congestion in many areas; independently developed regional railroads resulted in a totally incompatible national rail network requiring extensive rework.

7. Cost and time estimates for developing AHS must be carefully and accurately determined.

   Budget overruns and schedule slippage can lead to negative publicity, poor public acceptance, and reduced political support for the system. System design, testing, and implementation must remain within budgetary guidelines and time constraints for the project to ensure continued support. Cost and schedule "bad news" can reduce public acceptance of AHS, even when the shortfalls are due to estimation errors, rather than the more serious system problems. Also, it is important to plan for schedule and cost contingencies. Despite good planning, unforeseen problems are likely to emerge and require unplanned effort.

   For these reasons, AHS developers must carefully make realistic estimates concerning the amount of time the system will take to implement, and the amount of money it will cost to complete. Neither the financial backers nor the general public is pleased when a project requires sudden increases in financial support halfway through, or when the project takes significantly longer to complete than predicted. This is especially true for projects financed by public funds. Overly optimistic budget and schedule estimates look good at planning time but lead to almost certain failure, at least as measured against budget and schedule.

Evidence for this issue has been found in the study of several comparable systems, including the Morgantown Personal Rapid Transit (PRT) System, the Denver International Airport (DIA), the Chunnel, and the SST. The Morgantown PRT is a good example. The project was initially under-estimated in terms of both budget and schedule. When it became apparent that the project required significantly more time and money to complete, political pressure led to design and development shortcuts. These, in turn, led to system deficiencies and problems requiring rework. Even more extensive cost and schedule overruns resulted, leading to very poor public perception. The project took years to complete and support for other PRT projects was also jeopardized.

8. Consortiums of private and public agencies can facilitate AHS successful development.

A consortium approach to AHS development can help to ensure that the AHS system is successfully implemented. The consortium approach will allow the project to benefit from a wide range of expertise and perspectives, and to share the costs involved with implementation. Even more importantly, cooperation among the various industries and organizations interested in AHS will facilitate efficient and effective designs that can be supported by products and services developed independently, yet which must operate within a common infrastructure. The motivation for investment, participation in the consortium, and diligence in the task comes from the increased market share potential that results from design participation. Winners and losers are sorted out in the market place.

A consortium approach to system development has been effective in many situations similar to AHS (i.e., large, market driven systems). Some examples studied during this task are commercial flight and ATMs. The airlines and associated Government agencies from all nations (except Russia) joined to form the International Air Transport Association (IATA) in 1944. They established international standards for safety, navigational controls, air maps, and even the setting of international air fares (Solberg, 1979), providing safer and more efficient international air travel. These accomplishments would not have been possible without this widespread cooperation. When New York City banks joined to develop the New York Cash Exchange (NYCE) system they were able to overcome the ATM market head start previously enjoyed by Citibank. Cooperative ventures between Government and private industry in Europe and Japan to develop IVHS technologies have also been successful. By contrast, the lack of cooperation among early U.S. railroad companies led to a national system of largely incompatible tracks.

9. Community outreach and public involvement will be important to AHS success.

It will be wise to keep the public educated and informed throughout the AHS planning, design, and development phases. AHS developers and supporters should make the public aware of the benefits of AHS, and immediately deal with any criticisms and/or concerns raised. AHS developers and promoters should also build coalitions with opposition groups (or at least be prepared to counter negative arguments). Environmental concerns will be important considerations. Public education and outreach, in addition to maintaining support for the program, will help attract users to the system, by allowing them to understand how the system works and the benefits it offers.

Also, our research has found that full public disclosure and education are important for avoiding liability problems. According to the U.S. legal system, definitions of a defective product and dangerous conditions are based on perceptions held by the general public. It is necessary to inform and educate the public about AHS operation and limitations in order to help mitigate legal challenges.

Evidence for this conclusion comes from our study of ramp metering, the interstate highway system, ETTMs, the automobile, commercial flight, the SST, and the planning of mass transit. For example, ramp metering projects have encountered public resistance in several locations, in one instance leading to litigation. Experience has shown that, by involving the affected communities during the planning process, these problems are greatly reduced.

10. AHS may produce significant changes in society that may be difficult to predict.

It is difficult to predict the effect that introducing AHS will have on the national highway system, and on society, in the United States. We have found that the introduction of new technology in the United States has often led to unforeseen effects. Research to explore the non-obvious affects of AHS should be undertaken as part of the AHS planning process (e.g., through focus groups and market research).

Evidence for this conclusion comes from our study of automobile history, the railroads (primarily interurbans), the elevator, and office automation (primarily the typewriter). To take an example, the elevator had far reaching effects beyond simply moving people between floors more quickly and comfortably. They made it possible to build taller buildings. The result has been a completely new look to our urban centers. Even the rent structure for offices was reversed when elevators were put in use (higher floors received premium rents). An example where unforeseen consequences of technology led to a systems failure (at least for a while) is the typewriter. When first introduced and marketed, there was great resistance to the typewriter due to societal norms in effect dealing with penmanship and the social etiquette of letter writing. Letters typed with the typewriter seemed impersonal, and issues of authenticity were raised. The practice of signing otherwise typed letters adopted later helped overcome these concerns. It will be important to determine if AHS will have effects that could hinder its development and success.

11. Potential markets for AHS should not be overlooked.

The wider the potential market-base, the easier it will be to gain widespread acceptance of the new technology. This may also help to keep operating costs low. Limiting the potential market for AHS could exclude potential users, and result in poor public perception of AHS. That is, it could be seen as having limited usefulness and value, or being toys for the rich and powerful. To maximize the potential for AHS success, it is best to open up the system to as many categories of users as possible (e.g., consider commercial and consumer markets). This approach of seeking the broadest possible market is recommended on the basis of the study of several comparable systems.

This conclusion is based on our study of the interstate highway system, ETTMs, the automobile, automated group transit systems, office automation (the typewriter), domestic appliances (the VCR and electricity itself), and ATMs. In all cases, success was facilitated by expanding the market to a wider user base. For example, early automobiles were very expensive and sold only to the wealthy. With the introduction of the Model-T, the average citizen became included in the potential market. The automobile's success was greatly increased. Similarly, the initially unsuccessful typewriter became a great overnight success when the business market was targeted.

12. A large return for AHS can be achieved with transit vehicles.

    AHS when combined with transit and/or HOV treatments can provide very significant improvements to the people-moving capacity of our highways. These treatments are especially applicable to (and perhaps limited to) AHS applications in urban areas and along congested corridors. When considering the AHS goal of congestion mitigation, the potential of these treatments cannot be overlooked. For example, an AHS implemented in the Lincoln Tunnel Express Bus Lane could potentially provide people-moving capacity greatly exceeding that possible with heavy rail mass transit (although this would require expanded terminal capacity). Even HOV treatments on AHS could potentially provide service comparable to existing light rail systems.

13. AHS design insights and technology foundations can be found through the study of comparable systems.

    No single comparable system was found (or expected) to provide guidance across all AHS design aspects. However, many comparable systems have been found that can provide insight and technology to support specific aspects of AHS development and implementation. In some cases, comparable systems can provide insight into public relations and social aspects of AHS development. In other cases, design approaches are recommended, or technology solutions suggested. This is the most general finding resulting from this task and relates to all comparable systems studied. It is recommended that the comparable systems studied during this task, as well as others, be considered during AHS design and implementation.

14. AHS will face liability issues. These should be anticipated and plans made to avoid or overcome legal challenges.

    We live in a litigious society. It seems clear that AHS implementations will face legal challenges (like all other systems). These can stem from mismanufacture, defective design, failure to warn, and/or product/service misrepresentation. AHS development should be managed in a way that minimizes legal vulnerability. Safety analyses will be required to support design decisions. It will be important to educate drivers about AHS capabilities, limitations, and safety procedures. Plans for updating AHS to avoid antiquated technology will need to be made, and AHS must be based on capable technology. Government standards and design redundancy can help reduce liability for private industry. Since legal foundations are built on precedents, legal issues left unaddressed will be decided in court.

Evidence supporting this recommendation is based on an analysis of the liability experience with cruise control, ABS brakes, and air bags in today's cars.

15. AHS should be designed with maintenance and system upgrade in mind.

AHS design must consider requirements for accomplishing system maintenance. This will include incident management, routine roadway maintenance such as snow removal, preventive maintenance and system inspection, and infrastructure repair. It must be possible to accomplish these functions without significant disruption of service.

It should also be possible to accomplish system upgrades and expansion with only minimal disruptions of service. One design consideration related to system upgrades is that it should be possible to accommodate earlier AHS users after upgrades are accomplished.

These recommendations are based on the study of several comparable systems including the automobile, automated group transit, air traffic control, elevators, and office automation. For example, the rapid development of and improvements to computer technology have been facilitated by the common practice of making changes downward compatible (e.g., designing new hardware to work with old software). This preserves and supports the development of the customer base.

16. Public acceptance will be critical for AHS success.

If we build it, will they come? And will they support its development? These are very important questions for AHS. Public demand for systems can drive the development and expansion of markets to worldwide levels. On the other hand, public opposition to systems can create serious obstacles to success. Issues of public acceptance for AHS will be very important.

Many factors contribute to public acceptance. Important factors include cost relative to other transportation modes, convenience and ease of use, ability to match users' origins and destinations, obviousness of fail-safe features, and impact on pollution. It will be important to pay attention to public relations and privacy issues, and to the needs of special user groups (e.g., non-English speakers, handicapped). The perceived impact of AHS on job security can impact the acceptance for commercial AHS applications. Finally, even the general appearance of AHS can be a factor in AHS public acceptance. It will be important to consider and assess these issues throughout AHS development.

This recommendation is based on several comparable systems, including ETTMs, the automobile, aircraft automation, the bicycle railroad, commercial flight, office automation, and ATMs. For example, the employment of nurses as flight attendants during the early days of commercial flight helped to reduce the public's apprehension about flying, and helped facilitate the success of this market.

17. The degree of centralized control and human decision making can slow system response.

The degree of centralized control can slow system response time and reduce the ability to deal with local conditions. This could affect spacing and flow achievable. Highly centralized control approaches can create lags in the control system and make it difficult to deal with local conditions. The requirement for human decision making in the control loop is especially problematic and should be limited to global, non-time-critical-parameters. Finally, the requirement for driver assimilation and interpretation of messages can slow response. Commands sent to the driver should be clear and unambiguous. If a centralized control system is selected for AHS, it must be designed in a way that it does not create serious control lags.

The evidence for this conclusion comes from study of the air traffic control (ATC) system. The ATC system is highly centralized. The speed, spacing, and flight path of aircraft are determined and controlled from the ground. Human air traffic controllers determine the desired aircraft flight parameters and issue voice commands to pilots, who make appropriate adjustments. This system is slow, cumbersome, and makes the ability to adjust to local conditions (e.g., weather) difficult. It leads to an inefficient use of airspace, because aircraft must be kept widely separated to allow for control system lags.

18. AHS exit efficiency will be critical for handling high AHS flow rates.

Bottlenecks can be created at popular exits if the exits cannot handle traffic demand. This could require closing an exit to avoid vehicles from backing-up onto the AHS lane(s). Approaches for mitigating this problem include proactive planning and the use of multiple parallel exits or buffer zones. Proactive planning could include placing, under system control, groups of exits in congested areas (e.g., near an activity center such as a stadium or CBD). Drivers desiring to exit could be assigned an exit by the system in a way that optimizes overall exit efficiency and flow. When there is room, an additional exit lane could be also added.

This conclusion is based on the study of the ATC system and the management of finish chutes at foot races. ATC restricts aircraft take-off permission until landing slots are available. Foot race finishes handle the processing of large numbers of runners at race finishes without backing-up into the race by careful management of parallel finish chutes.

19. AHS marketability will be influenced by design and economic factors.

AHS will be one of several options for travelers. Its design and pricing approach will affect its potential market base. Innovative approaches to AHS pricing and the sales approach used can increase the potential market achievable. For example, whether AHS systems must be purchased or leased will affect their price to consumers and impact their competitiveness within the transportation market. Also, the development of the AHS market can be facilitated by "piggybacking" on other markets (e.g., market to those using existing ETTM systems, offering commuter packages that include AHS and connecting mass transit passes). In planning for AHS marketing, it will also be important to consider prevailing economic conditions. If the AHS industry is characterized by significant competitive forces, this can facilitate development of innovative marketing approaches.

Several comparable systems form the base for this conclusion,including ETTM systems (the New York State E-Z Pass system), commercial flight, office automation, and domestic appliances.

20. There may be regions that favor AHS implementation over others.

There may be regions in which geographic or traffic conditions favor AHS, while other areas may be less favorable. On the one hand, this will make it possible to select locations for AHS demonstration where AHS can provide significant benefits within the larger transportation system. It also will help guide the planning of AHS evolution and system expansion. On the other hand, it will be difficult to gain political support from legislators representing areas with little to gain from AHS. In fact, those areas where AHS is less applicable can be sources of opposition.

This conclusion is based on the study of the interurbans, and high speed trains. For example, interurbans were most applicable in areas were cities and suburbs were closely spaced and the terrain was relatively flat.

1.5 RECOMMENDATIONS FOR FURTHER WORK

The conclusions and recommendations described in this volume are based on the study of many comparable systems. The study was broad-based to identify sources of insight and technical foundations for AHS. Because the study considered many comparable systems, each was considered at a high level. More detailed information may be available. It is recommended that the results and data provided in this volume be used as a starting point for further investigation as appropriate. Specific literature and data sources included in the references, bibliography, and literature review sections should be consulted during AHS development and implementation. For example, when design decisions must be made, it might be valuable to contact persons involved in highly relevant studies and projects.

The conclusions presented in this volume may be more relevant to some aspects of AHS than others, and to some AHS design phases more than others. The conclusions presented should be applied as appropriate, considering the specific tasks at hand.

2.0 INTRODUCTION

Our society has undergone extensive changes over the past 50 to 60 years as a result of new systems and technology applications to public, business, and private activities. These changes have required new ways of thinking, behaving, and performing everyday tasks affecting large portions of the American public. People's fears and reluctance to change have had to be overcome (e.g., acceptance of commercial flight), new public policies at all levels of Government have had to be reconciled with private interests across the spectrum of American society (e.g., introduction of HOV lanes), and innovative approaches to moving large numbers of people in an organized and efficient fashion have had to be developed (e.g., queuing at various people mover entrances). The Comparable Systems Analysis task has drawn lessons about designing and managing technologically based change from past experience.

The objective of this task was to identify, analyze, and compile lessons learned from systems that bear important comparisons and similarities to the AHS. These AHS comparisons and similarities are associated with specific aspects of AHS, or bear relevance across broad ranges of design, development, and/or deployment concerns. Areas of comparison include issues of public acceptance, management of public/private investments, application of Government regulation, and the design of public interfaces.

Comparisons were made at a high level to identify lessons learned which could be applied to AHS. These will serve as guidance for AHS design, development, and/or deployment, and were provided as inputs to the analyses under the other Precursor Systems Analyses for Automated Highway Systems (AHS) tasks.

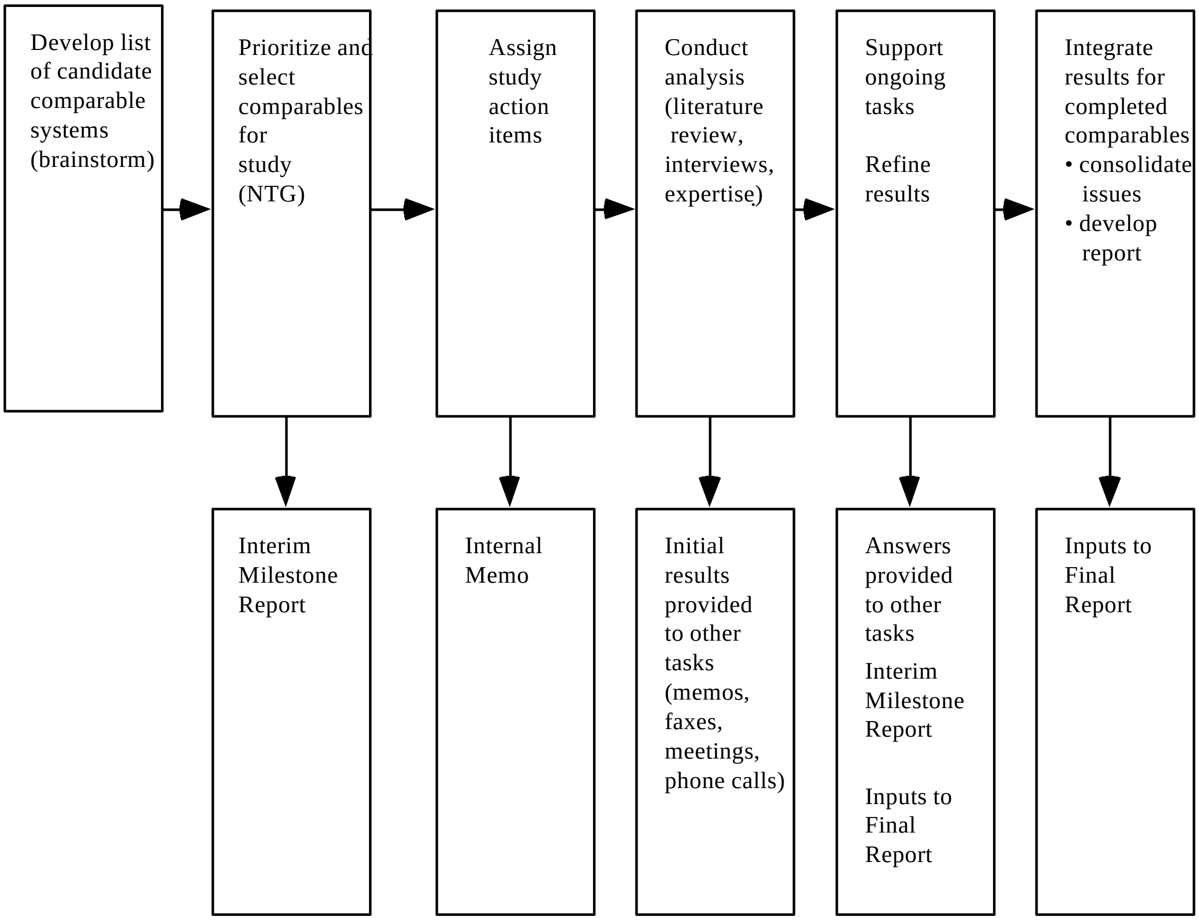
The remainder of this volume contains the technical results of the Comparable Systems Analyses Task. An overview of the methodology which is presented in Section 3.1, and Section 3.2 presents detailed results from each comparable system studied. These comparable systems are organized within four categories of comparable systems: those that are highway-based (e.g., HOV lanes, tunnels); those dealing with drivers and vehicles (e.g., cruise control); those that are concerned with non-automobile-based transportation (e.g., commercial flight); and those that are not transportation related (e.g., automated teller machines). Section 4 presents conclusions for the comparable systems analyses including those that are comparable system specific, and overall integrated conclusions. Sections 5 and 6 contain referenced literature and a comprehensive bibliography, respectively. A summary of referenced articles in presented in Appendix A. Appendix B contains case studies from a report titled: *The Law and Automated Highway Systems,* which provides summary accounts of litigation associated with cruise control, automatic braking systems (ABSs), and air bags.

3.0 TECHNICAL DISCUSSION

3.1 OVERVIEW OF ANALYSIS METHODOLOGY

The approach taken for this task maintained a high-level perspective. Brainstorming, literature review, and personal contacts/interviews with experts were applied as appropriate. The analysis process is summarized in figure 1.

i.Figure 1. Comparable Systems Analyses Approach Overview



Each step taken [so reader can identify with verb lead-ins] is discussed in more detail below:

- Enumerated potential comparable systems and determined the focus of relevance for each. This began with the list of potential comparable systems shown in table 1, which was developed during a brainstorming session held at the first Team coordination meeting and refined through subsequent analysis and iteration. We also reviewed the results of the comparable systems studies conducted on the human factors Design of AHS Project by the Honeywell Team. This was done to avoid duplication of effort.

Table 1. Initial List of Candidate Comparable Systems

Candidate Comparable Systems - Highways		
Comparable System	**Relation to AHS**	**Tools/Approach**
Introduction of HOV lanes and reversible lanes	• Driving behavior change required • Driver education required • Public acceptance • Safety implications	• Knowledge of Team members • Interviews of DOT personnel • Review of literature • Safety data
Introduction of freeway metering	• Driving behavior change required • Driver education required • Public acceptance • Safety implications	• Knowledge of Team members • Interviews of DOT personnel • Review of literature • Safety data
Toll collection booths on turnpikes	• Effect on flow • Models for relating booths (automatic and manual) required to flow required (relate to check-in) • Source of revenue • Public acceptance (especially when first introduced) • Safety Implications	• Knowledge of Team members • Interviews of DOT personnel • Review of literature • Safety data
Interstate implementation	• Driving behavior change required • Driver education required • Safety implications	• Knowledge of Team members • Review of literature • Safety data
Highway tunnels	• Restricted access for maintenance • Surveillance/operational requirements • Effect of and approaches to malfunction management • Safety implications	• Knowledge of Team Members • Interviews of DOT personnel • Review of literature • Safety data
Paving roads	• High infrastructure that yielded high payoff • Environmental impact • Public acceptance	• Review of literature
Candidate Comparable Systems - Other Transportation		
Comparable System	**Relation to AHS**	**Tools/Approach**
Commercial flight	• Public acceptance • Public wilingness to pay for service	• Literature review
Regulation of trucking industry	• Interjurisdictional issues • Potential AHS regulation requirements	• Literature review • Interviews of experts • Knowledge of Team members
High speed train	• Public acceptance • Safety precautions	• Literature review
Planning/building mass transit systems	• Estimating ridership • Locating entry/exit points and requirements • Public acceptance during planning and construction	• Literature review • Interviews of experts • Knowledge of Team members
Airport closes down	• Public acceptance • Notification of travelers	• Literature review

Table 1. Initial List of Candidate Comparable Systems (continued)

Candidate Comparable Systems - Other Transportation		
Comparable System	**Relation to AHS**	**Tools/Approach**
Operation of air traffic control system	• Approach to dynamic control of independent vehicles (e.g., similar to cueing for landing) • Approach to scheduling and managing vehicles across system	• Literature reveiw • Knowledge of Team members
Autopilot/coupled landing systems/automatic formation flight, terrain-following flight	• Public acceptance • Transitions between automated and manual control • Technical approaches	• Knowledge of Team members • Literature review
Aircraft with bigger engines	• Public acceptance of increased noise	• Literature review
People movers	• Entry/exit of individuals to/from lock step system • Public acceptance	• Knowledge of Team members • Literature review
Cruise control and ABS brakes (and airbags)	• Public willingness to purchase equipment • Liability implications • Driver actions required to initiate	• Knowledge of Team members • Review of literature
Ferry boats, car trains, and car washes	• Communication to coordinate movement of vehicles • Inefficiencies	• Literature review • Interviews of experts • Observation
Use of seatbelts	• Compliance with rules of use	• Knowledge of Team members
Candidate Comparable Systems - Non-Transportation Related		
Comparable System	**Relation to AHS**	**Tools/Approach**
First use of elevators	• Public acceptance	• Literature review
Intelligent spacing of elevators	• Where to locate entries/exits for synchronized AHS • Platoon management • Performance measurement	• Literature review (what algorithms used, parameters optimized, how success is measured)
Ski lift and foot races	• Entry/exit of individuals to/from lock step system	• Literature reveiw • Interviews of experts • Observation
Introduction of color TV and HDTV	• Interdependencies between infrastructure development and public willingness to pay for service	• Knowledge of Team members • Literature review
Office, factory, and military robots	• Public acceptance • Safety and reliability	• Literature review
Personal information databases (e.g., telephone network, credit cards, credit agencies)	• Privacy issues	• Literature review
Bank ATMs	• Public acceptance • Public user interfaces	• Literature review • Interviews of experts

Introduction of telephone area codes and postal 5- and 9-digit ZIP codes	• Public acceptance • Public education required	• Literature review • Interviews of experts

Table 1. Initial List of Candidate Comparable Systems (continued)

Candidate Comparable Systems - Non-Transportation Related		
Comparable System	**Relation to AHS**	**Tools/Approach**
Office automation and personal computers	• Public acceptance • Changing ingrained behaviors • Public user interfaces • Need for standardization vs. market forces	• Knowledge of Team members • Literature review • Interviews of experts
Introduction of CDs, replacing phonograph records	• Industry retooling and transition • Marketplace transition • Public acceptance	• Literature review • Interviews of experts
Time-ordered reservation systems	• Demand management	• Literature review • Interviews of experts

- Prioritized and selected comparable systems for analysis. This was accomplished by applying the nominal group technique (NGT) following the brainstorming session held at the first Team coordination meeting. This nominal group analysis involved development of a matrix of all comparables crossed with the 16 task areas. All task leaders were asked to rate the relevance of each comparable to the various tasks. A 5-point scale was applied, with 5 indicating highly relevant with important lessons to be derived and 1 indicating very limited value, don't study. The results were compiled to indicate those comparables that were consistently rated high across task leaders, and to indicate the task areas that were most relevant. Task area leaders also indicated specific resources and expertise available within their respective organizations that could be brought to bear during the study.

- Assigned resources and authorized studies. Those comparable systems studies given the highest priority during the NGT described above were given priority for more in-depth analysis. Resources, authorization, and guidance for further study were given on the basis of the priority rankings determined. Team members were assigned to perform the studies on the basis of their particular expertise relative to the particular comparable systems. Those comparable systems rated highest were studied in greatest depth. Those rated low were studied at a very high level or altogether discarded as a comparable system.

- Conducted studies. The selected comparable systems were analyzed to determine lessons learned that can be applied to the AHS. The studies involved reviewing appropriate literature, small group brainstorming sessions, and personal contacts with experts relative to the comparable systems. In some cases, lessons learned were developed directly from the knowledge of a Calspan Team member.

- Supported ongoing PSA tasks. The results of the analyses were provided to other PSA of AHS task leaders as appropriate, based on relevance to the respective tasks. This was done via internal memorandum, draft interim report documentation, and informal personal contract.

- Integrated and documented results. The results of all analyses conducted during this task were documented. Issues were summarized with respect to the individual comparable systems studied, then analyzed and documented in an integrated fashion. The final issues are also being documented using the issue/risk database. Reference to detailed analysis data and documentation in the database allows efficient access to supporting data and documentation.

3.2 ANALYSIS RESULTS AND DISCUSSION

3.2.1 Highway-Based Systems

3.2.1.1 HOV (High-Occupancy Vehicle) Facilities

3.2.1.1.1 Introduction

Urban and suburban traffic congestion has become the nation's major transportation issue. Peak-hour congestion frustrates motorists, reduces productivity, and incurs significant delay costs. On selected corridors commuters are offered predictable reduced travel time using freeway preferential travel lanes if they will change their travel mode to bus or van/carpooling.

The concept of preferential lane use on freeways has the attention of AHS proponents who see the conversion of existing HOV lanes to AHS use as the starting point for deployment. Deployment of HOVs has experienced many of the issues associated with AHS:

- Entry / exit
- Transit use
- Malfunction management
- Deployment
- Safety
- Institutional/social

HOV lanes were first implemented in the late 1960s and early 1970s due to growing concern about urban highway congestion. HOV strategies grew in times of limited financial resources and right-of-way availability. Some of the initial projects include the exclusive bus lanes on the Shirley Highway in Northern Virginia in 1969 and the Los-Angeles-San Bernardino Freeway Busway in 1973. Buses were the only vehicles allowed to use the HOV facilities during the initial stages, with carpools and vanpools allowed later. HOV facilities differ in design and operation, but they all have similar purposes. As of April 1990, there were 40 HOV facilities in operation in North America.

3.2.1.1.2 Approach

Information sources were obtained from a review of HOV literature and from Parsons Brinckerhoff HOV project papers and reports including their manual,*"High-Occupancy Vehicle Facilities: A Planning Operation and Design Manual."*

3.2.1.1.3 Results

HOV Objectives

There are several objectives that appear to be common among HOV facility projects. The main objectives of an HOV facility are to reduce congestion, improve the capacity of the highway system, and improve safety. These objectives are achieved by altering highway designs or operations and providing priority treatment for high-occupancy vehicles. The results of priority treatment are travel time savings and increased travel time reliability. As incentives to use HOV facilities, these service improvements increase highway efficiency by placing more people in fewer vehicles. The goal of implementing HOV facilities is to increase capacity on congested highways for a relatively low cost. The scope of these projects can range from restriping lanes or using the shoulder for HOV use, to long-term improvements such as constructing exclusive HOV lanes along highway right-of-ways.

Adding an HOV lane can increase highway efficiency in at least four ways: (1) by increasing people moving-capacity of the facility, (2) offering high-speed travel to more people, (3) providing incentives for people to carpool, and (4) decreasing vehicle operating costs. The goals of HOV facilities are very similar to the goals and objectives of AHS. Increasing safety and reducing congestion while providing comfort to the commuter are major goals of AHS. With goals similar to AHS, HOV facilities can provide insights into the successes AHS can enjoy and the pitfalls it should avoid.

There are many ways to fulfill the objectives of HOV facilities. Batz provides a list of 19 treatments; improvements designed to give car-poolers, van-poolers, and bus riders preferential treatment over single-occupancy vehicles (SOV), that can be implemented as part of an HOV facility.(Batz) These treatments can be broken into four categories: Economy, convenience, space, and time. *Economy Treatments* attempt to make a particular trip less expensive for the HOV user; *Convenience Treatments,* attempt to make a particular trip easier and more convenient. *Space Treatments* reserve an area for HOV users and require non-users to choose another route. *Time Treatments* reduce HOV users' travel time without requiring non-users to change routes. HOVs are given preference, but non-HOV users share the highway resources. Table 2 lists preferential treatments for HOV users provided by Batz.

Economic Treatments. Preferential toll charges have a marginal effect on increasing carpools. This method directly benefits HOV users, but it reduces revenue and toll operators are reluctant to implement it. This method may increase positive public perception of HOV facilities and could be included with AHS to achieve the same ends. Preferential freeway congestion pricing has not been implemented in the United States, and limited conclusions can be drawn from the preferential parking projects that have been implemented.

Table 2. HOV Preferential Treatments

Treatment	Description
Economic Treatments: • Preferential toll charge • Preferential freeway congestion price • Preferential parking price	• Reduced toll for HOV users. • Fee charged for SOV users during congested periods. • Reduced parking fee for HOV users.
Convenience Treatments: • Park-and-ride lot • Preferential parking	• Centralized lot for HOV users. • Reserved parking in most desirable spaces for HOVs.
Space Treatments: • Exclusive freeway ramp • Exclusive HOV lanes or roadways • Transit mall	• Existing freeway ramp reserved for HOV users. • All automobile traffic restricted to HOV. • Street reserved for transit users.
Time Treatments: • Counterflow freeway preferential lane • Concurrent-flow freeway preferential lane • Signal preemption • Exclusive bypass ramp • Toll facility preferential lane	• Freeway lane from off-peak direction used to carry peak direction HOV traffic. • Freeway lane from peak direction lanes dedicated to HOV traffic. • Traffic signal control gives preference to transit vehicles. • Ramp metering bypass ramps for HOV users. • Reserved toll booth for HOV vehicles.

Convenience Treatments. Park-and-Ride lots have been found to reduce energy use, vehicle miles traveled, and operating costs. Coordination of AHS with park-and-ride lots could help integrate AHS within an intermodal transportation system.

Space Treatments. Dedication of highway lanes to HOV use has led to more efficient use of highway resources. Exclusive freeway ramps also appear to have had a positive effect on increasing carpools and/or bus use. Exclusive freeway ramps may be useful for AHS, especially if they lead exclusively to the automated section of the road.

Time Treatments. Separate roadways, counterflow, and concurrent flow lanes have succeeded in increasing carpool and bus use, which reduces congestion. Furthermore, bus reliability increased and travel times decreased, which reduced emissions and energy use. Separate roadways and, potentially, concurrent flow lanes could be used to implement AHS. Safety is a concern with the counterflow and concurrent-flow lanes. Many of the problems experienced with these approaches occur during the off-peak hours, perhaps because drivers mistake the preferential lane for general highway use. Accidents in counterflow and concurrent-flow lanes create major problems for the system as a whole, since the traffic has to be redirected back to the general highway lanes. Safety is also a major concern for these design approaches to AHS because an incident in an automated lane leaves no place to redirect the automated flow of traffic.

Exclusive metering bypass ramps are in abundant use across the nation. Carpool and bus ridership both increased as a result of their use. However, violations are a problem with this treatment, some reported as high as 50 percent. (Batz) These ramps could be useful in an AHS in RSCs that share right-of-way with non-AHS traffic (e.g., 11 or 12). Signal preemption improves travel time, which improves reliability and reduces transit company costs.

One provision of HOV is that it adds an extra lane to the present system. The purpose of HOV strategies is not to penalize SOVs, but to reward HOV users. By adding a lane to the highway (when this is possible), the current congestion does not have to suffer from one less lane, but rather is relieved as more vehicles use HOV lanes. Likewise, AHS should, when possible, also add a lane to the highway. This feature of HOV detracted from its success in that removing a lane of traffic for HOV has often proved unsuccessful.

HOV Configurations

HOV facilities supplement existing freeways by providing preferential lanes using the following five AHS Comparable Configurations. The first four are located within the freeway Right-of-Way and the last is generally within a separate ROW.

- Barrier Separated—Lane(s) physically separated by barriers from other freeway lanes to operate portions of the day on a reversible-flow basis (AM inbound, PM outbound) or two-way (bi-directional) basis. This type of facility provides a high degree of security (access control, safety), but occupies a wider space for barrier and breakdown offset. There are also problems for incident management.

- Buffer Separated—Separation of one or more feet (without physical barriers) to operate in the same direction as adjacent mixed-flow lanes during portions of the day. This facility is usually the inside lane adjacent to the median barrier.

- Non Separated—A designated freeway lane, usually located adjacent to the median barrier as an inside lane or located on the outside lane or shoulder. Operates in the same direction as adjacent lanes for portions of the day.

- Counterflow—A designated freeway lane(s), usually the inside lane of off-peak direction, separated from the off-peak travel lanes by insertable plastic posts or movable barriers. Operates only during peak-hour period.

- Independent—A road, usually two lanes wide, that operates as a busway. These can be uni-directional or bi-directional.

Evaluation Techniques

Evaluation of HOV projects has been difficult because of a lack of before-and-after data and poorly defined goals. Inadequate before-and-after data is not uncommon among transit projects. Some of the data problems include the lack of “before” data, limited “after” data, and non-uniform measures of peak traffic periods. A reason for this lack of data has been limited availability of funds. Furthermore, evaluation measures to determine the effectiveness of the project are frequently absent. Many HOV projects have used general evaluation criteria such as a reduction in travel times for commuters. However, there is no agreed level against which this evaluation can be compared. Subjective evaluation measures such as “improve” or “increase” are not adequate for assessing effectiveness of HOV facilities. Additionally, early studies have concentrated solely on the HOV lane, without considering the impacts on non-HOV users and the general operation of the entire system.

In order to effectively evaluate an HOV facility, three steps should be followed. First, a clear set of objectives and goals should be set. This is the most important step in evaluating a project since the remaining steps are used to determine if the goals are met. Second, define measures of effectiveness (MOEs) to assess if the objectives have been met. Table 3 gives some example objectives and MOEs for evaluating HOVs taken from Turnbull. (Turnbull) Third, identify the information required to evaluate the HOV project against the MOEs. Without appropriate data, it cannot be determined if objectives have been realized. These three steps should be combined into developing a study design. The combination of project goals, measures of effectiveness, and data requirements can be compared with funding and other limitations of the project to ensure that the project can be completed. Finally, data collection is an important part of evaluating the project. “Before” data must be collected so that the impact of the HOV facility can be evaluated. “After” data must be collected to compare to the “before” data. When the before-and-after data are evaluated, the effectiveness of the HOV facility can be evaluated. The program should also be equipped with a means of ongoing monitoring and evaluation.

These same steps apply to evaluating the effectiveness of an AHS. The evaluation begins before the project has been implemented, with collecting “before” data. Only after clear goals have been set should AHS implementation continue. Many transportation projects have enjoyed only limited success because the project’s goals and objectives were undefined while the program was being implemented. Morgantown PRT is an example of such a project. Next, a set of thresholds should be set to measure the impacts of AHS. Finally, “after” data must be collected to compare to the “before” data. In order to convince the public and especially politicians that AHS is beneficial, there must be some standard against which AHS improvements will be measured.

Table 3. Sample Objectives and MOEs for Evaluating HOV Facilities

Objective	Measure of Effectiveness
Improve capability of a congested freeway to handle more people by increasing the number of people per vehicle.	Actual and percent increases of person movement efficiency, average vehicle occupancy rate, number of carpools, vanpools, and bus riders.
Increase operating efficiency of bus service.	Improved in-vehicle productivity. Improved bus schedule adherence. Improved bus safety.
Provide travel time savings and travel-time reliability to users of HOV facilities.	Peak-period travel time in HOV lanes should be less than regular freeway lanes Increased travel-time reliability in HOV lanes.
Favorable impacts on air quality and energy consumption.	Reduced emissions, total fuel consumption, vehicle miles and hours of travel.
Increase per lane efficiency of freeway system.	Improvement of peak-hour per lane efficiency of total facility.
No undue impact on operation of main lanes.	Level of service on the freeway should not drop.
Facility should be safe and not impact unduly on the safety of the general-purpose freeway.	Number and severity of accidents for HOV and general lanes. Accident rate per million vehicle miles of travel. Accident per million passenger miles of travel.
Public support.	Support among users, non-users, public, policy-makers. Violation rates.
Cost-effective transportation improvement.	Cost-benefit ratio.

Source: adapted from Turnbull et al.

Cost-Benefit Analysis

Benefits of HOV lanes include travel-time savings, reduced vehicle operating costs due to smoother operation of the freeways, reduced costs through ridesharing, and the ability to arrive at destinations without delay. Many of the benefits of HOV facilities are the same for AHS. The costs associated with HOV lanes include construction and maintenance of the facilities, enforcement of lane use, and the subsidy required to provide additional transit and ridesharing services. Likewise, many of the costs associated with implementing and maintaining HOV facilities compare to the costs of AHS. Henk et al. provide a simplified cost-effectiveness approach to HOV facilities, using the following formula to determine a benefit-cost ratio:

$$P_t=A(1+i)^n - 1 / i(1+i)^n$$

n

P_t = present worth of annual value of travel time savings
A = annual value of travel time savings
i = discount rate
n = number of years of project-life
B/C = P_t / Cost

A benefit/cost value of greater than 1 means that for every dollar spent, the return is greater than one dollar. The discount rate is used in the analysis to reflect the potential value of investing a dollar today rather than spending it. Although Henk et al. determined that an annual benefit equivalent to 7.4% of construction costs would be needed to achieve a benefit/cost ratio of 1.0, they suggest using a conservative value of 10% to achieve the breakeven point. (Henk et al.)

Data collection is extremely important to benefit-cost analysis. The data required for building a cost-effectiveness model is described in table 4.

Table 4. Data Required for Building an HOV Cost Effectiveness Model

Data Required	Explanation
Person-trips	The number of people traveling through the corridor.
Percent preferring peak	If capacity is limited, some people may not be able to travel when they want.
Number of HOVs	Volume of carpools and vanpools.
Lane capacity	Highway capacity 1,800 passenger cars/lane/hr. Arterial capacity 500-700 passenger cars/lane/hr.
Number of lanes	Obvious on freeways, not necessarily on arterial roads.
Relationship between capacity and speed	A capacity of 1,800 cars/lane/hr could mean that traffic is dense and moving slowly, or sparse and moving quickly.
Access times	A travel cost model must take into account travel times to various facilities to fully appreciate the difference between the alternatives.
Total trip length	Total length of a trip has an impact on costs. Vanpool trips tend to be longer than carpool and bus trips. SOV trips tend to be the shortest.
Minimum and maximum speeds	Minimum speeds determine when travelers shift their time of travel rather than experience greater congestion. Raising the maximum speed increases automobile operating costs.
Vehicle operating costs	These are an important part of total travel costs. The American Automobile Association has figured a cost of $.235 per mile in 1985 dollars.
Bus fare	Agency costs are offset by traveler fares.
Parking costs	Vanpools generally have free parking. Carpools have varied costs across the nation.
Construction costs	This is the major cost associated with an HOV facility.
Maintenance costs	Vary from place to place depending on bridges and underpasses. Lanes that take shoulders could increase costs since the shoulder is not available to daytime repair crews, which forces night wages to be paid.
Enforcement costs	HOV lanes require additional enforcement. Law enforcement officers and HOV user enforcement through a telephone number to report violations can be implemented.
Value of time	In past studies, the value of travel time savings has ranged from $3.00 to $10.00 an hour.
Discount rate	The higher the discount rate, the less appealing capital investments become.

Benefit-cost models for AHS would include the same data requirements in order to measure the effectiveness of an AHS program. Hopefully, some lessons can be learned from the lack of available data for HOV. The necessary highway data must be collected prior to implementing AHS so that AHS impacts can be assessed.

Public Perception of HOVs

Positive public perception of HOV facilities is crucial both to their effectiveness and political viability. If the public perceives that HOV facilities will save them time, money, and lives, they will be more inclined to take advantage of the facilities. The increased use of HOV facilities will in turn reinforce and support these perceptions. A survey taken by Jacobson et al. provides results of public awareness of HOV facilities in the Seattle, Washington area. (Jacobson et al.) Table 5 indicates public perceptions on the survey.

Table 5. Public Perceptions of HOV Facilities in the Seattle, WA, Area Based on Survey Results

Questions	Percent Agreeing
HOV lanes save time for users	96%
HOV lanes worsen traffic in other lanes	27%
HOV lanes are unfair to those who do not use them	19.6%
HOV lanes reduce congestion in all lanes	56%
HOV lanes increase the number of accidents	22.1%
HOV lanes reduce air pollution	45.2%

Source: Jacobson et al.

The results of this survey were favorable. The almost unanimous belief that HOV lanes save time for those who use them supports expectations that the number of commuters who use the lanes should increase. The perceptions that these lanes do not increase traffic in the general lanes of the highway; are not unfair to non-users; and do not increase the number of accidents provide reassurance that the general public does not feel HOV lanes create traffic problems. However, the percentages agreeing that HOVs reduce congestion in all lanes and reduce air pollution were not as positive. Since HOV lanes handle such a small percentage of daily trips, their relative impact is seen as insignificant by many. On the whole, the attitude toward Seattle's HOV facility was positive. This positive perception, along with the potential for more cost-effective traffic flow, indicates that the investments in HOV facilities are appropriate.

Problems in attracting users of HOV lanes lie in the distribution and scheduling of trips, together with the requirement that travelers must give up their privacy and control over travel decisions. HOV attempts to remove cars from the highway by promoting the benefits of carpooling. In order for people to travel together, their trips must originate near each other, end near each other, and occur at the same time (for both going and returning). And all these decisions must be made and committed to before the trip. Because these criteria are demanding, HOV lanes usage has been limited.

AHS developers can learn from this survey and the experience of HOV implementations. Public support is critical to the success and future of AHS. It will be important to assess public support and promote positive feelings toward the benefits of AHS. AHS must conform to the needs of the people who are going to use it. Although AHS avoids the complications of carpooling, there are other complicating issues to be considered, including perceived safety. Not only must the resulting system be safe, but the occupant must feel safe. Otherwise, AHS will not be accepted by customers.

Accepted Guidelines for HOV Development

HOV lanes have been in use in the United States for several decades. This experience has led to the development of guidelines for ensuring the success of new HOV lanes. These are documented in the HOV handbook titled: "High-Occupancy Vehicle Facilities; Current Planning, Operation, and Design Practices." (Fuhs, 1990) When first implemented, the HOV's failure rate was about 50%. Today, the success rate is well above 90%. Many of the guidelines that have allowed HOVs to be successful can also be applied to AHS. Some highlights are given below.

A critical aspect for the success of HOV is public acceptance. The public must see the new HOV facility as improving overall traffic flow. Some of the most important factors in this perception are the apparent level of HOV lane use and the impact of HOV facilities on non-HOV lanes. This experience has led to the following recommendations for HOV implementations. First, the number of persons using the HOV (even though the number of vehicles is less) should exceed the number of persons in each adjacent non-HOV lane. Typically, this means that HOV vehicle flow should be in the range of 400 to 800 vehicles per HOV lane per hour unless there is significant bus usage (in which case a lower vehicle flow can be tolerated). In summary, the benefits of increased people movement must be obvious.

A related issue is that HOV implementation should not reduce service on adjacent lanes. It is very difficult for a reduction of service on non-HOV lanes to be offset by the efficiency increase provided by the HOV lane. For this reason, it is highly recommended that lanes be added for HOV use, rather than taking away existing lanes. Because of the importance of this issue, this approach is almost always followed today when HOV lanes are implemented.

HOV treatment is one of several ways to reduce congestion. When HOS=Vs have been planned and evaluated within a larger intermodal transportation plan, they gain public and political support. Intermodal HOV approaches have facilitated HOV success. These lessons also apply to AHS. AHS should be part of a larger transportation system plan. It should be implemented within other transportation modes and its costs and benefits evaluated in this larger context.

These lessons developed as a result of the experience in implementing and operating HOV facilities can, and should be, applied to the development and implementation of AHS.

Why HOV Lanes Work

HOVs work because they increase people moving capability over vehicle moving capacity. The effectiveness of AHS can also be enhanced when combined with HOV treatments. Table 6 compares current experience in moving people using existing transportation systems. It also shows the potential people moving capacity if these approaches are combined with AHS. It can be seen that if AHS is combined with HOV treatments, the potential people moving capacity can easily equal or exceed that of mass transit systems as currently implemented.

Table 6. Comparison of People-Moving Potential
(Highest Achievable, Persons/Hour)

	Existing Facilities (Experience)	***55 mph***	***65 mph***	***75 mph***	**Assumptions**
Current Traffic Mix • *35 mph* • *1.2 persons/vehicle* • *1800 vplph* • *128-ft gap*	2,100	4,400	5,000	6,000	• *1.2 persons/vehicle* • *60-ft gap*
HOV Only (Rt. 55, CA) • *35 mph* • *2.4 persons/vehicle* • *1700 vplph* • *128-ft gap*	4,000	8,000	10,000	12,000	• *2.4 persons/vehicle* • *60-ft gap*
Mixed Traffic Bus Service • *80 buses/hour*	4,000	NA	NA	NA	—
Light Rail Rapid Transit	9,000	NA	NA	NA	—
Heavy Rail Rapid Transit	35,000	NA	NA	NA	—
Dedicated Bus Lane *(Lincoln Tunnel)* • *35 mph* • *48 passengers/bus* • *210-ft gap*	35,000*	115,968	137,136	158,544	• *48 persons/vehicle* • *80-ft gap*

*Significant accordion action due to backup at terminal.

The Lincoln Tunnel Express Bus Lane (XBL) clearly illustrates the potential of enhanced people moving capacity of HOV treatments. The Lincoln Tunnel XBL currently moves 35,000 persons per hour, more than three other (conventional) lanes combined. This is shown in figure 2. It is noted, however, that the terminal facilities handling buses coming out of the Lincoln Tunnel are currently saturated and sometimes lead to accordion affects in the XBL. Improvements in people flow due to AHS treatment would easily overload these existing terminal facilities. Terminal capacity would need to be improved if XBL capacity were increased. Many improvements to these terminal facilities can be easily achieved, however. These include more efficient procedures for moving buses in and out of the terminal, and improved bus designs for quicker loading and unloading. The high flow rates indicated in figure 2 for the Lincoln Tunnel XBL with AHS assume terminal enhancements. Further analyses of the potential AHS application to the Lincoln Tunnel XBL and similar facilities are given in Volume VII, Commercial and Transit AHS Analysis.

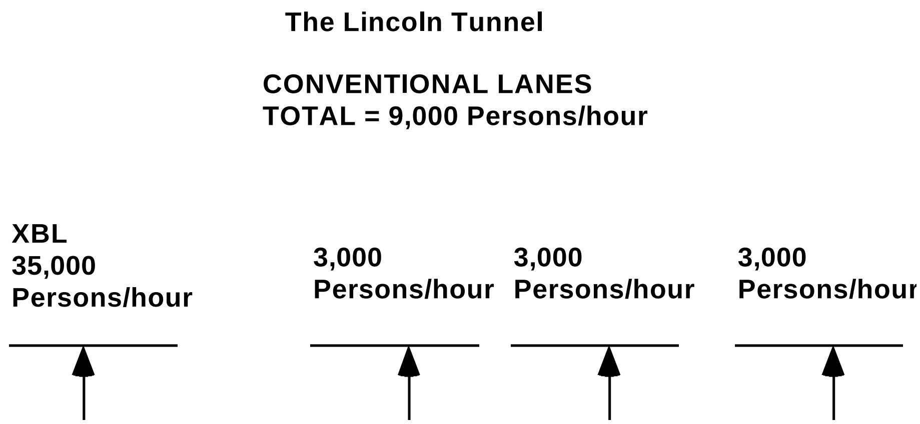


Figure 2. The Lincoln Tunnel Express Bus Lane (XBL) Moves More People Than All Three Other Traditional Lanes Combined

Considering AHS as a tool for enhanced movement of *people* rather than *vehicles*, movement offers potentially great benefits for the U.S. transportation system in congested areas. Such approaches for AHS implementation would be more effective in reducing congestion, and less sensitive to latent demand, when compared to conventional design approaches that emphasize primarily vehicle movement. Approaches emphasizing people movement would also gain greater public support (perhaps including support from environmental groups) and can be achieved in many locations without building any new lanes.

Lessons learned for AHS based on the Calspan Team's analysis of HOV facilities are summarized in table 7.

Table 7. Introduction of HOV Lane Lessons-Learned Worksheet

Guidelines for HOV Facilities	Lessons Learned
Recurring congestion can be relieved by providing multiperson-vehicle reserved lanes, which stress person movement rather than traditional vehicle movement.	A large return from AHS will be transit vehicles. Similarly, an AHS that encourages (e.g., through pricing strategies) or requires HOV use will provide the biggest benefit.
HOV lanes are relatively quick and inexpensive to implement, most often as retrofits into medians or use of existing lanes of congested freeways.	Maximize instrumentation, minimize construction for rapid implementation at the least cost. Emphasize evolutionary approaches building on existing infrastructure.
HOV facilities are appropriate only in urban congested corridors where preference for ridesharing and transit use is high.	A potentially large need and return for AHS investment is when applied to high volume urban / suburban freeways including support for HOV/transit use.

Table 7. Introduction of HOV Lane Lessons-Learned Worksheet (continued)

Guidelines for HOV Facilities	Lessons Learned
HOV facilities serve longer-distance (more than 10 miles) commuting trips to one or limited destinations thus access can be restricted and infrequent.	Limit AHS entry and exits.
HOV lanes are considered only where they will provide reliable travel time reduction in the order of 1 minute/mile or a minimum of 5 minute savings (desirable 8 minutes) for an entire trip.	Evaluation of AHS benefits must consider the entire trip, not just the AHS portion.
Accidents and other non-recurring incidents account for approximately 50 percent of freeway delays. Although incident rates on HOV lanes match mixed-flow traffic lanes, trip time reliability is greater because HOV lanes can be segregated from mixed-flow lane incidents, thus providing a preferential level of service. Incident response to barrier-enclosed HOV lanes is usually accomplished by counterflow travel to reach the incident site, a cumbersome exercise.	Barrier-separated AHS lanes can isolate AHS from the effects of non-AHS incidents. If this approach is taken, approaches for dealing with incidents must be considered.
The number of persons to use HOV lanes should exceed the average number in each adjacent mixed-flow lane in the same direction. Also, initial HOV use should be 400 to 800 vehicles per lane hour, minimum, with lower number acceptable where there is a significant bus use/mix.	The apparent AHS use level will impact public perception. AHS must quickly attract the heavy freeway users (commuters, transit, etc.) to ensure public acceptance. An evolutionary deployment of AHS beginning with mixed traffic should be considered for building the critical user base before dedicated lane deployment.
The person-moving capacity of an HOV lane depends on overall volume mix of buses, vanpool and carpools. The Route 495 Lincoln tunnel bus lane serves 700 to 800 buses per hour representing over 35,000 passengers per hour, which matches the best for transit facilities. Route 55 in California with mostly two or more occupant carpools moves 1,700 vehicles or 4,000 persons per hour.	Special busway use appears to be a prime candidate for AHS. Heavily used HOVs can out-perform expected AHS lanes for people movement, unless AHS traffic includes significant HOV traffic.
Implementing HOV facilities by addition of new lanes to freeways is recommended. Taking away a mixed-flow lane is not recommended. Gains by HOV operation cannot easily offset lower level of service to mixed-flow lanes.	Gains by AHS cannot easily offset lower level of service on other lanes caused by loss of lanes, priority for AHS entry/weave/exit, etc.
HOV treatment is only one of a number of management means to reduce congestion. Its success is enhanced when integrated within an overall improvement program that has both public and political acceptance.	AHS must be planned as an integral component within the overall transportation system.

Table 7. Introduction of HOV Lane Lessons-Learned Worksheet (continued)

Guidelines for HOV Facilities	Lessons Learned
HOV facilities should be implemented only when resources and commitment are made for effective enforcement and incident management services.	AHS requires similar operating services.
HOV facilities implementation should be evaluated for cost effectiveness, measured as benefit/cost compared against other available alternatives and not simply benefit/cost.	The benefit/cost ratio can be used for AHS deployment to set timing for staged implementation and order of priority for service. The benefit/cost for AHS should be calculated relative to alternative transportation modes.
Many HOV facilities are successful due to integration with an overall traveler service including park-and-ride lots, intermodal transfer stations, etc.	AHS must be part of an overall commitment by providing off- roadway support facilities and integration with other transportation modes.
Successful HOV projects have solved commuting problems with a sound operating plan developed in consort with multi-agency involvement, public education, and political support. Failures were the result of poor planning, marketing and operation conspicuous by the lack of public/political understanding/acceptance, underutilization, difficult/expensive operation/maintenance (see Fuhs 1990 for examples).	AHS deployment is a national issue that will extend down to local community issues. Multi-agency involvement, public education, and political support at all levels will be needed.
Demonstration of benefits derived from HOV implementation requires collection of before and after data relating to HOV measures of effectiveness (MOEs).	Collect data relative to AHS MOEs prior to AHS implementation for use in assessing AHS effectiveness after implementation.

3.2.1.1.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of HOV operations are summarized in in Section 4.1.

3.2.1.2 Ramp Metering

3.2.1.2.1 Introduction

Description

Ramp meters are traffic signals on freeway entrance ramps that supply traffic to the freeway in a measured or regulated amount. Meters discharge traffic at a measured rate so that the capacity of a downstream bottleneck is not exceeded. As long as mainline plus ramp traffic demand does not exceed capacity, throughput is maximized, speeds remain more uniform, and congestion related accidents are reduced.

Ramp meters can also regulate ramp traffic to break up platoons of vehicles that have been released from nearby signalized intersections. The mainline, even when operating near capacity, can accommodate merging vehicles one or two at a time. However, when groups of vehicles attempt to force their way into traffic, the resulting turbulence causes mainline flow to break down. Reduced turbulence in the merge zones also leads to reduced sideswipe and rear-end accidents associated with stop-and-go, erratic traffic flow.

Various forms of ramp control were used experimentally in Detroit in the early 1960s. In Chicago, ramp meters on the Eisenhower Expressway have been in operation since 1963. Los Angeles metering, which began in 1968, has been continually expanded to over 1000 meters in operation today—the largest ramp metering system in the country. Currently ramp meters are in operation in 20 metropolitan areas in North America. These metering systems vary from fixed time operation at a single ramp to computerized control of every ramp along many miles of a freeway. One measure of the effectiveness of metering, perhaps, is that every existing system has been, or is proposed to be, expanded.

Rationale for Study

Ramp metering fundamentally changed the way the freeway system is operated. In fact, one could argue that prior to ramp metering, freeways were not operated at all. After construction, Government took virtually no role in operations aside from any required enforcement and maintenance activity. Today, there is a rapidly growing awareness that the freeway network (as well as surface roadways) must be controlled to some degree to ensure efficiency of use. In effect, the automated highway is a different way to operate freeway lanes. For this reason, ramp metering represents a comparable system for evaluation.

Comparable Features

Several ramp metering features relate to automated highway issues. These issues are associated with the following PSA of AHS tasks:

- AHS Safety Issues
- Commercial and Transit AHS Analysis
- AHS Impact on Surrounding Non-AHS Roads
- Institutional and Societal Issues
- AHS Entry/Exit Implementation

3.2.1.2.2 Approach

Analysis was conducted to identify and analyze the ramp metering features comparable to those likely to be encountered in an AHS. Four main apporaches were used:

- Available literature was reviewed.

- The Team's first-hand experience in operating the INFORM Traffic Management System (78 ramp meters) was applied.

- First-hand experience with the design and implementation of several ramp metering systems was applied, including those in Detroit, Northern Virginia, Connecticut, and New York.

- Anecdotal reports from other operating agencies were obtained.

Each comparable feature of ramp metering was analyzed with respect to:

- Issues that emerged and were dealt with during design or operation of the ramp meters.
- How issues were resolved in the ramp metering context.
- How lessons learned relate to AHS.

3.2.1.2.3 Results

The concept of ramp metering met and still meets considerable resistance because of the way it changes the public's perception of freeway use. In virtually all areas where ramp metering has been implemented, this resistance was successfully overcome, and substantial benefits were obtained. These benefits ultimately led to enhanced public acceptance.

Many lessons learned in the development and implementation of ramp metering can be applied to AHS, as summarized in table 8.

3.2.1.2.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of ramp metering operations are summarized in Section 4.1.

Table 8. Ramp Metering Issues: Lessons Learned Worksheet

Ramp Metering Issue	Ramp Metering Resolution	Lessons Learned For AHS
Requires vehicles to stop on ramp. Ramps were designed to allow vehicles to enter mainline at highway speeds. The requirement for stopping shortens the available distance for accelerating to highway speeds.	Ramp metering safety has generally not been an issue. The distance available for accelerating between the ramp signal and the merge area has been adequate. In fact, most studies claim safety improvements due to one-at-a-time entry into mainline vehicle stream. Often agencies improve ramp geometries when installing ramp meters to ensure adequate acceleration distance from ramp meter stop line, when necessary. Examples include I-395 in Northern Virginia and I-476 in suburban Philadelphia.	Changes in ramp operations due to check in, check out, vehicle rejection, queues, etc. must be accounted for in geometric design. Adequate acceleration distance must be provided for entry to AHS and possible re-entry into conventional lanes. Standards for these distances are found in AASHTO (1990).

Table 8. Ramp Metering Issues: Lessons Learned Worksheet (continued)

Ramp Metering Issue	Ramp Metering Resolution	Lessons Learned For AHS
Non-standard use of red/green ball. Red/green is not used to assign right-of-way as with conventional traffic signals. Green ball does not guarantee right-of-way at freeway merge.	Initially, many traffic engineers thought that using a conventional traffic signal to meter traffic rather than assign right-of-way would confuse motorists. Experience has shown that motorists readily adapt to metering signal operation.	Motorists can adapt to new displays or unconventional use of displays if required for AHS operation. However, use should be standardized throughout all AHS applications and made as compatible with existing conventions as possible.
Omission of yellow clearance intervals; i.e., ramps signals display only red and green.	Some traffic engineers thought that to conform to the Manual of Uniform Traffic Control Devices, a yellow interval should precede the red ball. However, the short cycle, (as little as 4.5 seconds) virtually precludes use of yellow clearance. Drivers readily adapted to this operation, without any apparent safety implications.	Same as above.
Initiation of ramp metering. Since metering is usually off during off-peak hours, drivers may be confused when the metering signal is first turned on.	• Drivers are alerted to metering operation by a flashing yellow beacon initiated just before the metering signal is turned on. • Metering is not initiated when there is a vehicle between the head of the ramp and the metering signal.	If AHS operation is not continuous (e.g., due to weather, construction, malfunction, etc.), initiation and termination of automated operation must be clearly communicated to drivers.
Stopping on ramps with downgrades may lead to accidents. Ramps with upgrades may cause more sluggish acceleration, particularly for commercial vehicles.	Design of metering systems must consider ramp geometries. Also metering can be turned off during inclement conditions.	Ramp designs must be adequate for all maneuvers associated with AHS operation. For example, adequate acceleration distance will be required if AHS lanes operate at higher speeds than current speed limits.
Queues at the metering signal can back-up to the surface street and interfere with local circulation.	When a queue extends to a queue detector, system can increase metering rate or shut off metering. Surface street lanes can also be used to accommodate queues.	Adequate storage must be provided for all contingencies of AHS operation, including shutdown of AHS operation, or insufficient number of available slots.

Table 8. Ramp Metering Issues: Lessons Learned Worksheet (continued)

Ramp Metering Issue	Ramp Metering Resolution	Lessons Learned For AHS
In some locations, meter bypass lanes for HOV traffic have been established to encourage HOV use. Single occupant vehicles (SOVs) may illegally use the HOV bypass lane. Enforcement has been a concern.	Spot enforcement appears to resolve this problem.	Enforcement provisions may be required to prevent unauthorized use of AHS lanes.
Trucks under load, not wanting to stop, may not obey the metering signal.	In effect, queues make metering signal self-enforcing.	Attention to the special needs of commercial vehicle operations may be required at AHS ramps.
Perception that ramps closer to downtown will be metered more strictly than outlying ramps (equity concerns).	Some projects encountered resistance due to this perception. Some local politicians in northern Virginia brought suit to enjoin the state from metering the Shirley Highway. Suit was dismissed. Metering has been generally accepted without controversy.	Location of AHS ramps could generate controversy and local opposition. Unequal access to AHS could be raised as an issue. Also, AHS ramps could draw additional traffic to feeder streets. Mitigation could be required.
Public Acceptance/Education	Some locales have rejected metering due to public resistance, most notably Toronto. Public education can mitigate this type of reaction. For example, on Long Island, a very gradual implementation of ramp metering resulted in public acceptance.	Incremental deployment of AHS may be required to gain public acceptance.
Ramp metering restricts access to a formerly free flowing ramp. Concept is to store vehicles on ramp to prevent reduction of throughput on mainline.	Proved effective. Public accepts waiting at ramps if better mainline flow is achieved.	Public must perceive overall benefit to both AHS and non-AHS users.
Drivers will not wait longer than about 15 seconds for green signal.	Minimum practical metering rate of about 4/minute or 240/hour. Drivers must perceive system is "doing something " Otherwise they conclude there is a malfunction and may violate a control signal.	If access to AHS lane is temporarily delayed, suspended or halted, timely information must be conveyed to driver.

3.2.1.3 The U.S. Interstate Highway System

3.2.1.3.1 Introduction

The development and implementation of the interstate highway system involved massive investments of public funds and provided dramatic improvements in vehicle-based travel in the United States. This system was built over many years beginning in the early 1940s with accelerated development efforts throughout the 1950s and 1960s. A few interstate development projects continue today.

The interstate highway system was initiated in response to an immediate highway transportation need. Pre-existing inter-city roads were poorly designed and in many areas were unsafe. Highways that could separate vehicles traveling in opposite directions, limit the requirements for negotiating steep grades and sharp turns, and eliminate problems of crossing traffic (automotive and railroad) were highly desired and needed. The proposed interstate highway system offered these features.

There are many parallels between the development of the interstate highway system and AHS. Both involve Government leadership in transforming a vision for improved highway design into reality; large investments for development and implementation (interstate investments were larger than those needed for AHS); improvements in roadway safety, efficiency, and convenience; and the requirements for public education to accommodate changes in driving behavior. This section relates milestones in the development of the U.S. interstate highway system to issues associated with the design, development, and implementation of AHS.

3.2.1.3.2 Approach

The approach taken during this part of the study relied exclusively on a review of available literature. Several articles describing the development of the Pennsylvania Turnpike, one of the earliest components of the interstate system, were reviewed along with articles and books dealing with the development of the larger U.S. interstate system. (Heppenheimer, 1991; Robinson, 1971; Leavitt, 1970; Kelly, 1971; and Davies, 1975)

3.2.1.3.3 Results

The design and development of the interstate highway system was planned and implemented over many years, resulting in many successes as well as many problems that had to be overcome. This section attempts to identify lessons for development of AHS that can be derived from experiences in developing the interstate highway system.

Major milestones in the implementation of the interstate highway system are outlined in table 9, along with lessons learned for AHS.

There are also safety issues and lessons to be learned from the existing interstate highway system that can be applied to the development of AHS. The implementation of the interstate highway system involved the development of new ways of driving, including requirements for developing new driving skills (e.g., at speed merging, vigilance during low event driving). Team members have investigated existing freeway accident data to better understand the relationship between interstate design features and accidents. To the extent that these or similar conditions will exist on an AHS, design guidelines can be derived. For example, there are similarities between AHS check-out and coming to toll booths at the end of a thruway segment, and issues of driver fatigue as a result of low event driving could be exacerbated by AHS. This is discussed in Volume IV, Chapter 2, Automated Check-Out.

3.2.1.3.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of the interstate highway system are summarized in Section 4.1.

Table 9. Evolution of the Interstate Highway System Lessons Learned Worksheet

Interstate Development Milestone	**Lesson Learned for AHS**
• Initial Government funding for an "interstate" highway put in place in 1916 ($75M with equal state match required).	
• 1st median-separated highway built in 1922, the NYC Bronx River Parkway • 1st cloverleaf exchange built in 1928 in Woodbridge, NJ • German autobahn network was under construction in 1929 (1260 miles planned) • Plans for Pennsylvania Turnpike proposed in the early 1930s called for use of unused railroad right-of-way. • 1st US freeways were built, or under construction, in 1939: the Merritt Parkway (open) and the (then 160 mile) Penn. Turnpike (under construction.). • In addition to satisfying needed improvements in highway safety, the Pennsylvania Turnpike garnered political support on the basis of national defense in that munitions could be transported from the Pittsburgh steel mills to factories on the East Coast. Labor was provided from the PWA job creation program during the depression. Political advocacy from President Franklin Roosevelt was instrumental.	• Good ideas, with reluctant and intermittent support, start small and develop over many years. • Political support for transportation programs can be broadened if projects can be shown to enhance national defense. • AHS advocacy from high levels of Government can facilitate success.
• Funding for a multi-lane, divided-highway interstate network proposed and defeated in 1938 and in 1941.	
• The proposed interstate highway map was developed in 1941. This map forms the basis for today's interstate system.	

Table 9. Evolution of the Interstate Highway System Lessons Learned Worksheet (continued)

Interstate Development Milestone	Lesson Learned for AHS
• The National System of Interstate Highways Bill passed in 1944, but was insufficiently funded and focused on conventional roads. Many porkbarrel projects were funded.	• Funding for AHS should be sufficient and specific to the goals of AHS
• Many states took the initiative after WW2 using bonds to build toll highways (Maine was in 1947 followed by PA, NJ, and NY).	
• Construction proceeded with little opposition (e.g., 240 buildings torn down or moved in Elizabeth, NJ with little opposition), but in the 1960s, groups opposing freeway development halted specific development plans.	• Historical lessons learned must be tempered with knowledge of prevailing attitudes
• NJ Turnpike was an immediate success -The toll for the entire length ($1.75) equaled cost of gas for trip -Travel time from NYC to Wilmington was reduced from 5 to 2 hours. -Turnpike use was 51% higher than predicted. -Turnpike revenues were 28% higher than predicted.	• Public acceptance of AHS will be facilitated by obvious/desired transportation benefits
• Toll roads were a success but were restricted to high volume traffic areas — Rural implementations met with failure.	• Use of tolls for AHS could limit viable implementation to high volume traffic areas.
• Safety needs together with the desire for faster inter-city travel were the paramount considerations and motivations for early freeway development.	• AHS can be sold on the basis of faster, safer highway travel.
• In 1955 a bill that would raise $25B through sale of bonds to develop an interstate highway system was defeated. The Senate was not willing to borrow for this purpose.	• Requirements for high levels of Government borrowing could scuttle AHS projects.
• The Federal-Aid Highway Act of 1956 was financed by a modest gasoline tax increase. This bill was also sold as a national defense development. It promised something for everyone without imposing high taxes on truckers and passed 89 to 1 in the Senate. • Funds generated by highway users would pay for the system.	• Pay-as-you-go financing is preferable to borrowing • If AHS benefits can be identified for numerous constituencies, political support will be more available.

Table 9. Evolution of the Interstate Highway System Lessons Learned Worksheet (continued)

Interstate Development Milestone	Lesson Learned for AHS
• In the 1960s many highway projects met with public opposition (especially in California)	• Public and community support for AHS will be important (especially in more affluent, well organized communities).
• The interstate was implemented in urban areas without system level planning. This led to unforeseen problems of congestion.	• AHS must be planned to merge into the overall transportation system. • The impact of AHS on non-AHS roads and facilities must be considered.

3.2.1.4 Highway Tunnels

3.2.1.4.1 Introduction

Highway tunnels typically have narrow lanes, no shoulders, minimal off-set from wall barriers, low ceilings and heavy traffic flow; a horror to drive through with regulations for every move. Hopefully AHS will not model this type of driving experience. The confined tunnel space results from high construction costs; therefore, the following features are built into the tunnel to ensure the same degree of safety expected on an open highway:

- Mechanical ventilation system
- Fail-proof lighting system
- Fire detection and suppression system
- Traffic surveillance and control system
- Over-height vehicle and hazardous cargo control
- Evacuation passageways and stairwells.

The early deployment of AHS will most certainly employ many of the tunnel Traffic Management System (TMS) capabilities. In fact, many existing tunnel TMS operating agencies will eventually manage both AHS and non-AHS traffic.

This section outlines approaches to tunnel TMS and relates them to the following AHS operations:

- Vehicle/driver check in/out

- Monitoring traffic flow
- Traffic flow control
- Motorist information system
- Malfunction (incident) management

Although different in design concept from most highway tunnels, the Chunnel (Channel Tunnel) being developed between England and France offers interesting comparisons to AHS. The Chunnel is a very large, infrastructure-intensive tunnel project with mixed public support. On the basis of the Chunnel experience, we can offer a few comparisons and lessons for AHS.

3.2.1.4.2 Approach

This comparative analysis of highway tunnels has been drawn from the expertise of Parsons Brinckerhoff, who have designed numerous tunnels including physical design and operational procedures. Insights from an article also provide comparisons to AHS issues.

3.2.1.4.3 Results

The applicability of highway tunnel management techniques to the design and operation of AHS is summarized in table 10; lessons from the current Chunnel between England and France, in table 11.

Table 10. Highway Tunnels Lessons Learned Worksheet

Guidelines for Tunnel Facilities	Lessons Learned
Over-height vehicles approaching tunnels are detected when they break an infrared light beam projected across the roadway. This activates a sign instructing the truck to enter an inspection station. If the illegal truck does not stop for inspection, it will break a second light beam which activates signs/signals to stop all traffic entering the tunnel.	• Long lead and/or special stations are needed to detect and prohibit entry to AHS by non-AHS vehicles. • Procedures for dealing with unauthorized AHS access must be developed.
Traffic approaching and passing through the tunnel will cross pavement-embedded loop detectors or overhead mounted microwave/video detectors which measure flow or stoppage, and vehicle speed and length (for type of vehicle classification auto, truck, etc.).	Traffic flow monitoring technology has been proven and is now part of all tunnel Traffic Management Systems. This technology can be applied to AHS.

Table 10. Highway Tunnels Lessons Learned Worksheet (continued)

Guidelines for Tunnel Facilities	Lessons Learned
All closing of travel lanes or tunnel bores and stopping traffic movement is accomplished using standard traffic signs and signals as visual commands or by traffic police.	Visual displays are currently the only accepted means of traffic control other than police. Other approaches may require motorist training and/or involve jurisdictional issues. It may be possible to consider in-vehicle displays for AHS messages.
Variable message signs were first developed for tunnel facilities to display regulations and provide motorist advisories. A motorist's visual attention is currently the primary sense for communication of information/regulation. Auditory signaling must compete with in-vehicle radios and conversations. Standard AM & FM radio re-broadcast with override capabilities is possible in tunnels to allow the tunnel operation to furnish voice information. This is now a backup to the visual displays.	Current driving tasks involve continual visual attention. Signaling has been developed on the basis of this premise. This cannot be assumed for AHS. Alternative approaches to communicating information to AHS "drivers" will be needed (e.g., attention-getting devices, automatic approaches to dealing with emergencies not involving the "driver").
The quick identification and clearance of an incident has high priority in tunnel operation due to the catastrophic impact of a fire. Because tunnels are critical transportation links, they cannot remain out-of-service for extended periods. Incident management includes identification through traffic flow monitoring, verification by closed circuit television, and response from waiting emergency assistance/towing trucks and crew.	AHS will require highly efficient methods of incident management, especially when separated lanes are employed. Either facilities for immediate response to incidents or breakdown lanes will be needed to ensure continued AHS traffic flow.

Table 11. The Chunnel: Lessons Learned Worksheet

Issues from the Chunnel Experience	Lessons Learned
The Chunnel project began construction in 1986 and has accrued a $15 billion debt, much of it due to cost overruns and construction delays. This will require charging customers between $240 and $460 per round trip per car. This compares to about a $100 charge for the competing ferry service. The Chunnel trip will take 35 minutes, one way, compared to about 90 minutes on a ferry. There is concern as to whether sufficient numbers of customers will use the Chunnel.	• AHS should strive to control development and operating costs. These will ultimately be passed to users, reducing the cost/benefit advantages of AHS, or require public subsidy. • AHS can be built incrementally, one small project at a time (unlike the Chunnel). An incremental development approach can help avoid problems of runaway expenditures.
The Chunnel was initially marketed as technological wonder to be experienced. The response was negative. It is now being marketed on the basis of its ease of use and convenience. The success of this approach is yet to be determined.	• AHS success will depend on an understanding of potential markets, marketing approach, and ultimately public perception of AHS costs versus benefits offered. • An incremental approach to deploying AHS can serve to control costs and build a realistic understanding of potential markets.

3.2.1.4.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of highway tunnels are summarized in Section 4.1.

3.2.1.5 Electronic Toll and Traffic ManagementSystems (ETTMs)

3.2.1.5.1 Introduction

In recent years, Electronic Toll and Traffic Management (ETTM) systems have been introduced on selected interstates and toll highways. ETTMs share important features with AHS. These features include the following: (1) information must be communicated between the highway infrastructure and vehicle while the vehicle is in motion; and (2) issues of public acceptance of this new technology must be addressed. The E-Z Pass ETTM system which is used on the New York State Thruway was studied to identify lessons learned that can be applied to AHS.

3.2.1.5.2 Approach

The approach taken for this task involved: (1) discussions with New York State (NYS) Thruway officials to gain an understanding of the E-Z Pass ETTM system from both technology and operational perspectives; and (2) attendance at a public meeting in which E-Z Pass users voiced their feelings about how the system was working.

3.2.1.5.3 Results

E-Z Pass System Overview

The E-Z Pass system employs a small transmitter mounted behind the rearview mirror with Velcro. This transmitter is provided to the vehicle owner at no cost, although there is a $10 refundable deposit required. It replaces commuter ticket books that were previously available. There are currently 42,000 subscribers (more than the number of people previously using the commuter ticket books). Subscribers set up an account in which they pre-pay for tolls using either personal checks or credit card. A minimum balance of $25 is required. The account is debited when toll booths are traversed. When vehicles successfully pass the E-Z Pass toll booth, a message on a sign mounted on the toll booth tells the driver that their toll was successfully collected. If there is a problem electronically collecting the toll (e.g., the account is empty, transponder did not work), the vehicle license plate is photographed, and the driver is told (by the sign) to go ahead and to call the E-Z Pass center. Subscribers are sent monthly statements of account activity, including date, time, amount collected, location of tolls, and account balance.

This service is only available at toll booths that charge all vehicles the same amount as they pass. It is not used for toll booths that charge on the basis of distance traveled, although this is planned for the future booths. E-Z Pass is currently in place at toll barriers in the New York City area and at the Grand Island bridges in the Buffalo, NY, area. This service is available only for passenger vehicles at this time.

Plans for Expansion of the Service

The Thruway Authority intends to expand this service to cover more tolls, and to use the system to monitor vehicle progress along the Thruway. This later application will involve adding additional transponder/readers along the Thruway (not just at toll booths). This will initially be used for detecting and responding to incidents (i.e., when all vehicles take a long time between transponder/reader stations, incidents can be implied). This capability will be in place by the fall of 1994. Eventually, information regarding detected incidents will be disseminated to travelers.

Another area of future expansion will involve implementing a system in which the vehicle equipment will be able to accept information as well as transmit vehicle identification. The NYS Thruway Authority is waiting until standard ETTM formats are defined by the I-95 Corridor Coalition before moving ahead with these plans. Once implemented, this will allow the system to be used on all portions of the Thruway, including those where tolls are based on distance traveled. Plans for including commercial vehicles are also projected.

Operational Procedures

The current system requires E-Z Pass vehicles to traverse the toll booths at 5 MPH. This is a limitation not of the equipment, but rather the toll booth configuration. It is not safe to pass through current toll booths at speeds greater than 5 MPH. Future plans call for reconfiguring the toll booths to allow at-speed toll collection. The E-Z Pass technology is capable of supporting highway-speed data communication.

Marketing Aspects of Getting E-Z Started

The marketing aspects of getting E-Z Pass started were straightforward, since this system replaced a previously offered service (i.e., the ticket books). The NYS Thruway advertised the service in press releases and used signs along the roadway. Signs at the toll plazas themselves were also employed. According to Rich Newhouse of the NYS Thruway Authority, demand was enhanced when motorists saw E-Z Pass subscribers negotiating the toll booths faster than non-subscribers. Perhaps the greatest inducement, though, was the fact that, with the elimination of the commuter ticket books, the only way for commuters to obtain toll discounts was through subscription to E-Z Pass. Subscription rates reached that of the previous ticket books within a few months of their availability; they now exceed the rate of subscription experienced with the ticket books.

E-Z Pass also offers special fares for frequent users and for HOVs. Use of the system more than 17 times a month reduces the toll price by more than half. HOV users pay about one-fifth of the regular cost. The effectiveness of these special offers has not been experimentally determined. However, HOV use through toll barriers using E-Z Pass has been substantial.

Difficulties Experienced in Implementation

Transition to E-Z Pass was pretty smooth. One problem that was encountered was over concern for the safety of manual toll collectors, who had to walk across the E-Z Pass toll booths. The toll collectors filed an injunction against the project which delayed the implementation by 4 to 6 weeks. We asked Mr. Newhouse whether there was any concern on the part of the toll collectors about reductions in staffing and resultant job loss. His answer was that some of these concerns could have been behind the injunction, although the Thruway Authority guaranteed that any toll collectors replaced by the automation would be reassigned elsewhere (i.e., there would be no loss of jobs). The problem was resolved by assigning a flag person to help toll collectors cross E-Z Pass toll booths.

The E-Z Pass Technology

Mr. Don Hubicki of the NYS Thruway Authority described the communication technology employed by E-Z Pass. E-Z Pass uses a system sold by Amtech Corporation. Competing systems are sold by AT&T, New York Telephone, MARK IV, and several others. The Amtech system uses RF technology. Bar codes and SAW (surface acoustic wave) technology have also been considered and marketed. Mr. Hubicki believes that RF technology is emerging as the dominant technology for ETTM.

E-Z Pass operates in the 902 to 928 MHz band. European systems operate at 2.45 GHz. Accuracy of the E-Z Pass system is estimated at 99.95% (5 errors in 10,000 transactions). There are currently 128 bits of information stored on the vehicle-mounted E-Z Pass "tag." This information is transmitted in about 40 milliseconds. The second-generation system that will incorporate both read and write capability will transmit 256 bits of information in about 80 to 100 milliseconds (this includes both the read and write operations). This is planned for implementation over the next 18 to 24 months (interview was in January, 1994). Finally, the third-generation system will be able to transmit 1 megabit, again within the 80 to 100 millisecond period. A schedule for implementing the third-generation system has not yet been determined. Antenna specifications and resultant "capture zones" for the current system can be made available if needed.

Table 12 summarizes the issues in this and the preceding sections and relates them to AHS.

A public meeting was held on 8 December 1993 (a very cold and stormy night) at the Grand Island High School near Buffalo, New York. It was attended by about 60 Grand Island residents and local politicians. The New York Thruway did not attend but received a transcript of the meeting. A copy of the transcript is on file at the Calspan Advanced Technology Center and can be made available to the FHWA if needed. The comments of those in attendance are summarized in table 13.

Table 12. Features of the E-Z Pass System and Lessons of AHS

ETTM Feature	Lessons Learned for AHS
ETTM technology allows communication of data to support the electronic toll collection process at highway speeds.	ETTM technology can be considered to support the data communication requirements for AHS.
The marketing of E-Z Pass was facilitated by the fact that it was replacing a previous commuter ticket book system. This provided an immediate market.	Consider approaches for building an AHS market from pre-existing markets. (E.g., as AHS evolves, offer those using earlier AHS equipment incentives to upgrade, market AHS to drivers already using ETTM or other IVHS services.)
E-Z Pass offers discounts for frequent users and HOVs.	Consider offering reduced tolls on non-AHS toll ways for AHS subscribers.
Safety concerns about the safety of manual toll collectors as a result of E-Z Pass implementation led to the filing of a court injunction against E-Z Pass implementation. Job security concerns may have also been involved.	• AHS developers must be prepared to demonstrate that the system is safe. • Guarantees of job security for professional drivers may help mitigate concerns about job security associated with commercial AHS implementations.

Public Reaction from Grand Island, NY, Residents

There is an important feature of Grand Island that should be understood in order to interpret many of the residents' concerns. This is that Grand Island is an island accessible only via the New York State Thruway toll bridges. Further, most Grand Island residents work, and have friends and family that live, off the island. For these reasons, anything that is done with respect to these bridges and the associated tolls directly affects the residents of Grand Island. They are a captive audience. Many of the concerns expressed were related to these facts.

Table 13. Reactions to the E-Z Pass System from Grand Island Residents

E-Z Pass User Comment	Lessons Learned for AHS
Residents felt that E-Z Pass was implemented without input from the affected communities and felt that it was being forced upon them.	AHS must outreach to affected communities and involve the public at large in plans and decisions. Without public involvement, some public opposition can be expected.
Some were concerned about safety issues associated with non-E-Z Pass users having to cross lanes to avoid the E-Z Pass-only toll booths.	AHS entry/exit configuration must consider safety issues.
Some were concerned with long-term health affects of the radio frequencies to which they were exposed on a daily basis.	Safety concerns associated with AHS-related technology and communications will need to be addressed and communicated to the public.
Many residents were upset that the previous commuter ticket books were eliminated. • They felt that E-Z Pass was being forced on them. • They feared that the Thruway Authority would be able to increase the tolls without prior notice.	• AHS developers should avoid designs that force highway users to make unwelcomed changes to their accustomed behavior patterns. • Involve the public and affected communities in the AHS development process.
A few residents expressed displeasure that the customer service staff were impersonal, bureaucratic, and evasive (and even rude, according to one individual) when faced with questions.	Pay attention to customer relations details.

Table 13. Reactions to the E-Z Pass System from Grand Island Residents (continued)

E-Z Pass User Comment	Lessons Learned for AHS
A few complaints were voiced about hidden costs including $20 to replace the vehicle tag if lost (or stolen), the cost of batteries, and the "refundable" $10 dollar deposit for the first tag that will never be refunded unless they move from the island or stop using E-Z Pass.	All AHS costs should be communicated up-front.
One resident complained that the locations of the E-Z Pass-only toll booths were frequently moved, making it difficult to know which lane to get in.	Use consistent approaches for accessing and exiting AHS.
The standard E-Z Pass tags don't work well on some vehicles (e.g., some vans). When this happens, a special tag must be obtained and installed under the hood.	Thoroughly test AHS prior to implementation and continue to work to fix "bugs," even after implementation.
Several residents expressed concern that it would be possible to discern their movement patterns and even to know when they are not home as a result of tracking toll crossings (data used for billing). This is a special problem on Grand Island, because the toll bridges are the only way on and off the island. One resident asked whether the Thruway Authority would sell E-Z Pass data on resident travel patterns.	AHS developers must be sensitive to concerns about invasion-of-privacy issues. Design approaches that minimize the ability to track AHS customer movements are preferred over equally sound approaches that do not protect people's privacy.
Some felt that the requirement for paying another bill, monitoring, and replenishing an account was burdensome.	Make AHS easy to use. Design AHS in ways that do not create work for customers.
Some felt that New York Thruway Authorities were reluctant to face Grand Island residents about their concerns.	Public and community outreach are important for AHS acceptance.
A few residents expressed concern about making a mistake in complying with proper procedures (e.g., would there be a ticket issued if they didn't notice the sign indicating a problem, or if they forgot to call in after a problem?)	Make AHS procedures straightforward, and as obvious as possible.
There were two residents who spoke in favor of E-Z Pass. They liked the added convenience of not having to stop to pay the toll and not having to roll down the window in cold weather. Some people who had complaints about E-Z Pass also noted these features as being positive.	AHS outreach and marketing material should emphasize positive features and benefits.

As can be seen in table 13, the tenor of the meeting was quite negative. It is noted that meetings such as this one tend to attract those who have complaints. Individuals who don't have complaints or problems are likely to feel that attendance at such a public meeting is unnecessary. Nevertheless, while the feelings expressed at the meeting cannot be interpreted as being reflective of all of those who use E-Z Pass, they are real problems and concerns for those in attendance, and they indicate the types of problems that can be encountered with a system like E-Z Pass. Lessons for AHS should be noted.

3.2.1.5.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of E-Z Pass System operations are summarized in Section 4.1.

3.2.2 Vehicle Driver Systems

3.2.2.1 Introduction and Evolution of the Automobile

3.2.2.1.1 Introduction

The introduction and evolution of the automobile played a major role in shaping our culture and in determining the nature of our existing transportation system. The history of the development and evolution of the automobile is a fascinating one; one which can only be summarized here. Those aspects of the automobile's development that bear lessons for the design, development, and evolution of AHS are highlighted. Issues relating to why the automobile was such a great success, why the automobile flourished while other competing forms of transportation were less successful, and how critical events in the history of the automobile led to its success are compared to AHS in the following subsections.

3.2.2.1.2 Approach

The approach taken during this part of the study relied exclusively on a review of available literature. We reviewed several of the many books documenting the important history of the automobile.

3.2.2.1.3 Results

The results of this study are organized in two subsections. The first chronicles the history of automobiles and provides an overall context for understanding the relationship and lessons of this history applicable to AHS. This short summary of the automobile's history does not begin to capture the richness and complexity of this fascinating history. More complete accounts can be found in the references at the end of this volume. The discussions in John B. Rae’s *The American Automobile: A Brief History* (1965) and Christopher Finch’s *Highways to Heaven: The Auto Biography of America* (1992) are especially recommended.

The second subsection relates important events and historical notes associated with the introduction and evolution of the automobile to AHS. It identifies and documents specific lessons applicable to AHS, and recommends approaches for AHS planning and development.

The Development of Early Automobiles and Their Evolution

The first self-propelled vehicle was built and demonstrated in France in 1769 by Nicholas Joseph Cugnot. His vehicle, a three-wheeled carriage, utilized a steam engine and ran at a top speed of three miles per hour. Although this vehicle offered no improvement over a horse-drawn vehicle, it illustrated the potential for a self-propelled vehicle. As the steam engine was improved in the early 1800s for use in locomotives, others began experimenting with the development of steam driven-vehicles.

Between 1800 and 1850, several Englishmen built steam-driven omnibuses that operated on regular routes with excellent safety and reliability records. However, the railroad and stagecoach industries joined together to fight this new technology. They managed to harass the bus operators with tolls and fees, and finally with the passage of the "red flag" law in 1865. This law required that any self-propelled vehicle be preceded by a man on foot carrying a red flag. This served to limit the motorized vehicles to a maximum of four miles per hour on all public highways. Essentially, the steam omnibuses were driven out of business by their competition. The "red flag" law appealed to the people's concerns for the safety of unproven technology, and essentially prevented England from keeping up with the rest of the world in automotive technology. This law was not repealed until 1896, almost ten years after the introduction of the internal-combustion vehicle.

Steam engines were expensive and inefficient for supplying small amounts of power, and better suited for larger loads (like locomotives). Because of this limitation, alternative types of engines were sought. In 1860, Etienne Lenoir patented the first two-cycle internal combustion engine. His engine depended solely on the expansion of the gases when the fuel was ignited. Lenoir's engine was a commercial success. Over the next eighteen years, engineers worked to further develop the internal combustion engine. In 1872, George B. Brayton introduced a two-cycle engine that compressed the fuel in a separate chamber outside the cylinder, and Nicholas Otto built the first four-cycle engine in 1878. These early engines were immediately recognized for their potential applications in transportation.

George B. Selden, an inventor and patent lawyer from Rochester, NY, saw the Brayton engine demonstrated at the Centennial Exposition in 1876. He believed that he could develop a road vehicle using the new technology. In 1879, he applied for a patent on his design: an engine for use in a road vehicle, combining a motor using a hydrocarbon fuel, a mechanism for disengaging the engine from the driving wheels, and a steering device. He managed to keep his patent pending for sixteen years, during which he constantly updated the patent to include new technological developments. He received his patent in 1895, although he had never built a vehicle conforming to his specifications. Even with the patent, Selden was not able to obtain financial support for his work. Investors seemed unwilling to provide financial backing for a technology that they knew little about and seemed so revolutionary. They doubted that such a radically different idea could work and become a commercial success. Selden eventually sold his patent in 1899 to the Electric Vehicle Company, who used the patent in 1903 to file a lawsuit against Henry Ford and the other U.S. automotive companies. In 1911, the patent was ruled to be valid, but not infringed by the U.S. automotive industry. The victory of the automotive industry helped propel Henry Ford into his role as an American hero.

However, the invention of a practical engine was not the sole catalyst for the further development of the automobile. The popularization of the bicycle stimulated public interest in highway travel, and the bicycle made many important technical contributions to automotive development. As Hiram Percy Maxim, an early automotive developer, wrote in his autobiography:

> It has been the habit to give the gasoline engine all the credit for bringing the automobile--in my opinion this is the wrong explanation. We have had the steam engine for over a century. We could have built steam vehicles in 1880, or indeed in 1870. But we did not. We waited until 1895.
>
> The reason why we did not build road vehicles before this, in my opinion, was because the bicycle had not yet come in numbers and had not directed men's minds to the possibilities of long-

> distance travel over the ordinary highway. We thought the railroad was good enough. The bicycle created a new demand which was beyond the ability of the railroad to supply. Then it came about that the bicycle could not satisfy the demand which it had created. A mechanically-propelled vehicle was wanted instead of a foot-propelled one, and we know now that the automobile was the answer. (Rae, 1965)

The internal combustion engine may have helped to initiate "modern" automotive development, but it did not dominate the automotive industry until the 1920s. In fact, during the 1890s, internal combustion (gasoline), steam, and electric automobiles were all produced and promoted.

In 1895, the Pope Manufacturing Company, the nation’s biggest bicycle producer, started commercial production of motor vehicles. In the first two years, the company produced five hundred electric and only forty gasoline carriages because the company’s owner, Albert A. Pope, believed “You can’t get people to sit over an explosion.” (Rae, 1965) Other automotive companies were soon founded by the Stanley Brothers (who produced steam automobiles, 1897), Ransom E. Olds (Olds Motor Works, 1899), Alexander Winton (Winton Motor Carriage Company, 1897), and James W. Packard (The Ohio Automobile Company, 1900). By 1900, almost five thousand automobiles had been produced and sold in the United States.

The early automobiles had been designed and built for racing, as this offered a means for testing design ideas, and it provided a good advertising medium. In addition, Charles J. Glidden formed Glidden Tours in 1904, which organized endurance runs for automobiles. These runs demonstrated the reliability and safety of automobiles, and developed feelings of admiration and trust from the general public. The public enthusiastically accepted the automobile, and it received little opposition as it was introduced into society. People believed them to be reliable and safe.

As the automotive industry continued to grow in the early 1900s, more automobile manufacturers joined the industry. Henry M. Leland organized Cadillac in 1902, the Buick Motor Car Company was formed in 1904, Maxwell-Briscoe in 1903 (later known as Maxwell, and eventually Chrysler), Ransom Olds left his old company to form the Reo (for R.E. Olds) Motor Car Company in 1904, and Henry Ford founded the Ford Motor Company in 1903. By 1908, Buick, Ford, Reo and Maxwell-Briscoe were considered to be the “Big Four” of the automotive industry, each company having achieved annual production of over eight thousand vehicles. By 1910, total automobile production in the United States reached 187,000, while total registrations reached almost 500,000.

At this time, Benjamin Briscoe (of Maxwell-Briscoe) and William Durant (Buick) attempted to join their companies with Ford and Reo, to form one large organization. They realized that such an organization would provide the capability to produce a wide variety of models, using their own suppliers for parts and components, and establish a position of price leadership. However, Henry Ford and R.E. Olds demanded cash payments for their companies, and the merger never took place. Durant and Briscoe then separated, and Durant went on, in September 1908, to form the General Motors Company. This new company incorporated Buick, Cadillac, Oldsmobile, Oakland (later Pontiac), and a variety of parts manufacturers into one larger company. However, General Motors had many difficulties, and remained in almost constant turmoil until 1923.

When Ford Motor Company was first founded in 1903, Ford began by producing medium-priced automobiles to compete with the automobiles being produced by its competitors. However, Henry Ford was determined to build a car that would appeal to the mass market. He realized that a car for the general public would have to be inexpensive, durable, easy to operate, economical to maintain, and simple to repair. In 1907, Ford successfully designed a car meeting these qualifications, the Model-T. After designing the car, Ford focused his attention on cutting production costs and simultaneously improving the precision of the manufacturing process. In 1908, almost six thousand Model-T's were sold for $850 each. With the introduction of assembly line production in 1914, the price dropped to $490 and over 260,000 were sold (table 14). (Rae, 1965)

Table 14. Marketing of Model-T Fords, 1908 - 1916

Calendar Year	Retail Price (Touring Car)	Total Model-T Sales
1908	$ 850	5,986
1909	950	12,292
1910	780	19,293
1911	690	40,402
1912	600	78,611
1913	550	182,809
1914	490	260,720
1915	440	355,276
1916	360	577,036

Ford’s competitors continued to produce medium-priced cars ($1000-$1500), which offered, to those who could afford it, status over Model-T owners. They offered financing plans to buyers, making their products accessible to a wider range of potential customers.

Between 1900 and 1910, automobile manufacturing climbed from 150th to 21st in value of products among American industries. This rapid growth led to the simultaneous development of supporting industries, such as petroleum, rubber and other service industries. The petroleum industry, before 1900, had considered gasoline to be an undesirable product, and had produced as little as possible. Their main commodity was kerosene, which had been used for lighting. However, as gas and electricity replaced kerosene, the petroleum industry was faced with a serious decline. When the automobile was introduced, the petroleum industry found a new, more profitable market. In fact, after 1910, the petroleum industry focused its attention on the production of gasoline in order to keep up with the increasing demands of the automobile.

Rubber also became a crucial commodity with the introduction of the automobile. Companies continuously worked to improve their tires, and to supply the growing number of automobiles. Also, service industries, including gas stations, repair shops, and automobile parts supply houses were developed to provide support for automobile owners and operators. In the early years of gasoline automobiles, gasoline was sold in general stores. However, in 1905, the first gasoline station appeared, and became increasingly popular. The major oil companies—Gulf, Texaco and Standard Oil—began, in 1913, a widespread effort to build gasoline stations on corners throughout urban and suburban neighborhoods.

Suburbia is not merely a consequence of the automobile. Railroads and interurbans (electric trolleys) had helped establish the pattern of suburbs around inner cities before the automobile was popularized. However, development was limited to locations around the rail lines to facilitate travel into the inner city. The introduction of the automobile allowed the suburban areas to expand. No longer dependent on the rails for transportation, the public did not necessarily want to live within walking distance of a rail station. Consequently, rail passenger traffic consistently declined after 1920.

The public found that a private automobile was more convenient, less expensive and allowed greater flexibility than the rails. Commuters were no longer limited by the fixed schedule of the rail lines. In fact, in many cities the transit system was forced to close, due to the lack of riders. In other cities, the transit system remained, but was often considered to be a hindrance to effective automobile traffic.

The automobile had allowed families to move farther away from the inner cities, and from established mass transit systems. However, these suburban areas forced families to become dependent on their automobiles. The automobile was the only access to employment, education, entertainment, and shopping (not yet available in the suburbs). Businessmen soon realized that customers preferred shopping where they could park conveniently, rather than make trips to the inner city. Businesses quickly began following the public to the suburbs. The first automobile-dependent shopping center, built in 1922, offered a wide range of stores, each set among large parking lots. The shopping center was intended to fulfill the needs of suburban families, and was only accessible by automobile.

Supermarkets were also developed to serve automobile traffic. Previously, families had purchased groceries at the neighborhood general store, which was often located within walking distance of their home. Supermarkets operated on a larger scale and were able to offer a wider variety of goods, at lower prices. To succeed, they needed to attract a wide range of customers, most of whom could reach the store only by automobile. The large parking lots offered maximum driver convenience. Drive-in restaurants, movies and banks were also introduced to capitalize on the widespread popularity of the automobile.

By the end of the 1920s, the automobile had evolved into the mechanical and structural form it would retain. Of course, throughout the years, it underwent many technical improvements and refinements. The United States automotive industry produced a record 5,337,087 cars in 1929, a level of production that would not be reached again for another twenty years. The automobile had reached all economic sectors of American society; those who could not afford luxuries owned a Model-T.

Automobiles had become so entrenched in American society that the *Middletown* study, conducted by Robert and Helen Merrell Lynd in 1929, found that families were willing to make extreme sacrifices to keep their automobiles. (Rae, 1965) Ownership of a car had reached the point of being an accepted, essential part of everyday living. The automobile was as much a social need as a means of necessary transportation.

During the depression (1929-1932), car ownership in the United States dropped by only ten percent. However, there were fewer new cars sold, as people were holding on to their old cars or buying a used car if absolutely necessary. Because of the lack of sales, most of the smaller automobile manufacturers were forced out of business, while the “Big Three” (General Motors, Ford and Chrysler) managed to survive relatively unharmed. Many companies used this period of low production to concentrate on research and development of new technologies. The automatic transmission, overdrive, more powerful engines, and more efficient diesel engines all were developed during this time. In fact, General Motors was even able to expand into new areas of operation, including the manufacturing of refrigerators, diesel locomotives, and aircraft engines. As the United States began to come out of the depression, Government became concerned with restoring the automobile and its supplying industries back to full health. These industries would lead the way in promoting economic reform. The automotive industry, faced with Government regulations and labor disputes, remained in almost constant turmoil for ten years.

During World War II, the automobile industry was required to use its resources to produce military equipment. In December 1941, production of civilian automobiles was totally suspended in order to conserve materials for war purposes and to improve efficiency of the production of military equipment. Civilian use of automobiles was also severely limited by imposed restrictions on rubber, for tires, and on gasoline. However, even with rubber and gasoline rationing, the automobile continued to be used daily by many people. There was no alternative means of transportation for workers to use for the commute between work (often in the factories producing military supplies) and the suburban neighborhoods.

After the war, developers built neighborhoods of tract houses located even farther from the inner city than the existing suburbs. Tract houses were generally one-story houses, each with a garage or carport, and a driveway connecting it to the main street. These houses were very affordable for young families, and were quite popular. Jobs, schools shopping and other services were usually located relatively far from these neighborhoods, and an automobile was required for daily living. Some families even required more than one automobile, so one could be used for daily commuting and the other could be used to run errands at home during the day.

The increased number of cars on the roads and highways stimulated the demand for improvements to the roadway system. As improvements were gradually made, the number of automobiles continuously increased. Roads, especially into and out of inner cities, became more and more congested. To maximize driver convenience under these circumstances, the automotive companies began offering more "comfort" options on their cars in an attempt to keep their customers happy in all weather and traffic conditions. Car radios, and eventually cassette tape players, made sitting in traffic more tolerable to commuters stuck in traffic; improved heating and air-conditioning systems made drivers more comfortable in all climates; and power steering and automatic transmissions reduced the amount of physical and mental concentration required to drive, and made it easier to cope with the constant stop-and-go driving conditions found in most cities.

Most cities in the United States were established long before the introduction of the automobile. Streets were designed for transportation systems no longer in use, and not for the amount of automobile traffic currently utilizing them. As a result, many cities continue to suffer from serious congestion, as the street system cannot handle the amount of traffic and there is not enough parking to accommodate all of the vehicles. Automobile traffic, especially in congested areas, has also caused pollution problems for cities. Although in recent years a great amount of effort has been expended in trying to combat congestion and pollution, few satisfactory solutions have been found and implemented.

Why the Internal Combustion Engine became Successful over Steam and Electric Vehicles

Of the three types of automobile engines introduced in the 1890s, only the internal combustion engine survived to become a standard in the automotive industry. Some attribute the success of the internal combustion engine to its technological superiority over its competitors, the steam engine and the electric motor. This, however, does not fully explain the situation, because consumers do not buy products based solely on technical superiority. Most consumers are more concerned with how well the product meets their particular needs and expectations, and are willing to sacrifice technical superiority for a product that better satisfies their needs. In addition, a product's success may not depend solely on the technology involved, but on a wide range of technical, economic and social factors.

Initially, both the steam engine and the internal combustion engine were quite difficult to operate and required constant driver attention. The drivers of steam cars were required to constantly monitor and regulate the steam generation process, while the drivers of gasoline cars needed to control the engine's spark advance and manual choke, and work a complicated clutch and transmission system. Both types of cars were difficult to start. Steam cars required many operations to get started and took about twenty minutes to warm-up before they could be driven. Gasoline cars were started by cranking, a process that required significant strength, and which could break an arm if done incorrectly (due to engine kickback). The public seemed more willing to exert the physical effort to crank than to wait twenty minutes for the steam car to warm up. Steam cars also required the driver to make frequent stops to replenish the car's water supply. Americans also seemed reluctant to take this extra time.

Over time, internal combustion vehicle manufacturers successfully developed improvements to their engines such as the electric starter, which eliminated the requirement for cranking. While these changes were making gasoline cars easier to operate and maintain, steam engine manufacturers made very few improvements to their product. Steam cars continued to be complicated to operate and to require constant attention to maintain. And while the gasoline-powered vehicles became easier to operate, their supporting infrastructure was also improved as the oil industry began aggressively building gasoline stations. This allowed gasoline car owners flexibility and convenience. The steam engine lacked a strong advocacy group, and lacked the necessary supporting infrastructure. In many parts of the country the soft water necessary for the boilers was not available, and the infrastructure to make it available was not put in place. Thus, it would have been necessary for drivers to carry large amounts of water when traveling through these parts of the country. This was impractical, and an effective system was never established. The steam car, then, could only be used in certain geographic areas, which limited its potential for success.

Although both the steam and internal combustion engines were quite difficult to operate, there was another, simpler, alternative for consumers. Electric vehicles were simple to operate and maintain: they had no clutch or transmission to operate, no difficult starting procedures, and they were quiet, odorless, and reliable. Despite these advantages, the electric motor was limited in range and speed due to the inherent inefficiency of available batteries. However, most people used their cars only for short-range city driving. The electric car seemed ideally suited.

The failure of the electric car can be attributed more to social and market factors than to technical factors. Electric cars, although cheaper to operate than gasoline cars, were much more expensive to buy. This was mainly due to the attitudes of the manufacturers, who felt that electric cars were not for the masses, but rather fine-tuned machines for those who could afford them (i.e., the rich). The industry emphasis was on a highly skilled workforce, which kept production costs extremely high. In addition, the ease of operation of these cars attracted mostly women drivers, alienating many potential male buyers who did not want to be associated with a technology that appealed to women. Also, the electric companies were unwilling to help develop the infrastructure that would have been required to support electric vehicles on a large scale.

For electric vehicles to succeed, they needed a system of charging facilities that would allow motorists to charge their batteries away from home. Another solution would have been allowing motorists to trade-in used batteries for fully charged ones at battery-exchange stations. The electric companies were unwilling to establish these necessary charging locations until electric vehicles became more popular; however, even with an infrastructure, electric cars may still not have succeeded. Although electric cars were ideally suited for daily transportation needs, the public did not consider cars simply necessary transportation, but a source of fun and excitement, with potential for long trips at high speeds. The inherent limitations of the electric automobile continued to be a major drawback; one that contributed to its limited success in the marketplace.

By 1917, steam and electric cars were virtually eliminated from the automotive industry. As improvements were made to the internal combustion engine, the limitations of both electric and steam engines became more significant. The internal combustion engine was able to satisfy the needs of most consumers at a reasonable price. Manufacturers of steam and electric automobiles either went out of business, or switched to the production of internal combustion vehicles, which have dominated the automotive industry since 1917.

Recently, with society's concern about pollution and environmental issues, alternative propulsion systems are once again being considered; e.g., electric vehicles and hybrid electric/gasoline powered vehicles. United States automakers have formed a consortium to develop more effective battery technology, and several prototype electric vehicles have been developed and demonstrated. There are plans for making these vehicles available on the market in the next few years. California already has laws on the books requiring that vehicles sold in California include a growing percentage with zero emissions (i.e., electric powered). Other states are considering similar legislation.

The success or failure of transportation products is determined by a combination of factors relating to technology, economy/market, and social issues. Many of these factors, as they affected the competition between internal combustion, steam, and electric vehicles, are summarized in table 15.

The Contribution of the Bicycle to the Development of Automobiles

The first bicycle was built in Scotland by Kirkpatrick MacMillan in 1839. MacMillan developed his bicycle with the intention of developing a machine that could enable him to visit his sister in a town forty miles away. This was one of the earliest attempts to develop a personal mode of transportation that was not dependent on a horse. However, MacMillan’s invention led to only a few imitations, and cycles did not become a widespread phenomenon.

Not until the mid-1860s was a more practical cycle design introduced by the French carriage maker, Pierre Michaux. This cycle, the velocipede, was brought to the United States in 1865, where it initially was met with little enthusiasm. It was not until 1869 that the velocipede began to gain popularity, and American inventors worked to make technological improvements to the French design. For example, they used hollow tubes instead of solid steel in the frame to make it lighter and cheaper. Also, they developed a “self-acting” brake, a front fork permitting easy lubrication of the axle, a pedal crank with a slot that allowed its length to be adjusted, and they began to surround the wheels with rubber to cushion road shock. As these innovations

Table 15. Comparison of the Technical, Market, and Social Factors that Affected the Success of Internal Combustion, over Steam and Electric Vehicles

	Internal Combustion	**Steam**	**Electric**
Operation	• Early models required control of spark advance, clutch and transmission • Kick-back from crank start could break an arm • Ride was loud, with much vibration • Could be maintained by owners/operators	• Required constant monitoring and regulation of engine parameters • Required complicated starting procedure and 20-minute warm-up • Required constant maintenance by highly skilled mechanics • Ride was smooth and quiet, with steam "hiss" the only noise	• Simple to start and operate • Ride was smooth, quiet, and odorless
Design	• Complex; required many moving parts, dynamic spark/cylinder synchronization and transmission • Industry constantly worked on improving the user interface (e.g., electric starter introduced in 1912)	• Relatively simple; few moving parts and no need for clutch and transmission • Boilers were small and inefficient • Industry made few improvements to the user interface	No difficult starting procedure, clutch, or transmission was needed
Manufac-ture/Cost	• Emphasis placed on mass production • Cost per automobile made very low	• As the technology improved to keep up with competition, production and retail costs increased significantly	• Emphasis was placed on a highly skilled workforce • Cost per automobile made very high
Public Perception	• Fun, exciting, and easy to operate (after driver interface improvements were made)	• Difficult to operate • Inconvenient in that a long time was required for warm up, and frequent stops were necessary	• Sufficient for most uses, but seen as slow, limited in range, and not exciting. • Appealed to women (somewhat of a turn-off for men)
Advocacy	• Strong advocacy from oil industry (who had few other markets) • Support infrastructure was developed	• No strong advocacy group emerged • Some manufacturers "gave up" and switched to internal combustion	• Electric industry voiced support but did not develop needed infrastructure or help market electric cars • Recently, environmental groups have provided advocacy
	Reasons for Success	**Reasons for Failure**	**Reasons for Failure**
Summary	• Low cost due to mass produced vehicles • Improvements in driver interface • Advocacy from oil industry • Infrastructure support developed	• Vehicles were expensive • Difficult to operate • Limited range due to small, inefficient boilers	• Vehicles were very expensive • Limited range and speed • Infrastructure for remote charging (away from home) not available

improved comfort and performance, the public became more interested in the American models of velocipedes.

By 1870, the public had lost interest in velocipedes, and the American cycle industry had basically collapsed. The lack of industry standards created wide variations in cost and quality. The unsafe, uncomfortable, and inefficient design of the velocipede are often considered to be reasons for this collapse.

During the early 1870s, British inventors worked to improve the velocipede by developing the "ordinary" bicycle. This bicycle was lighter and more efficient than any previous model, in spite of its awkward and dangerous seating arrangement. Although the new design was quite popular in Europe, American industry seemed reluctant to reenter the bicycle market. Interest in cycling was not rekindled until the 1876 Centennial Exposition in Philadelphia, when the American public had an opportunity to see the new bicycle.

Albert A. Pope, an advocate for the bicycle industry, realized that bicycles would only become popular if they were cheap enough for large numbers of people to afford them. He managed to obtain more than a dozen patents for the bicycle, and licensed them cheaply to the manufacturers. This encouraged a competitive market to emerge, and cycling quickly became a popular sport in the US.

The British continued, through the 1880s, to improve the "ordinary" design. They improved their manufacturing techniques, allowing them to use light tubing in frames, instead of heavy gauge metal, without a loss of strength. Also, they developed bicycles with gear arrangements, which allowed the wheel size to be reduced to safer and more convenient sizes. In 1884, a British firm introduced the safety bicycle, which later developed into the bicycle design in use today. This new design was a rear wheel driven by a chain and sprocket, reducing the risk of losing control of the cycle. Some felt that the safety bicycle would never be successful, because the inherent dangers of cycling added to its popularity. Even so, the safety bicycle soon dominated the cycle market.

Many social changes were brought about by the popularization of the safety bicycle. Women , who had been reluctant to ride the dangerous early bicycle models, eagerly accepted the safety bicycle, which offered freedom and mobility previously available only to men. In addition, the introduction of the pneumatic tire in 1888 changed the bicycle from a purely recreational toy to a truly practical road machine. Bicycle supporters began clamoring for improvements in road conditions to facilitate bicycle travel.

Although the bicycle remained popular in the United States, the bicycle industry made few new contributions to bicycle design during the 1890s. New road construction and improvements to existing roads were progressing slowly, making it difficult for bicyclists to travel far distances. In addition, the idea of improving speed and range of the bicycle by adding an engine of some type was becoming increasingly popular. Many of the top bicycle engineers left the industry to concentrate on the development of the automobile. Even Pope himself, the most prominent bicycle supporter, began concentrating on the automobile and became the leading automobile producer by the year 1900. Others, like the Wright Brothers, left the bicycle industry to concentrate on developing the airplane.

One interesting use of the bicycle was the introduction of a bicycle railroad in 1892. The railroad was established to provide transportation for the residents of Mount Holly, New Jersey . It was designed to allow them to commute to and from their jobs in Smithville, New Jersey, 1.8 miles away. The infrastructure for this railroad looked like a wooden fence, and the top rail of the fence served as the track. The rail was capped by an inverted iron T-rail, upon which the grooved wheels of the vehicles rode. Turntables and switching spurs were installed at strategic locations to allow easy access to the railroad and rider travel in both directions. The vehicles on this railroad were essentially standard bicycles with a double triangular frame that straddled the track. The wheels ran along the top of the track, and the rider's seat was located on the frame connecting the two wheels. The bicycles were powered by treadles (pedals), and a set of idler wheels kept the bicycle steady. Handlebars were used to support the rider, and also acted as brakes.

In 1893, the bicycle railroad was demonstrated at the World's Colombian Exposition. Although the railroad was not a financial success at the exposition, several bicycle railroads were later built as amusement devices in resort towns. The Mount Holly & Smithville Railroad operated until 1898, when the lack of riders forced it to shut down. The last bicycle railroad ceased operations in 1910. Reasons for the failure of bicycle railroads are discussed in table 16.

Table 16. Reasons for the Bicycle Railroad's Failure

Reason	AHS Lesson Learned
• Safety bicycle had been introduced in 1884, and had become popular. The safety bicycle was more flexible than the bicycle railroad, since it had no pre-defined destinations.	• Consider requirements/demands of local traffic users on AHS exit spacing.
• The wooden track for the railroad was not maintained. Over time it deteriorated, resulting in frequent accidents and injuries to riders.	• AHS design should include considerations, plans, and facilities for on-going maintenance.
• The route of the railroad became less desirable. Fewer people were commuting between the two towns served by the railroad, and the railroad had no other destinations.	• AHS must serve long-term transportation needs in terms of the destinations served.

In many ways, the bicycle facilitated the development of the automobile. The bicycle provided technology that was used in automobiles including chain drives, steel-tube framing, headlights, roller bearings, differential gearing, and the pneumatic tire. Bicycle manufacturers had developed machines and tools for affordable mass production, which were applied to automotive and other industries. In addition, the bicycle made apparent the benefits of mechanized travel. This helped create the demand for automobiles and led the way to improvements in road construction techniques.

Lessons for AHS

Table 17 summarizes automotive history and its lessons for AHS.

Table 17. Highlights from the History of the Automobile with Associated Lessons for AHS

Automobile Development Milestones	Lessons Learned for AHS
• The first self-propelled vehicle was built and demonstrated in France in 1769, by Nicholas Joseph Cugnot. • This vehicle utilized a steam engine, ran at a top speed of three miles per hour, and offered no improvements over the horse.	• AHS demand will be contingent on travel improvements offered over non-AHS travel.
• The steam-driven bus industry emerged in England in the mid 1800s. • In 1865, the "red flag" law was brought about by opponents of the steam bus. This law killed the entire steam bus industry.	• Build coalitions between different industries to consider a multi-modal solution. • Need to identify potential opponents to AHS before its implementation.
• Etienne Lenoir introduced the first two-cycle internal combustion engine in 1860. • Nicholas Otto introduced the four-cycle internal combustion engine in 1878. • George B. Brayton introduced, in 1872, a two-cycle engine that compressed fuel in a separate chamber outside the cylinder.	
• George B. Selden applied for a patent on a road engine, in 1879, which combined a motor using a hydrocarbon fuel, a mechanism for disengaging the engine from the driving wheels, and a steering device. However, he never built a vehicle conforming to his specifications. He obtained the patent in 1895, and used it to file a suit against Henry Ford and the other automotive companies in 1903. Later, in 1911, this patent was found to be "valid, but not infringed" by the US automotive industry.	
• Prior to this century, automobiles were seen as a novelty. Few saw realistic applications for the general public. • With the popularization of the bicycle in the late 1800s, the value and potential of mechanized travel began to be realized. • Several technologies developed for the bicycle found application for improving automobile design. (e.g., steel-tube framing to provide strength and lightness, the chain drive, ball and roller bearings, differential gearing, and the pneumatic tire) • The popularity of the bicycle created demand for road improvements over those needed by horse-drawn vehicles. These later served automobile traffic.	• Public acceptance of novel ideas (like AHS) is enhanced when concepts can be experienced (in part or in total). • Technology from related fields should be considered to support AHS.
• Three types of automobile engines were introduced in the 1890s: internal combustion (gasoline), electric and steam. — Steam driven automobiles had more power than the original internal combustion engines, and did not require a complicated transmission. However, steam engines required constant skilled maintenance, and were difficult to operate. — Electric automobiles were quiet, clean and easy to operate. However, they were severely limited in speed and distance, due to the unavailability of a battery with sufficient endurance to make long runs and high speeds possible. — Internal combustion-powered automobiles were easy to operate, mass produced and therefore low cost, and found advocacy in the oil industry which developed supporting infrastructure. • Thus, the US automotive industry focused its efforts on improving the internal combustion engine for use in motorized vehicles.	• The success of AHS will be facilitated if it is low cost and if there is sufficient supporting infrastructure available. • All feasible options should be considered for AHS. It should be left to some experimentation to make definite decisions regarding which technological aspects of the system will be accepted.

Table 17. Highlights from the History of the Automobile with Associated Lessons for AHS (continued)

Automobile Development Milestones	Lessons Learned for AHS
• Commercial production of motor vehicles in the US was started by Pope Manufacturing Company and Winton Motor Carriage Company in 1897. • In 1900, a total of 4,192 automobiles were produced in the US. • By 1908, production levels had risen to 65,000, and automobile registrations approached 400,000.	
• Problems with solid and liquid wastes from horse-powered vehicles provided incentive for the introduction of an alternate propulsion system.	• Pollution caused by transportation systems can lead to demand for alternate transportation modes and/or propulsion systems.
• The post office, in 1899, began experimenting with using trucks for mail delivery. This step seemed to give official sanction to the new technology.	• Public seemed willing to trust a technology that was being utilized by a well-known and respected Government agency.
• Automobiles first emerged in the US as racing vehicles, which aroused public interest in the technology. • Endurance runs and reliability trials, such as those run by Glidden Tours, demonstrated automobile reliability and safety, and elicited feelings of admiration and trust from the general public.	• Demonstrated proof of AHS reliability and safety will facilitate public acceptance.
• Ford popularized the idea that owning a car was not a luxury, but something every family could aspire to. • In 1908, 5,986 Model Ts were sold for $850 each. • Ford introduced assembly line production in 1914, lowering production costs and the price of a Model T to $490. That year, over 260,000 cars were sold.	• AHS success will be facilitated if it can be afforded by all economic sectors of the population. It may be possible to offer more luxuries and comforts to those who can afford more, but the basic service should be available to all for best market penetration.
• Other automobile companies developed automobiles in the medium-priced range. This offered, to those who could afford it, status over Model T owners. • Some of these companies offered financing plans to buyers, making their products accessible to more buyers.	• Offering financing to potential AHS buyers would be an advantage in the 1990s.
• Simultaneously with the popularization of the automobile came the development of supporting industries, such as petroleum, rubber, and service industries. These industries stood to gain from automobile sales, and served as advocates for the development of the automobile and associated infrastructure. • A number of organizations, including the American Automobile Association (AAA), the National Association of Automobile Manufacturers, and the Automobile Club of America, were established to further the rights of motorists and the automobile industry. There were few active special interest groups opposed to the automobile.	• Support from AHS advocacy groups can facilitate AHS market access. • Lobbying groups can help to further the cause of AHS. They can even help to counteract any groups that oppose AHS implementation.

Table 17. Highlights from the History of the Automobile with Associated Lessons for AHS (continued)

Automobile Development Milestones	Lessons Learned for AHS
• In 1922, the first automobile-dependent shopping center was built. It offered a number of stores, each set in a parking lot. This was to be the basis for the modern shopping mall. • Drive-in restaurants, movies, and banks were established to capitalize on the automobile's popularity. • The development of supermarkets revolutionized the way families did their grocery shopping. Supermarkets were built to open onto large parking lots, to maximize motorist convenience.	• The success of one transportation system over another can have far-reaching (and often unforeseen) consequences, good and bad.
• Although railroads and interurbans had helped to establish a pattern of suburbs surrounding the inner city, the automobile permitted these suburban areas to expand. It was possible for development to break away from the grid fixed by the rail lines. • The ownership of automobiles resulted in a sharp decline in rail passenger traffic after 1920. Cars were more convenient and less expensive, and the motorist was independent of someone else's schedule. • Automobiles offered travel that was not dependent on preset routes or fixed schedules. They allowed drivers to go wherever they wanted, whenever they wanted. • City transit systems were practically eliminated, due to the widespread use of the automobile. In places where transit systems continued to operate, they were often considered a hindrance to automobile traffic.	• The success of one transportation system over another can have far-reaching (and often unforeseen) consequences, good and bad. • AHS will provide a transportation system that maintains the freedom of an automobile, while providing some of the benefits of mass transportation (e.g., drivers would be relieved of driving in rush hour traffic).
• By the end of the 1920s, the automobile had evolved into the mechanical and structural form it would retain, subject to improvements and refinements. • In 1929, US automobile production reached 5,337,087, a record that would not be reached again for another twenty years. • The *Middletown* study, in 1929, indicated that "ownership of an automobile has now reached the point of being an accepted essential part of normal living." The family car had become a social need; families used it to go to and from work, shopping, visiting friends, or on a vacation that they could not have otherwise afforded.	
• Many social changes have occurred since the introduction of the automobile, which is often blamed for the negative social consequences (e.g., weakening family life by allowing individuals to disperse to their separate interests).	• Negative social changes that occur with the introduction of a new technology (whether or not there is a relationship) are often blamed on the technology.
• During the Depression (1929-1932), car ownership dropped by only ten percent. This still corresponded to one car for approximately every one-and-a-half American families. • However, there were fewer new cars sold, as people held on to their old car, or bought used cars.	

Table 17. Highlights from the History of the Automobile with Associated Lessons for AHS (continued)

Automobile Development Milestones	Lessons Learned for AHS
• During W.W.II, new cars were virtually non-existent, gasoline was rationed, and tires were repeatedly patched. • Even so, the private car remained in daily use because it was considered indispensable. There was no other way for workers to commute between work and their suburban homes.	
• After the war, developers built neighborhoods of tract houses, which were very affordable to young families. Often, schools and other services were located far from these tracts, and an automobile was required for everyday living.	
• Car manufacturers began to place greater emphasis on comforts, in an attempt to keep customers happy in all weather and traffic conditions. • Car radios made congestion more tolerable; improved heating and air-conditioning systems made driving more comfortable in all climates, while power steering and automatic transmissions made it easier to cope with stop-and-go driving. • Recently, anti-lock brakes (ABS) have become quite popular with motorists. They offer drivers a superior technology which can out perform the human's physical ability to brake an automobile. Drivers perceive automobiles with ABS as safer than cars with traditional braking systems.	• Car manufacturers will support AHS if they perceive competitive benefits. • Drivers have been receptive to developments that make performing tedious tasks (e.g. shifting gears) easier or help to improve the performance of safety features (e.g. ABS), despite reducing the amount of driver input and control. Similarly, AHS will improve convenience and safety while reducing driver control.
• Most cities were not designed to accommodate automobiles. Thus, they suffer from serious congestion and a lack of adequate parking. • Pollution problems have been experienced in urban and suburban locations due to heavy automobile traffic not too unlike the pollution created by the horse which helped motivate the automobile's acceptance.	• The effect of AHS on parking facilities must be simultaneously considered. • The impact of AHS on urban/suburban pollution and congestion should be considered. — The elimination of stop-and-go driving will reduce pollution. — If AHS results in more vehicle miles traveled, pollution could be increased. — If smaller, more fuel efficient vehicles are used, issues of pollution and congestion could be kept under control. • AHS should consider likely changes in vehicle design that may be common in the future, (e.g. alternate propulsion).

3.2.2.1.4 Issues

The major issues, risks and recommendations for AHS derived from the analysis of the history and development of automobiles are summarized in Section 4.1.

3.2.2.2 Cruise Control, ABS Brakes, and Air Bags: Liability Issues

3.2.2.2.1 Introduction

In our litigious society, product liability is an issue we must be concerned with at all stages of AHS development. AHS designers and manufacturers will ultimately be responsible for each decision made during the design and implementation processes. The designers and manufacturers may eventually be held liable for system problems. Most importantly, we must be concerned with any potential problems in AHS that may cause an accident.

Although AHS is still in the research stage, technology already exists which assumes some level of control over normal driving functions. Cruise control systems give control of speed regulation to the automobile, anti-lock brakes assume some of the braking control, air-bags automatically inflate to prevent injuries in case of accidents, and on-board computer systems regulate many other automobile systems. Because these technologies have already been challenged by the legal system, we have used them as a basis of comparison to identify potential AHS litigation issues.

This section presents our overview of potential liability issues based on analysis of these comparable systems. We also discuss relevant patentability issues identified as a result of this analysis. Since AHS may need to address some of these patentability issues at later stages of AHS development, we have included a brief discussion.

3.2.2.2.2 Approach

The approach taken for this analysis involved an extensive literature review, including a survey of court cases involving cruise control, anti-lock brakes, computer systems, and airbags. Emphasis was placed on identifying liability issues surrounding cruise control, anti-lock braking, air-bags, and on-board automobile computer systems.

Based on the liability issues associated with these systems, we have developed design and planning recommendations that may help to protect AHS manufacturers from potential liabilities in the future. We provide an overview of how problems involving technical components of an automobile have been handled in the legal system to date. The review of court cases is not comprehensive because outcomes of trials and settlements are not regularly published. The information that is available is typically submitted voluntarily for educational purposes only. (Huffman et al., 1994)

We have highlighted the major points from the report, *The Law and Automated Highway Systems: Investigations of Cruise Control and Anti-Lock Brakes* , prepared at Princeton University by Bart W. Huffman, Alain L. Kornhauser, and Eric C. Huber. We have also identified relevant lessons for AHS. [Refer to Huffman et al., located in Appendix B, for a summary of cases reviewed.]

3.2.2.2.3 Results

The results of this section are organized into three parts. The first part includes an overview of liability issues that might face AHS. The second part includes an overview of the types of cases concerning cruise control, anti-lock brakes, airbags, and automobile computer systems that have been resolved by the legal system in the United States. The third part provides an overview of the legal framework corresponding to the patenting of new inventions.

Liability Overview

AHS development depends on the introduction and implementation of an advanced technological system. Like any new product in American society, AHS development will almost certainly face a wide range of legal concerns before, during, and after implementation. It is necessary to anticipate and predict these legal concerns, so that they may be addressed while AHS is still in the planning and design phases. Addressing the concerns now will prevent, as much as possible, costly litigation after AHS implementation.

There are four scenarios which may result in a product liability lawsuit:

- Mismanufacture (defective product)
- Defective design or formulation
- The Failure to give adequate warnings or instructions for safe use
- The Failure to truthfully represent the quality of a product

It is important to define the main areas of product liability that may apply to AHS designs, as summarized in table 18.

*Strict Liability***.** Any entity which sells a product that is unreasonably dangerous and defective and a proximate cause of injury is liable. (Huffman et al., 1994) The term*defective* is defined here as having a condition which may be unreasonably dangerous to the consumer, when this condition is not anticipated or obvious to the consumer. *Unreasonably dangerous* is defined as being more dangerous than a level that would be acceptable to an ordinary consumer, based upon common knowledge about the product's characteristics. In strict liability actions, it is not necessary to prove that the manufacturer is at fault, only that a defect in the product caused the accident.

Design Liability. Design liability is one specific type of strict liability. A design liability case asks the jury to decide whether the design chosen for a product was the best one, considering the safety of consumers as the most important criterion. Although an examination of every conceivable scenario is impossible during the design phase, the potential liability for a design defect requires the most thorough safety analyses possible. (Huffman et al., 1994) Simply the existence of a safer system may be enough to show liability for a design defect. The determination of design liability involves a balancing of the chosen design's characteristics against the likelihood and seriousness of injuries resulting from the product's use. (Huffman et al., 1994) Recovery on a defective design suit is also allowed for an event involving a product that should have been foreseeable, although not an event intended by the manufacturer. (Ramsdell, 1992)

Table 18. Summary of Product Liability

Type of Liability	**Liability Scenarios**				**General Definition**	**Comment**
	Defect Caused by the Manufacturer	Defective Design	Failure to Give Adequate Warnings or Instructions	Failure to Truthfully Represent a Product		
Strict - Manufacture - Design	X	X			The product is unreasonably dangerous due to a defect, and/or the safety of consumers required a different design.	It is not necessary to prove that either the manufacturer or the designer is at fault, only that a defect (or safer design alternative) exists.
Negligence - Manufacture - Design	Only if the Manufacturer acts or fails to act in a way which caused the defect	Only if the Designer acts or fails to act in such a way which caused the defect	X	X	The product designer, manufacturer, or distributor acts, or fails to act, in such a way that creates risk, harm, or injury.	It is necessary to prove that the designer, manufacturer, or distributor failed to act with reasonable care.

Negligence Liability. Negligence liability is defined by the rule: “A product seller is negligent if he acts, or fails to act, in such a way as to create an *unreasonable risk of harm or loss* to the user of a product or to others who might be injured by the product” (Huffman et al., 1994). In negligence liability it is necessary to show that the designer/manufacturer failed to act with reasonable care under given circumstances.

Negligent Design. The design of a product may also be examined under negligence liability laws. A negligent design case asks the jury to review the manufacturer’s design tradeoffs between cost, amenities, and safety, and holds the manufacturer liable if the jury believes the tradeoff should have been done differently. Negligence implies that actionable conduct (i.e., failure to look for design alternatives) must be proved.

Overview of Litigation Cases involving Cruise Control, Anti-Lock Brakes, Airbags, and On-Board Computer Systems

Cruise Control Cases. Many of these cases were filed by drivers who had been involved in "sudden acceleration" accidents. These cases usually named car manufacturers as defendants. In some cases, the plaintiffs (drivers) claimed that a malfunction in the cruise control system caused their vehicle to suddenly accelerate, causing an accident. Other plaintiffs claimed that their cruise control systems self-activated or locked, preventing them from stopping (or slowing) in time to avoid an accident. Generally, defendants (manufacturers) won cases where there was no evidence that the cruise control system caused the accident, or when alternative viable explanations for the accident could be provided. Surprisingly, many plaintiffs won cases in which it was shown that they, as drivers, could have taken some action to avoid the accident (e.g., by using the emergency brake, turning off the car, putting the car in neutral, etc.). In addition, the courts have been generally unwilling to excuse a driver for speeding on account of an alleged cruise control defect. In these cases, the courts have ruled that "a motorist who entrusts his car to the control of an automatic device is 'driving' the vehicle and is no less responsible for its operation if the device fails to perform a function which under the law he is required to perform." (Huffman et al., 1994)

Anti-Lock Brake Cases. Most of these cases were filed by drivers who blamed failure of their braking system, or a defect in the anti-locking brakes, for an accident. In these cases, verdicts were made for defendants (manufacturers), because the plaintiffs (drivers) failed to show any of the following: defects actually were present in the braking system at the time of the accident, the braking system was defectively designed, a braking problem actually caused the accident, or that the brakes were defective at the time they left the manufacturer. One case alleged a design liability in the braking system because an anti-lock braking system had not been installed in his vehicle. This case was won by the defendant because the Federal safety standards preempts the case for strict design liability, and there are no Federal safety standards or regulations requiring an anti-lock braking system on automobiles.

Airbag Cases. There is an ongoing debate concerning the plaintiff's right to compensation in cases where airbags were not installed. Until recently, Federal safety standards did not require automobile manufacturers to install passive restraints or airbags in their vehicles. However, because such technology has existed for a number of years, some plaintiffs (drivers) have won cases based on injuries that may have been prevented by the inclusion of an airbag in their automobile. (Refer to the full report in Appendix B for a more complete description of this debate.) Defendants (manufacturers) have also won cases in which accidents occurred at speeds below which an airbag is supposed to deploy (a limitation of the airbag system which is communicated to automobile owners), and cases in which the driver’s negligence caused the accident. They won because it was determined that the installation of an airbag would not have affected the outcome of the accident, or that the driver caused the accident himself.

Computer System Cases. In one case, a plaintiff sued an automobile manufacturer claiming that a defect in the car’s computer system caused a malfunction in all of the car’s other systems, resulting in an accident. The evidence in this case, however, presented an alternative explanation for the accident, claiming that a driver’s error caused the accident to occur. The defendant (manufacturer) won this case.

The above examples illustrate that there is not a consistent manner in which automobile litigation is decided. Because most of these cases were decided by juries, there is much room for personal interpretation of the evidence presented during the trial. Many juries were asked to decide whether a defective system was at fault, or whether the accident was simply a result of human error. Some verdicts absolved the driver of all personal responsibility for the car (whether or not control was given over to an automated system), while other cases placed fault with the driver of the automobile for not showing reasonable care in avoiding an accident.

Lessons Learned for AHS

In AHS similar questions may be raised in future litigation. It may be necessary to decide what is responsible for an accident: the technology in the AHS system, a computer malfunction, or a driver error. However, because of the concerns of product liability, AHS designers must be careful to anticipate potential safety problems, and provide adequate fail-safe designs. Comprehensive safety analyses must be conducted to support design decisions. Manufacturers must educate users to limitations of the AHS system, and provide adequate warnings and instructions on how to handle all possible situations.

AHS may learn from previous legal experiences with current automobile technology. Also, by becoming familiar with the legal issues that may apply to AHS, designers/manufacturers can work to minimize chances of future litigation. In table 19, we have summarized some features of the legal system in the U.S., and the corresponding significance for AHS development and implementation.

Table 19. The Legal System:
Lessons Learned for AHS

Legal System Feature	Lessons Learned for AHS
• The definition of a defective product and a dangerous condition are based on the perceptions of the general public.	• Educate the public about AHS operation and limitations. • Provide adequate warnings about the consequences of system misuse. • Any design features or warnings that can be misused or misunderstood, and thus lead to mishaps, need to be identified and redesigned before system implementation. • Early AHS demonstrations need to be strongly supported, in order to generate sufficient experiences with the new technology to make liability risks seem relatively small and manageable. (Syverud, 1993)
• The legal system is becoming increasingly complex. • The legal system is constantly changing. New legal approaches may be applied to product liability that may influence product design. (Huffman et al.1994)	• Consult a lawyer early in the design process. Legal guidance may also be required throughout the AHS development process. • Must be constantly aware of changes in the legal system to ensure that no legal issues are left unaddressed.

Table 19. The Legal System:
Lessons Learned for AHS (continued)

Legal System Feature	Lessons Learned for AHS
• Legal foundations are built on the basis of precedents. The decisions made in one case may affect (or guide) decisions made in all future related cases.	• Legal issues not clearly or adequately addressed may be decided in court. Those decisions could impact all aspects of AHS.
• Manufacturers are held liable for all design decisions they make. High risk decisions include the technology chosen for a system, the safety issues addressed, and the delegation of tasks between machine/automation and humans. • Government design and safety standards can help reduce liability of private industry.	• Private industry may be reluctant to make AHS design decisions. • Government standards may need to be established to specify upper-level design decisions, and to reduce the reluctance of industry to participate in AHS implementation.
• Black-box recorders can help to isolate faults in a system. The recording may help to identify when, why, and how problems in the system arose. (This may help to avoid liability when products are misused.)	• Consider including "black-box" technology in AHS components. This would allow for review of events if a problem were to occur, and thus mitigate liability for a well-designed system. • "Black-box" technology can be associated with check-in/check-out components of the AHS system (and thus not add significantly to costs). • The diagnostic capabilities of AHS components may also help in recording problems in the system.
• Antiquated technology/designs that are not updated can be grounds for liability. • Designs must use capable technology if it is available. • Equipment must be updated if this is shown to be important to system safety.	• Government standards may help to mitigate liability. • AHS designers must be aware of the state-of-the-art technology in AHS and related fields. • AHS updates must incorporate improvements needed to maintain safety.
• Safety features must be considered and incorporated, otherwise designers may be held liable.	• The more redundancy in AHS to prevent failures, the better. • AHS design must include safety analyses and incorporate hazard mitigation features.
• Potential safety issues that are identified in design and development phases must be disclosed and dealt with to avoid later liability.	• AHS must be built with adequate safety measures. • Existing Government standards may help to define what adequate safety in an AHS means. — AHS specific standards and guidelines may need to be developed.
• Technology is poorly understood and therefore dealt with harshly in the judicial system.	• AHS technology should be obvious, and easy to use (keep it simple). — The public must be educated about the benefits, limitations, and realistic expectations of AHS. • Government standards may help to clarify what is acceptable technology and safety standards.
• User responsibility can resolve technology-based liability (e.g., voluntarily giving up control to cruise control system).	• Make drivers responsible to the extent practical where liability is an issue. • Drivers must understand their role in the AHS system. The system should be designed to minimize potential for driver interference, while still requiring the driver to take control if necessary. Drivers need to understand under what conditions they may override the automated controls of the system (e.g., emergency situations).

Patentability Overview

It may be possible for an AHS system or AHS components to be patented at some point in the future. Thus, we have discussed some of the issues that may be relevant, and that may need to be addressed early in the design phase.

The United States Constitution specifically states that Congress has the power "To promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries." (Huffman et al., 1994) Practically, this means that inventors who obtain patents for their inventions may, for 17 years, exclude others from using or selling the invention throughout the United States and/or may "lease" the use of their patent.

A patent application must include a written description of the invention, and the ways in which the invention is to be built and used. Enough details should be included in the patent specification so that another person in the field could make and operate the invention. The application must also include claims which explicitly and distinctly state the subject matter (e.g., the concept or the particular design) which is considered by the applicant to be the invention.

In general, inventions must meet three requirements before they can be patented. First, the invention must prove to be *novel*. Even one example of a product meeting the limitations of the claimed invention is enough for the patent application to be deemed not novel. (Huffman et al., 1994) In addition, an inventor has one year from the time he or she introduces the invention to the public to apply for a patent on it. Any sale, public use, or foreign patents more than one year before the application date causes the invention to be ruled not novel.

Second, the invention must be proved *non-obvious* before it can be patented. If a person of ordinary skill in the field of invention recognizes the differences between the invention and previous inventions to be obvious, then the invention is not patentable. However, only the subject matter of the claims of the invention need to be proved non-obvious. Parts of the invention's specification may be obvious. This distinction may lead to a "blocking patent" situation, in which an inventor patents an invention which improves or incorporates patented technology. The improved invention may only be sold or used with permission of the original patent holder, and the original patent holder cannot use the improvement without permission from the improver. (Huffman et al., 1994)

Third, the invention must be shown to be within the *statutory subject matter* of patents. Patents may be granted to "whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter." (Huffman et al., 1994) Thus, ideas, abstract concepts, and theories are not patentable. This is sometimes a difficult requirement to satisfy when dealing with computer programs and software, and thus is an important concern for possible AHS patents. Recently, the courts have decided that a program (and the algorithms behind it) may be patented if it is applied to, or limited to, a specific situation involving specified physical elements and/or process steps. Thus, the wording of the patent application is critical; any computer algorithms for AHS must be described as a function of the total AHS system, and they must also be specified as a tool to perform specific physical or process manipulations, if they are to be patentable.

3.2.2.2.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of cruise control, ABS brakes, and air bags liability issues are summarized in Section 4.1.

3.2.3 Other Transportation Systems

3.2.3.1 Automated Guideway Transit

3.2.3.1.1 Introduction

Automated guideway transit (AGT) is a class of transportation systems in which fully automated vehicles operate on a fixed guideway, along a dedicated right of way. Generally, AGTs are classified by their application, rather than by the technology used. The term automated people movers (APM) refers specifically to AGT systems that provide short haul collection and distribution service, usually in a major activity center or in a central business district. APMs include both personal rapid transit (PRT) and group rapid transit (GRT).

PRT systems are designed to be in direct competition with the automobile in urban environments. Vehicles designed to carry individuals or small groups of people traveling together move along an extensive grid of guideways. These on-demand systems transport passengers directly from origin to selected destination. The cars run at very close headways to maximize capacity, and the many off-line stations give passengers many options for trip origins and destinations. PRTs provide service similar to that of automobiles, offering personal attention, short wait times, and trip flexibility. Although several PRTs have been planned, few have actually been put into operation. Notable exceptions are the CVS prototype system in Japan, and the Cabinentaxi System in Germany.

GRT systems utilize larger cars than PRTs, and attempt to provide service similar to that of traditional mass transit systems. They are designed to carry large numbers of people between limited origins and destinations. GRTs require less guideway mileage and fewer stations than PRTs, and are ideally suited for situations requiring the transport of a large number of people along predetermined routes. In recent years, most of the APMs constructed have been more like GRTs than PRTs. In fact, several systems designed as PRTs were ultimately modified and implemented as GRTs (e.g., the Morgantown System).

The motivation for AGT development is similar to that for development of AHS. In both cases, there is a recognized "need to provide transportation services at reasonable costs, that offer more of the social, psychological, and convenience needs supplied by the automobile, but without the congestion, pollution, petroleum consumption and accessibility drawbacks." (Office of Technology Assessment, 1980) This section examines the development of AGT/APM systems in the United States, with emphasis on the Morgantown project, and identifies lessons that can be applied to AHS.

3.2.3.1.2 Approach

The approach taken during this part of the study relied exclusively on a review of available literature that documents the history and current state of AGT/APM technology and system developments.

For more information, especially concerning the technological aspects of AGT/APM, we recommend three books. Neumann et al. (1985) and Bondada et al., (1989), published by the American Society of Civil Engineers, contain a collection of articles regarding APMs. The third book is *Innovation and Public Policy , The Case of Personal Rapid Transit* . (Burke, 1979)

3.2.3.1.3 Results

AGT/APM systems involve the application of innovative technology to solve traditional transportation problems. In the late 1960s and early 1970s, a major commitment of attention and resources was made by Government and private industry for the development of automated people movers.

The technology behind AGT is similar to that necessary for AHS. Like AHS, AGTs are controlled with automation, and can operate at small headways. Thus, AGT systems must be able to propel and brake the vehicles as necessary to control for position and speed (longitudinal control) and to ensure headway is maintained. AGTs must control vehicle entry and exit to/from the system (through either on-line or off-line stations); in some cases, the system must also have a way of knowing and reaching specific passenger destinations. The system must also perform frequent system status checks to ensure that all sub-systems are working properly. If any malfunctions are found, the system must be able to take immediate corrective action by either fixing the problem, removing the problem from the system, or shutting down the system. In addition, the system must be able to react extremely fast to emergency conditions.

Since AHS must also perform these and similar tasks, it may be helpful to examine the types of technology employed in existing AGT systems. Table 20 provides definitions for common terms used in conjunction with AGTs, and table 21 summarizes the system characteristics for 15 AGT systems. Note the list of references for more detailed information about any particular system, or for information concerning the technology used in the system. More detailed descriptions of the 15 AGT systems are contained in appendix C.

By 1993, over 84 AGTs were in operation (or under construction) worldwide. These systems, located in airports, amusement parks, institutions, and downtown settings, are described in appendix C. They utilize a number of different control, suspension, propulsion, and braking systems. The technological components of AGTs may offer some comparisons for AHS systems.

Table 20. Definition of Terms and Acronyms Used in Conjunction with Automated Guideway Transit

Term/Acronym	Definition
AGT	Automated Guideway Transit
PRT	Personal Rapid Transit
GRT	Group Rapid Transit
APM	Automated People Mover
Personal Transit Vehicle	A vehicle that carries a single person, or a small group of passengers traveling together by their own choice.
Shared Transit Vehicle	A vehicle that carries a large number of passengers having similar origins and destinations.
On-Demand Service	A system in which passengers request an empty vehicle when they enter the station. An empty vehicle is dispatched to pick up the passenger(s). The passenger(s) then enter their destination into the system, and the vehicle travels on the shortest available path, directly to the destination.
Scheduled Service	A system in which each vehicle has a schedule of departure times from each station. The vehicle travels over a prescribed route, serving particular stations. The schedule is predetermined according to typical demand patterns and to minimize passenger waiting time.
Velocity Control	Control of vehicle movement by relative movements of other vehicles along the guideway. Speed and position are based on the behavior of neighboring vehicles.
Point-Follower Control	Vehicles are assigned slots on the guideway in which they must stay. The slots move around the guideway at a predetermined speed and distance from neighboring slots.
Fixed-Block Headway Protection	The guideway is divided into segments (blocks). Each block has its own sensors and controls which can sense block occupancy and control vehicle speed. Only one vehicle is allowed in a block at a time. If a vehicle is about to enter a block occupied by another vehicle (indicating that it is too close) the block puts out a warning tone, and reduces the speed of the following vehicle so that it remains in its current block until the next block is empty.
Moving-Block Headway Protection	The guideway is divided into segments (blocks) which move along the guideway. Vehicles are assigned to a particular block, and must remain in it for the entire trip. The blocks are maintained at a fixed distance from each other, preventing any vehicle from becoming too close to another vehicle. The size of the moving block can vary in relation to the vehicle speed and braking capability.

In addition to identifying AGT design approaches and technology that might be applicable to AHS, the Team reviewed the historical context of AGT development to identify lessons learned that can be applied to the development of AHS.

The first major APM undertaking in the United States was the Morgantown people mover project in 1970. The Urban Mass Transportation Administration (UMTA) approved funds for the construction of a PRT at the University of West Virginia at Morgantown. The system's objective was to transport large numbers of students between the three campuses of the University in a personally flexible manner (i.e., users would select destination and obtain a direct route). In addition, the University wanted to establish a national demonstration facility for the study of the technical, behavioral, social, economic, urban design, and other aspects of Automated Guideway Transit (Office of Technology Assessment, 1975). The Morgantown project was faced with insufficient research and development time, which led to escalating costs. Design compromises were made and the system, while still referred to as a PRT, became much more like a GRT in operation. The project was finally completed in 1979, although a limited system was in operation in 1975.

Table 21. Selected AGT Characteristics and Specifications

AGT System	Type of Service	System Location	Lateral Control	Longitudinal Control	Headway Protection	Vehicle Total Capacity	Persons per Hour	Vehicles per Hour	Speed (mph)	Min. Head-way (sec.)
Airtrans	GRT, shared, scheduled	Dallas/Fort Worth Airport, Texas	mechanical, contact with sidewalls	Point Follower	Fixed Block	40	9,000	225	15	18
Aramis	PRT, personal or shared, on-demand	Orly International Airport, France	mechanical, lateral control guiderails	Vehicle Follower	Fixed Block, vehicles are platooned through electronic coupling	4/10	2,000 - 15,000	500 - 3,750	30	.2
Bendix - Dashaveyor	GRT, shared, scheduled or on-demand	Metro Toronto Zoo, Canada	mechanical, lateral control guiderails	Vehicle Follower	Fixed Block	32	7,680	240	30	15
Cabinentaxi	PRT, personal, on-demand	Ziegenhain Hospital, Germany	mechanical, lateral control spine	Vehicle Follower	redundant non-fail safe systems	3	9,000 - 15,000	3,000 - 5,000	22.5	.7
CVS	PRT, personal, on-demand	Demonstration System, Japan	mechanical, lateral control groove	Point Follower	Moving Block	4	15, 000	3,750	25	1
Ford ACT	GRT, shared, scheduled or on-demand	Fairlane Shopping Center, Michigan; Bradley International Airport, Connecticut	mechanical, lateral control guiderails	Point Follower	Moving Block	24	10,800	450	30	150
H-Bahn	GRT, shared, scheduled or on-demand	Dortmund University, Germany	mechanical, lateral control inside box-beam	Point Follower	Moving Block	16**	1,800**	113**	30	40
Horvair	GRT, shared, scheduled or on-demand	Duke University Hospital, North Carolina; Harbour Island, Florida; Sun City, South Africa; Serfaus, Australia	mechanical, contact with sidewalls	Vehicle Follower	Fixed Block	6/10	1,800 - 3,000	300	30	12
Monocab	PRT/GRT, personal, on-demand	Demonstration Track at Transpo 72	mechanical, guide wheels roll along a suspended monorail	Vehicle Follower	Moving Block	6	2,700	350	35	10
Morgantown	GRT, shared, scheduled or	University of West Virginia, West Virginia	mechanical, lateral control trough	Point Follower	Moving Block	21	5,040	240	30	15

In 1976, the UMTA introduced the Downtown People Mover (DPM) Program. The objective of this program was to construct fully automated transportation systems in urban environments. Six cities were selected for system development and construction. However, the DPM Program was canceled in 1981 before any of the systems could be built. Three of the selected cities, Detroit, Miami, and Jacksonville managed to continue their projects without Federal assistance. Similar projects were undertaken outside of the United States.

Table 22 describes the milestones in the introduction and development of APM systems and identifies lessons learned that are relevant to AHS.

Table 22. Automated People Mover Development Milestones:
Lessons Learned Worksheet

APM Development Milestones	Lessons Learned for AHS
• Electronic vehicle control capabilities began to be applied to transportation systems in the early 1960s. — Westinghouse began development of AGTs in 1963, starting work on a 2.3 mile test track in Pennsylvania. — By June 1966, Westinghouse had developed a new technology, which they called Transit Expressway. • Toward the end of the 1960s, and into the early 1970s, a major commitment of attention and resources was made by Government and private agencies for the development of an automated people mover (APM). The aerospace industry in particular made substantial technical and financial contributions to the research. • During the mid 1970s, the Urban Mass Transportation Administration (UMTA) policy shifted from enthusiastic support for new technologies, like APM, to a cautious policy based on traditional transportation systems. - Other nations also refocused their efforts on more traditional (manually operated) transportation systems.	• Government support for new technology-based transportation systems can be unsteady, especially when cost overruns and technical problems are experienced.
• In 1967, the UMTA initiated their New Systems Study, to begin researching transportation problems in the US. UMTA let seventeen contracts to industry, universities, and research groups to define a program of research and development, and to gather information on transportation demand patterns. (Burke, 1979) • Between 1967 and 1968, researchers for The New Systems Study uncovered over twenty existing proposals for personal rapid transit (PRT) systems. Most of these were still in the conceptual stage. — The technology to build a PRT was not yet developed, and researchers were still trying to identify the key service parameters and technological problems.	

Table 22. Automated People Mover Development Milestones: Lessons Learned Worksheet (continued)

APM Development Milestones	Lessons Learned for AHS
• In 1965, officials from the University of West Virginia began looking for ways to alleviate traffic problems near their campuses in Morgantown. They needed to develop a transportation system that could move students between three campuses quickly and efficiently. — Moving 1,100 people in twenty minutes was the goal of the system. • In 1969, the University was awarded a Federal grant of $154,000 to conduct a feasibility study of PRT for use in Morgantown. • The US Secretary of Transportation, John Volpe, became quite excited about the Morgantown project. He supported the idea of constructing a PRT system. -— The University of West Virginia had powerful support within the UMTA, as well as strong Congressional support for the project. • In September 1970, Morgantown was awarded a contract for the construction of a demonstration project, with 100 % of the funding from the UMTA. — $18 million was awarded, based on rough estimates made by University officials. This proved to be an underestimate. — The UMTA specified that the system must be dedicated and operational by October 1972.	• Having influential political support for AHS may facilitate the process of implementing the system.
• Jet Propulsion Laboratories (JPL) was hired in 1970 to manage the Morgantown project. — JPL estimated that a scaled down version of the system, using larger vehicles (working as a group rapid transit system instead of as a personal rapid transit system) could be completed on time, at a cost of $37 million. (Burke, 1979) • In 1971, JPL asked for additional time to perform detailed system analyses and to conduct further research. UMTA was unwilling to push back the deadline. — JPL left the Morgantown project in August 1971 and was replaced as project manager by Boeing Corporation.	• Overly optimistic estimates of the budget and schedule for AHS implementation looks good at planning time, but leads to failure. • The objective of an AHS system must be clearly defined to ensure that the design is sufficient to meet this objective.
• Boeing, faced with 14 months to complete the project, attempted to design, develop and construct the system simultaneously. This is a practice often done on defense contracts when cost is not an issue. • However, this caused numerous system deficiencies and problems which required redesign work an estimated cost of between $3 and $15 million. (Burke, 1979) — For example, building the guideway before the cars were designed resulted in a more expensive guideway than would have been necessary based on the final car design.	• An overly ambitious schedule for AHS development can lead to design deficiencies and problems.

Table 22. Automated People Mover Development Milestones: Lessons Learned Worksheet (continued)

APM Development Milestones	Lessons Learned for AHS
• In early 1972, UMTA concluded that the objectives of the Morgantown project were not being fully met by the project, and decided to extend the research and development efforts. • The original contract became Phase I of the Morgantown system, redefined as a demonstration of system feasibility rather than complete prototype system development. • Phase I of the Morgantown guideway was dedicated in 1972, but the vehicle failed in the initial demonstrations. — Work continued on the project, including extensive testing of vehicle configurations and design. — The Morgantown People Mover entered regular passenger service in 1975. • In 1977, Phase II construction began, forcing a complete shutdown of the entire system between July 1978 and June 1979. • Operation of the completed system began in July 1979. • Since final system acceptance in 1979, the University of West Virginia has been totally responsible for all operating and maintenance costs of the system.	• Once AHS service is initiated, further system development, enhancements, and/or extensions should not require long-term shut-down of service.
• During the first year of Phase I operation, there were many failures of the system, reaching an all-time low of 46 % reliability in February 1976. — Problems with inadequate power supply caused a number of vehicle malfunctions. — The effects of cold weather on the system were not correctly identified, causing freezing of all vehicle components that could possibly accumulate and hold moisture. — Scheduling was slightly erratic, resulting in frequent delays to passengers. • These problems caused some of the general public to doubt the effectiveness of the new technology. • In February 1989, Morgantown People Mover reached an all-time high of 99.4 % reliability.	• AHS must demonstrate safety and reliability from the outset. Any system failures can influence public opinion against the system, and people will be reluctant to use it. • It takes a significant amount of time for a technology to prove itself reliable, after receiving negative publicity.
• The negative experience with the Morgantown system may have hindered the development of other automated people movers (APM), i.e., PRT and GRT. — The UMTA had to reduce financial support for other APM systems, in order to provide funding for traditional transportation projects, and support the Morgantown overruns. — Public and political support for PRT systems was reduced due to the technical difficulties and high cost of the Morgantown project. — Although the Morgantown system was actually a GRT, it was always referred to as a PRT system. This led to negative connotations about all PRT systems for many years.	• Negative publicity on AHS prototypes or initial systems, may hinder future AHS implementations. • How systems are labeled can greatly influence how they are perceived.
• In 1973, the UMTA developed the high performance personal rapid transit (HPPRT) program to encourage further development and deployment of automated group and personal rapid transit systems. — The program was based on an initiative from Denver, Colorado, which had asked for funding to build an urban PRT. — For mainly political reasons, the Denver PRT was never approved.	

Table 22. Automated People Mover Development Milestones:
Lessons Learned Worksheet (continued)

APM Development Milestones	Lessons Learned for AHS
• In 1976, the UMTA introduced the Downtown People Mover (DPM) program. — The goal of the program was to provide an operating fully automated and unmanned people mover system in an urban environment, so that other cities could examine and evaluate a working system. — The DPM program envisioned the implementation of the type of system that had been proved safe and reliable over years of operation in airports and amusement parks. — 70 cities applied for the program, and 6 were selected for system planning and/or construction. • The DPM program was terminated in 1981, due to lack of Federal funding and political support, before any of the people movers could be built. — Three of the cities: Miami, Detroit, and Jacksonville managed to continue their projects without Federal funding, due to the firm commitments made early in the project by state, regional, and private sources.	• Inconsistent political and financial support for AHS can lead to reductions in achievable scope, only limited successes, and a general perception of poor performance. • Firm financial commitments must be obtained early in the AHS program to ensure financial resources will be available for system implementation.
• During the 1980s, the growth of the APM industry slowed considerably. Private investors were discouraged by the low profits earned from the systems, and the Government was discouraged by the high development costs and startup problems. • Public policy on mass transportation was also changed. When the Reagan administration was elected in 1980, they were committed to reducing Federal funding for mass transit. This policy was continued by the Bush administration.	• AHS development efforts will have to contend with changes in the political winds.
• APMs have become accepted as a viable mode of passenger transportation, especially in controlled environments, such as airports and amusement parks. • By 1993, there were 84 APM in operation world-wide, using a wide range of available suspension, propulsion, control, and switching technologies. — 62 of these are limited access systems, servicing airports, recreational parks, or particular institutions. — Only 22 are mass transit systems.	• Successful implementation of AHS for small-scale applications may facilitate future larger-scale implementation.
• APM/PRT systems have faced many of the problems currently facing AHS development. — Technology concerns, such as: headway, safety, reliability, switching, operations, and control. These needed to be addressed before an APM could be built. — PRT systems must also be concerned with malfunction maintenance, implementation and public acceptance of a new technology.	• Technical issues dealt with in PRT can be applied to support AHS development.

In addition to lessons for AHS derived from within specific historical contexts of AGT development (discussed in table 22), the Office of Technology Assessment has identified a number of general lessons learned from the AGT experience (Office of Technology Assessment, 1980). These lessons are summarized, and applied to AHS, in table 23.

Table 23. General Lessons from AGT, Identified by the Office of Technology Assessment, with Associated Lessons for AHS

Automated Guideway Transit Experience	Lessons Learned for AHS
• Money invested in alternative AGT technologies early in the design phase can provide relatively inexpensive insurance against the risk of implementing an inferior design. • At early stages of development, there is no technical basis for discontinuing work or reducing funding for any promising technology.	• All feasible alternatives for AHS technology should be considered during early design phases of AHS. A particular system should be chosen only after a complete analysis of all possibilities. This will help to ensure the best possible system is implemented.
• Introduction of innovative transit systems is constrained, not only by the need to more adequately develop new technology, but by major institutional and economic barriers as well.	• Institutional, social and economic issues must be addressed before AHS reaches the implementation phase. Resolving many issues early in the process will help to alleviate controversy when AHS is actually implemented.
• Cities in Federal DPM projects unable to accurately estimate costs of their AGT system suffered a loss of credibility which led (usually) to a failure to implement the system.	• Cost estimates for AHS must be carefully, and accurately determined. System design, testing, and implementation must remain within budgetary guidelines for the project. Seriously overrunning budgets may lead to negative publicity and poor public acceptance of the system.
• DPM projects failed in cities where developers were concentrated on the development of a system that would benefit only a small segment of the population. They were not focused on developing a system to benefit the general population of the city. This led to little public support for the program.	• AHS must concern itself with serving the needs of the general public, in order to achieve widespread support for the program.
• AGT suppliers are usually unwilling to make large investments in a new technology, given uncertain Federal support, unrealistically tight development timetables, complex institutional barriers, and/or lack of established stable markets. The Federal Government is often the only customer for new technology, and is often an unstable or risky customer. — Private companies often do not feel justified in investing large amounts of money trying to create a market for their new technology. • Experience has shown that 80% Federal funding is not sufficient inducement for cities to accept new transit technologies, especially if the new system will meet local needs at a reasonable cost is in question. — Cities want the Federal Government to underwrite the financial risks of system failure. — Investors are often wary because it is extremely difficult to make realistic and accurate cost estimates, especially considering the major cost overruns experienced on earlier projects.	• Government support, both politically and financially, is critical to the success of AHS. • Funding sources for the AHS program must be determined early in the design phase, and should be guaranteed for the long-range outlook of the AHS program.

Table 23. General Lessons from AGT, Identified by the Office of Technology Assessment, with Associated Lessons for AHS (continued)

Automated Guideway Transit Experience	Lessons Learned for AHS
• West Germany and Japan have developed cooperative relationships between Government and industry that have helped to establish an orderly program for long-range transit innovation. — Research and development on transportation systems is usually not handled by the same agency responsible for the construction and operation of the system. This division helps ensure longer-term continuity of development, since the R&D work is not competing for resources with short-term transportation projects. — Often, a consortium of private companies join in developing new technologies. If preliminary work is promising, the Government may offer financial incentives for prototype development and testing. This allows the companies to share the startup and preliminary research expenses.	• Cooperation between Government agencies and private industry can help ensure that the long-range goals of AHS can be met. • Consortiums of private and public agencies may help to ensure the long-term success of AHS research, development, and implementation.
• Although updating existing transit technologies should be a continuous process of short-range research and development programs, short-range programs are not a substitute for long-range programs aimed at achieving significant improvements in transit performance, cost, and service levels.	• AHS planning must consider long-term transportation needs. An AHS system should be able to meet future traffic demands.
• It is necessary to ensure that the decision to proceed to the development of production prototypes is not made prematurely. The decision assumes a wide base of knowledge about the relative merits of all technological options and their marketability. • System purchasers (often local Governments) are conservative, and are usually reluctant to take a financial risk on a new, unproven system, especially given the adverse publicity generated by failed systems.	• Development of a prototype system too early may be detrimental to the long-range AHS program. A system that fails in preliminary testing may generate negative publicity, which may hinder future acceptance of AHS technology.
• The complexity of public institutional arrangements and decision-making processes that can influence deployment of new technologies is a barrier to innovation in the private sector. Since the established systems, procedures, and expectations are difficult to change, incremental improvements in the existing transportation system is often preferred to new innovations.	• An evolutionary approach to AHS development is recommended. • AHS evolution can be facilitated with a coordinated program of education. — The AHS program should educate and inform Government officials, community leaders, and the general public on the potential benefits associated with AHS evolutionary progress.

3.2.3.1.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of AGT development are summarized in Section 4.1.

3.2.3.2 Air Traffic Control (Pilot Perspective)

3.2.3.2.1 Introduction

There are many similarities between AHS and the existing air traffic control (ATC) system in this country and abroad. In both cases, surveillance and command-control technology is applied to safely manage the movements of independently maneuverable vehicles. In both cases these technologies are integrated and applied to ensure efficient, coordinated, collision-free vehicle movement within well-defined spatial bounds. For ATC the bounds are defined in three dimensions and are less restricted than for AHS. AHS exists in a two-dimensional space along well-defined lanes. While ATC must deal with more wide open spaces, it also deals with fewer vehicles than AHS.

ATC includes three major components: ground control, landing approach and take-off control, and en-route control. Ground control is focused on safely managing airplane movement on the ground between gates and runways. Landing approach and take-off control is concerned with safely sequencing and controlling aircraft during take-off and approach to landing; it focuses in the airspace immediately surrounding airports. En-route air traffic control manages air traffic between destinations and is concerned with high altitude airspace outside the areas in the immediate vicinity around airports.

The present ATC system is highly centralized. Each aircraft is controlled from the ground by air traffic controllers, who issue commands to each aircraft. During flight, these commands include instructions for course, speed, altitude, and required maneuvers (e.g., turn, descend). The commands are generated based on ATC knowledge of the aircraft's destination, present position in three-dimensional space, direction of travel, and the location and status of other aircraft in the immediate area.

3.2.3.2.2 Approach

The approach taken during this study was narrowly focused, considering only the pilot's perspective. This approach was chosen for two reasons: (1) we did not want to duplicate the work of another contractor conducting an in-depth comparable study of ATC as it relates to AHS; (2) the Calspan Team has a seasoned staff of test pilots with extensive experience across a wide range of aircraft types including various military, commercial, small private, and flight test airplanes. In all of these various roles, these pilots have worked within the U.S. and international ATC systems. This perspective is a valuable component in assessing the AHS-comparable aspects of ATC; therefore, it has been given high-level consideration in this analysis.

The approach applied in studying the pilot's perspective of ATC used a small focus group with three Calspan pilots. A questionnaire with four general questions about ATC helped guide the conversation. These questions are reproduced in table 24. We also reviewed a recent article describing recommended changes to the existing ATC system to provide some higher-level context and understanding of the ATC system.

Table 24. Questions Regarding Experience with the Air Traffic Control System (Focus on Pilot Perspective)

• Describe ATC system operations from a pilot perspective. How does it work? What are its strengths? What are its weaknesses? Why?
• How would you like to see ATC designed? What major design changes would you propose? Why?
• How has ATC evolved to its present state? What difficulties have been encountered (e.g., as air traffic has increased, as hub and spoke philosophy has taken hold, as air traffic has gotten faster)? How has ATC service changed from your experience and perspective?
• What lessons do you see from your ATC experience for the design of AHS? Would you propose a similar command and control structure? Why/why not?

Secondary topics covered at the meeting focused on the pilot's experience with formation flight, autopilot, and coupled landing as it might relate to AHS. These are discussed in Section 3.2.3.3 of this report.

3.2.3.2.3 Results

The test pilots involved in the ATC comparable focus group were unanimous in their overall criticisms of the existing system. Their general criticisms related to perceived difficulties and inefficiencies associated with centralized control of local dynamic events (i.e., the control of aircraft from a remotely located Air Traffic Control Center), and difficulties in changing/improving ingrained procedures. This situation, given the present ATC system capabilities, they feel, leads to air traffic which is too sparsely spaced, causing delays, inefficient use of available airspace, and difficulties in responding to local events such as adverse weather conditions or other conditions that require deviation from defined or previously approved routes. Other issues were also discussed and related to AHS. Table 25 summarizes these discussions.

Table 25. US and International Air Traffic Control Systems from the Pilot's Perspective Lessons Learned Worksheet

AHS-Relevant Air Traffic Control Issue	Lesson Learned for AHS
Issues associated with highly centralized control: • The requirement for human decision-making about the control of local aircraft movements without precise position and intent information leads to system lags, requiring large safety margins and inefficient use of available airspace. • Centralized control of the movements of aircraft distributed in space makes response to local events difficult and inefficient (e.g., pilots must receive permission for any deviation from approved route). • An aircraft-based separation management system (i.e., one in which aircraft/pilots in an area had the capability and were empowered to manage their own local airspace) would improve system responsiveness and lead to reduced separation requirements. This would allow more air traffic on popular corridors at the most fuel efficient altitudes (this is especially a problem on US-to-Europe routes today). This would also allow more "direct to" flying, significantly reducing air miles between destinations and cost and time.	• The requirement for centralized human decision-making should be limited to global, non-time-critical parameters (e.g., setting overall speed limit). • AHS vehicle control approach should allow enough local discretion to permit vehicles to deal with local conditions (e.g., take action to avoid object in road). • Alternative AHS control approaches should consider effect on spacing requirements and flow achievable. Centralized control could create lags in the control system.

Table 25. US and International Air Traffic Control Systems from the Pilot's Perspective Lessons Learned Worksheet (continued)

AHS-Relevant Air Traffic Control Issue	Lesson Learned for AHS
Issues associated with the present communication approach: • Commands to aircraft and their confirmation employ voice communication. This is slow and subject to misunderstandings. A digital data link would be better.	• Commands to AHS vehicles from the roadway must be rapid and unambiguous. • Requirements for driver assimilation and interpretation will slow response.
Only IFR (Instrument Flight Rules) aircraft are controlled by ATC. VFR (Visual Flight Rules) aircraft (usually smaller private planes) may not be under control of ATC. • Pilots must be alert for and avoid aircraft not under ATC control. This is similar to AHS under the I1 concept (mixed AHS and non-AHS traffic). • Pilots must also be alert for aircraft under ATC control because of: location ambiguity and possible aircraft deviations from prescribed routes; systems failures (aircraft and ground) allowing aircraft to be closer than permissible; and the pilot's ultimate responsibility for mishaps. • VFR aircraft may not be seen by ATC because the system uses aircraft transponders to locate aircraft. VFR aircraft may not have transponders and raw radar returns are usually not monitored by ATC. • Pilots must rely on a "see and avoid" approach to maintain safe separations from other aircraft. • VFR aircraft do not fly above 18,000 feet. Pilots flying under IFR try to get above this altitude quickly to avoid problems and workload associated with presence of VFR aircraft.	• There will be a natural desire on the part of AHS users to move from an I1 AHS (mixed traffic) to I2 or I3 AHS (segregated AHS lanes) because workload and driving comfort will be enhanced. This will provide market forces that will naturally facilitate AHS evolution from I1 (mixed traffic) to I2 and I3 (AHS segregated traffic).
The ATC system has been improved as it became less responsive and more anticipatory: • Early ATC took aircraft to their destination, then planned landing sequences and patterns. This led to stacking (i.e., circling) of aircraft at destination airfields and inefficient use of airspace (e.g., fuel was wasted). The present system anticipates arrivals, delaying departures if necessary to avoid bottlenecks at destinations. This saves fuel,and improves safety, but does not appreciably save time.	• Bottleneck problems at activity centers or urban areas can be avoided by metering traffic having this destination at entry. If vehicle destinations are not known, predicted conditions at popular exits can be used to issue warnings that the exit may not be available and alternative exits suggested.
Improvements to the ATC system have been slow: • There is much inertia associated with large installed systems like the ATC system. Resistance to change exists throughout the bureaucracy. • Technologies that could improve the ATC system are not applied due to limited research budgets and resistance to change of procedures (e.g., Controllers are reluctant to relinquish control).	• AHS should be thoroughly tested and alternative designs thoroughly compared before implementation. It will be difficult to change later. • An AHS design consideration should be ease of making changes or improvements. Systems with vehicle-based components may be easier to change later than more centrally configured systems.
The new initiative to "commercialize" the ATC system cause pilots concern that the politically powerful airlines and commercial flyers will "put the squeeze on general aviation" (e.g., restrict access to the sky).	• There could be public concerns that if AHS were operated by private industry, commercial users would be given preference.

3.2.3.2.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of ATC operations are summarized in Section 4.1.

3.2.3.3 In-Flight Traffic Alert and Collision Avoidance System (TCAS), Instrument Landing Systems, and the Auto Land System

The questions posed in this area are reproduced in table 26.

3.2.3.3.1 Introduction

The Traffic Alert and Collision Avoidance System (TCAS), the Instrument Landing System (ILS), and the Auto Land System are systems that have been designed in an effort to increase the safety of airplane operations. These systems were developed by the aircraft industry primarily to decrease the influence of adverse weather on air traffic operations through the use of automation and intelligent systems. These objectives are similar to those of AHS. AHS is intended to improve the safety of highway travel through the use of automation and intelligent systems. This section includes a description of the TCAS, ILS, and Auto Land systems and describes several lessons that have been learned as a result of their development and use.

3.2.3.3.2 Approach

The approach taken for this analysis was to conduct a review of available literature. In addition, we interviewed pilots concerning their experiences with automated landing systems. The questions posed to the pilots may be found in table 26.

Table 26. Questions Regarding Experience with the Formation Flight, Autopilot, and Coupled Landing (Focus on the Pilot's Perspective)

- In many ways, formation flight and autopilot/coupled landing systems are similar to AHS. Have you had any experience with either of these systems?

- Describe how each of these systems (formation flight, autopilot, and coupled landings) is used from a pilot's perspective. Note issues of responsibility, mechanics of use, positive side effects, negative side effects, and psychological aspects.

  — Formation Flight
  — Autopilot
  — Coupled Landing

- Based on your experiences, what would you recommend for the design of AHS? Consider the following in your answer: safety concerns, mechanics of use, user interface issues (e.g., display recommendations), and driver responsibility issues (e.g., should the driver be allowed to sleep?).

3.2.3.3.3 Results

The purpose of TCAS is to reduce the risk of mid-air and near mid-air collisions, and to serve as a backup to the guidance provided by the Air Traffic Control (ATC) system. TCAS comprises electronic systems, a weather radar indicator, instantaneous vertical speed indicators, special antennas, and an auditory and visual alerting system. TCAS continuously emits signals in rapid cycles, which solicits replies from all transponder-equipped aircraft within 20 nautical miles. The TCAS system then measures the range, bearing, and altitude of these other aircraft and predicts the time it will take each to reach its closest point of approach to the aircraft.

Depending on proximity of other aircraft to the TCAS aircraft, the system can issue either a caution or a warning to the pilot, as well as a proximity advisory. Cautions are issued solely to aid the pilot in visually sensing the other aircraft. Warnings are issued to assist the pilot in correcting the flight path so greater separation can be achieved. The proximity advisory is issued in either case, and informs the pilot of the other aircraft. (Tillotson, 1988)

The purpose of ILS is to provide pilots with information that allows them to guide their aircraft to a point where visual sighting of the runway is possible, regardless of bad weather or poor visibility conditions. An Auto Land system can then guide the airplane through the landing process or this can be done manually. The ILS is composed of a localizer transmitter, localizer receiver, and two marker beacons. The associated Auto Land system includes a number of automatic control systems which include a localizer and glide path coupler, airspeed and altitude control, and an automatic flare control system.

The ILS helps the pilot to maneuver the aircraft into the correct position to land. The pilot, guided by ATC, descends from cruise altitude as the aircraft nears the runway. About six miles from the runway, the aircraft intercepts superimposed guidance signals of different frequencies. These guide the plane to the localizer centerline and the glide path centerline, ensuring the aircraft does not deviate from the desired flight path. Two marker beacons, one at four miles and the other at 3500 ft from the runway, serve to alert the pilot of the distance to the runway. Once the pilot has established visual contact to the ground and runway, touchdown can commence. If the aircraft is Auto Land-capable, then the auto land system would land the plane, through the use of pitch displacement autopilot, speed control autopilot, and flare maneuver. (Nelson, 1989)

AHS has many similarities to the TCAS, ILS and auto land systems. First, like AHS, all three aircraft systems are designed to improve safety of an existing transportation system. Furthermore, all of these systems also incorporate lateral and longitudinal automatic control. However, there are also significant differences between AHS and the aircraft systems. One such difference is how each of these systems affects vehicle control. TCAS and ILS serve to inform and advise the pilot. TCAS provides air traffic information, and ILS provides runway approach information, to the pilot. The pilot then can maneuver the aircraft accordingly, using the provided information. On the other hand, AHS is expected to control the vehicle with little driver intervention. AHS vehicles will receive control information directly from the system, and the system will make the necessary maneuvers to avoid dangerous situations. Another difference between AHS and both TCAS and ILS is the relative threat presence. TCAS is designed to prevent the collision of two aircraft, and may recognize a danger which is still many miles away. It may allow up to a minute for the pilot to react, and avoid the potential collision. AHS must deal with automobiles that are closely spaced, and which may face potential collisions in a matter of seconds.

Despite the dissimilarities, there are important lessons that can be learned from the study of TCAS and ILS. These lessons may be applied toward the implementation of AHS. The first lesson is that there must be substantial benefits identified for AHS in order to justify the expenditure of public funds. Safety is one important justification for the authorization and appropriation of public funds. This lesson was demonstrated by the introduction of TCAS. Studies showed TCAS to be an effective collision avoidance system and a good supplement to ATC. (Tillotson, 1988) The safety benefit of this system was a primary motivating factor leading Congress to enact legislation requiring all aircraft with more than thirty seats to install the TCAS system. (Gambarani, 1990) The costs associated with the research, development, and implementation of AHS are expected to be very large. Thus, it will be helpful to show that AHS can provide safety benefits over the existing highway system.

A second lesson that can be applied to AHS is that it is possible for an automated system to be safer than a manually controlled system. An FAA study has found that the standard deviation of an aircraft from a specified flight path was smaller with an automation-equipped aircraft than with a non automation-equipped aircraft under real-world situations. (Jones, Sexton and Yates, 1989) This is an important point, because it demonstrates that a "complicated" intelligent system can be safer than a human controlled system. This was true even for systems in which the human controller was "highly" trained and the system being controlled was considered to be very complex.

A third lesson is that AHS subsystems must be reliable, and have backup systems to protect against malfunctions. This lesson has been demonstrated by both TCAS and ILS. The success of TCASs and ILSs may be partially attributable to their supporting systems, ATC and the pilot. If either TCAS or ILS should fail or malfunction, the pilot, operating under ATC guidance, can intervene to avoid collisions and land safely. This emphasizes the need for backup systems in AHS. Both ILS and TCAS rely on the human operator as one of the backups. Further study is needed to determine the conditions under which the driver is able to override the automated system. Situations will arise in AHS where human intervention will be necessary, for example: complete failure of the roadside communications system, failure of the lateral or longitudinal control system, or failure of the centralized monitoring system. In these cases, vehicle operation may need to revert to manual control or other redundant systems.

One final lesson which can be applied to AHS is that unnecessary "advisories" should be limited. When the TCAS system was first tested, it constantly reported cautions and warnings to the test pilots which were considered unnecessary. This irritated the pilots, and caused dissatisfaction with the automated systems. Refinement of the threat detection algorithm helped eliminate a lot of these unnecessary advisories. (Tillotson, 1988) AHS alerts to the driver should be limited to those requiring driver action. This lesson may be applied to the lateral and longitudinal control of the AHS vehicle as well. If collision threat systems are too sensitive, this could cause an unsmooth ride which could be unsettling and undermine user confidence. Therefore, the AHS threat detection and avoidance algorithm must be effective in determining real versus unreal threats.

We also included discussion of pilot experience with and perception of auto-pilot and coupled landing systems. Some of the pilots' comments are related to AHS in table 27.

3.2.3.3.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of in-flight TCAS and ILS operations are summarized in Section 4.1.

Table 27. Pilot Experience with Autopilot, Coupled Landing Systems, and Formation Flight As It Relates to AHS

AHS Relevant Observation	Lesson Learned for AHS
Formation flight: • During formation flight, all aircraft fly off the lead aircraft. Variations in station keeping accuracy by individual aircraft are independent and, therefore, not additive (i.e., if each aircraft keyed off the nearest aircraft, errors would be additive, resulting in an unstable formation). • Separation to nearest aircraft is monitored to ensure safety margins are maintained.	• If platoons are employed with closely spaced vehicles, speed should be referenced to the lead vehicle, while spacing should be keyed off the nearest vehicle.
Coupled Landing: • These systems are very welcome when landing under difficult visual conditions. Performance is better than humanly possible. • Confidence in system performance is enhanced through monitoring of instruments. • Trust/confidence is developed over time as successful performance is experienced.	• User reluctance to use, or discomfort while using, AHS can be overcome by displaying information confirming proper performance. • Trust of AHS will increase over time with use. This will help overcome the reluctance to use AHS but could also lead to complacency (e.g., falling asleep).
Autopilot: • There have been problems with autopilot due to problems with the user interface in which pilot's entered incorrect parameters and for example, descended too fast. • Falling asleep has been a problem due to low event flying.	• The AHS-driver and/or AHS-ATM operator interface must be designed to avoid critical errors (e.g., entering unsafe speeds, etc.). • AHS design must consider the potential for driver's falling asleep (if highly trained pilots have this problem, it will certainly be experienced in the general public).

3.2.3.4 Railroads, Interurbans, and Maglev

3.2.3.4.1 Introduction

For almost one hundred years the railroad remained the primary mode of long-distance transportation in this country. Railroads offered speed advantages over horse-drawn vehicles and ships, the only alternatives to the railroads at the time of their inception. All major cities, and most small towns, had a railroad station, or at least were in close proximity to one. The railroads maintained a monopoly over transportation, and were seemingly unprepared for the technological developments that arose to become their direct competition.

In this section, we look at the development of the national railroad system in the United States, the transition from dependence on the railroad to dependence on the automobile, the decline of the railroads, and the recent resurgence of railroad transportation in this country. Lessons for AHS have been drawn from the history of the railroads.

3.2.3.4.2 Approach

The approach taken during this part of the study relied exclusively on a review of available literature documenting the history and present state of railroads in the United States.

3.2.3.4.3 Results

The results of this study are organized into four sections. The first traces the development of a national railroad system. The second section discusses the history of the interurbans, a short-lived technology used for intercity travel. The third section addresses the decline of the railroad industry in the United States, as well as recent regional successes of railroad technology. The fourth section provides a brief history of maglev (magnetic levitation) technology, and the difficulties it has encountered with implementation.

Railroad System Development

The first passenger railroad service was initiated in the United States in 1830. Passengers were initially considered little more than freight, and little attention was paid to ensure satisfaction. Passengers were offered no amenities during their trip, and were often forced to make frequent changes between railroad lines. During the 1860s, the Pullman Car was introduced, which offered luxurious passenger service for the first time. Passengers were willing to pay an increased fare for the privilege of traveling in a Pullman Car. However, it was still necessary to make frequent changes between railroad lines. Each line originally built its track to its own specifications, with little concern for compatibility with the track of the neighboring lines. This incompatibility prevented a car from one line traveling on the track of another line. It was not until the 1880s that all railroad lines in the United States standardized their tracks. (Husband, 1917)

The introduction of the Pullman Car improved passenger service and showed that passengers were willing to pay for the improved service. In addition, once the railroad lines standardized their tracks, it was possible for a passenger to travel coast-to-coast without changing trains. A national railroad system had been established.

The development of the national railroad system is discussed in *The Story of the Pullman Car* (Husband, 1917) and *One Gauge: How Hundreds of Incompatible Railroads*

Became a National System. (Stover, 1993) Milestones in the railroad's development, along with relevant lessons for AHS, are summarized in table 28.

Table 28. Railroad System Development Milestones:
Lessons Learned Worksheet

Railroad System Development Milestones	Lessons Learned for AHS
• In the middle of the 1500s, wooden railways were built to facilitate the travel of horse-drawn wagons. — It was easier for wagons to move on rails than on rough and rutted dirt roads. • The first iron rails were cast in 1767 to alleviate the wear from the wagon wheels.	• Good ideas often start slowly and evolve over many years.
• In 1814, George Stephenson utilized a steam engine to draw a "train," a series of connected wagons, along iron rails. Top speed for this first train was four miles per hour. • The first railroad to adopt steam as its primary power source was the Stockton & Darlington, operating in England, in September 1825. — These first steam trains were used for freight transport only. — However, the new technology became so popular that passenger service on steam trains was established one month later, in October 1825.	
• The first passenger service to be put into regular service in the US was the Charleston & Hamburg Railroad, in 1830. The passenger cars were little better than boxes mounted on wheels. — Passengers were barely protected from the weather. — Passengers had little comfort, and no amenities offered to them. — Passengers were also required to make frequent changes between railroad lines in order to reach their destination. Each change required the purchase of a new ticket.	
• The first sleeping car was introduced in 1836. — It was simply an adaptation of an ordinary day coach for sleeping requirements. • The first Pullman Car was not introduced until 1865. — It offered luxuries and comfort to the passengers. — Pullman Cars also incorporated improved safety devices in their design. — Travel in a Pullman Car was more expensive than travel in an ordinary sleeping car. — The public showed that it was overwhelmingly willing to pay the increased fare for Pullman service, to obtain improved service, comfort, and safety.	• The public will pay for increased service and comfort if the perceived benefits are sufficient relative to the increased cost.

Table 28. Railroad System Development Milestones:
Lessons Learned Worksheet (continued)

Railroad System Development Milestones	Lessons Learned for AHS
• The earliest American railroad lines were planned and built to serve a particular city and its surrounding area. None of the builders ever imagined a national railroad system. • Railroads used different gauge (the distance between the rails) tracks, resulting in little compatibility between different railroad lines. — Some railroad lines tried to match the gauge of neighboring lines. — Others purposely chose an odd size gauge to control business in a region. The odd size gauge prevented other railroads from using the tracks.	• Proprietary products can limit AHS interoperability unless standards are established and cooperative approaches to design are employed. (The consortium approach is recommended.)
• During the 1850s, rail mileage tripled, to over 30,000 miles nation-wide. • Trains were designed for use on one specific rail gauge size, and initially could not travel on a different gauge. — This required passengers and freight to be transferred between trains whenever the gauge size changed. — This transfer often took a considerable amount of time, and slowed down the entire trip. • Eventually, railroads developed systems to compensate for the differences in gauge. — Some railroad cars were built with sliding wheels, which could be adjusted to the necessary gauge. — Some railroads loaded freight into special boxes. These boxes could then be transferred from car to car, as necessary. — Some railroads laid down a third rail to accommodate cars of different gauges.	• Regional differences in AHS design, if not avoided, could require work-arounds to allow interoperability (e.g., cars equipped for use with multiple systems). This could be a problem nationally or internationally.
• Gradually, railroads began to standardize their gauge. — This was facilitated by the merging of the smaller railroads into larger companies. — By the early 1880s, most of the northern states had achieved a standardized gauge. • In 1886, officials from the southern railroad lines decided to change the gauge of their tracks to comply with the northern standard. Over a 2-day period, they standardized their tracks with the rest of the country by employing a huge (8,000 men) temporary (2 day) workforce. • By 1890, there were 164,000 miles of railroad track, working as an efficient, national network.	• Incompatible regional differences in AHS design could require difficult undertakings to rectify.

Interurban Development

The electric interurban railway provided a transitional step from dependence on the railroad to an almost complete dependence on the automobile. The interurban offered greater convenience and flexibility for short-distance travel between cities than the railroad, and greatly increased passenger mobility in the areas it served. However, the interurbans quickly gave way to the automobile, which offered even greater personal convenience and flexibility. (Hilton and Due, 1964)

The interurbans were developed in the late 1800s as a cross between the electric streetcar and traditional railroads. They were able to provide low-cost, frequent transportation to residents in rural areas, and gained much public support. As automobile technology was improved, the relative advantages of interurbans decreased, and many interurbans were forced to shut down.

Table 29 traces the history of interurbans in the United States, as well as many lessons that can be applied to AHS. More information about interurbans may be found in *The Electric Interurban Railways in America*. (Hilton and Due, 1964)

Table 29. Interurban Development Milestones:
Lessons Learned Worksheet

Interurban Development Milestones	Lessons Learned for AHS
• The New York and Harlem Railroad evolved from mules, to horses, and finally steam to power their trains, all during the first few years of operation. • After a locomotive exploded in 1839, injuring twenty passengers, locomotives were banned from densely populated areas. From then on, horses pulled the railroad cars through the city. Steam locomotives were used in the rural areas.	• AHS development may benefit from an evolutionary approach in which familiar and trusted technologies are gradually substituted with more seemingly radical approaches. • Early AHS mishaps can hinder further development and constrain public acceptance.
• During the 1850s, other cities began opening horse-drawn street railways, and by 1860 there were over 400 miles of street railroad tracks. — This trend continued, with 3,000 miles of track established by the early 1880s.	• Rapid expansion of transportation systems is possible once feasibility, safety, and benefits are demonstrated.
• By 1890, other forms of power had begun to be utilized. However, horse-drawn lines were still the most popular. In operation were: — 5,661 miles of horse-drawn lines. — 1,261 miles of electric streetcars. — 488 miles of cable railways. — 711 miles of steam dummy engines (small steam locomotives). • Neither cable railways nor steam dummy engines reached the popularity of the electric streetcar. — Cable railways required a large initial expenditure, and the infrastructure deteriorated quickly. —Steam dummy engines were expensive, and dirty to operate. They were only used in suburban areas, since they were totally unsuitable for congested urban areas. • By 1900, only 259 miles, one percent of the entire system, were still horse-powered. (White, 1992)	

Table 29. Interurban Development Milestones:
Lessons Learned Worksheet (continued)

Interurban Development Milestones	Lessons Learned for AHS
• The first electric streetcar system was built in Richmond, Virginia, in 1887. — The system offered essentially the same service to passengers as the horse-powered railways, but with less noise, less pollution (horses left urine and solid waste all over the street), improved reliability, and lower operating costs. (Horses required feeding and grooming, could work only 3-6 hours a day, and were susceptible to illness.) • By 1902, 97% of street railway was electrically operated, with over 15,000 miles of track.	• Demonstration of AHS benefits will facilitate acceptance.
• Interurbans were developed in the late 1800s as a cross between the electric streetcar and the traditional railroads. • Interurbans were defined by four characteristics: — They operated on electric power. — Primary emphasis was on passenger service. — Equipment was heavier and faster than electric streetcars. — Interurbans operated on the streets of cities, and along the sides of rural highways. • Interurbans would make stops anywhere along their route, eliminating the need for passengers to travel to a specified railroad station.	
• Many of the first interurban lines were constructed in Ohio (and its surrounding states). • Ohio was an ideal location for interurban technology because: — The rural areas were densely populated, and many of these rural residents were relatively wealthy. — There were many medium-sized towns, situated close together. — The terrain was flat, with few impediments to railway construction. — Local railroad service was insufficient for passenger needs. • Eventually, Ohio had the most interurban lines, and the greatest number of interurban miles.	• There may be regions in which conditions favor AHS success, while other regions may be less favorable.
• Interurbans earned public support, since they offered frequent, low-cost transportation to residents in rural areas. — Public support led to strong local pressure to build interurbans in many towns. — Organized opposition was led by merchants in the rural communities who feared the loss of their captive market to the bigger towns. • The railroads also waged campaigns against the interurbans. — Many railroads would not allow interurban tracks to cross their tracks; others simply charged exorbitant fees for the privilege. — Some railroads attempted to obtain injunctions against interurban construction, but none were successful in making the injunctions permanent. — Railroads even tried to compete with the interurbans by cutting fares and expanding local service. But, they could not cost-effectively duplicate interurban service.	• Identify groups that could represent organized opposition to AHS and work to overcome potential differences and/or counter negative arguments.

Table 29. Interurban Development Milestones:
Lessons Learned Worksheet (continued)

Interurban Development Milestones	Lessons Learned for AHS
• Interurbans were constructed mainly from 1899-1903, and from 1905-1908. — The gaps in construction were due to national financial panics that reduced the amount of available financing. — Many projects had to be abandoned midway through construction, and even when construction resumed, many of these lines were never completed. • Total interurban mileage peaked at 15,580 miles in 1916. After 1917, the mileage abandoned each year exceeded the new mileage of track constructed.	• Secure and continuous funding sources for AHS will be important to provide for uninterrupted implementation.
• The popularity of the interurbans stemmed from their flexibility, and the personal mobility offered to the passengers. — Railroads rarely ran more than two trains a day through most towns, while interurbans offered as many as sixteen cars in a day. • Interurbans worked to find a compromise between offering frequent stops (e.g., at every crossroad, at every farm, at every street corner), and the speed achieved through direct service between towns. — Frequent stops presented an advantage over railroad service for local traffic, but made service less attractive for the town-to-town passengers. — Generally, limited service (express service) was offered only in areas where there was no railroad competition.	• AHS marketability will be enhanced over mass transit alternatives by the more personal and flexible transportation offered.
• Interurbans were developed at approximately the same time as the automobile. — However, the automobile was originally quite complicated, and it took time to develop into a safe, reliable, user-friendly mode of transportation. — Interurbans thrived because they were best able to meet the need for a mode of short-distance, intercity travel. • As automobiles, trucks, and highways improved, the relative advantages of interurbans decreased. — The remaining passenger business for the interurbans was barely enough to justify their operation. — Automobiles were less expensive to operate, were not limited by scheduled departures, could travel beyond the range of interurban tracks, and could provide door-to-door transportation. — Trucks were able to carry freight faster, at less cost than interurbans, and to a more flexible range of destinations.	• AHS marketability will be enhanced over mass transit alternatives by the more personal and flexible transportation offered.

Table 29. Interurban Development Milestones:
Lessons Learned Worksheet (continued)

Interurban Development Milestones	Lessons Learned for AHS
• As interurban traffic declined in the 1920s, they were forced to cut their schedules to reduce losses. — This action further reduced the advantages of interurbans, and caused even further reductions in passenger traffic. • The interurbans offered a variety of excursions and special services to attract passengers. — They offered excursion fares for travel to special events, and some even constructed and operated amusement parks to attract new passengers. — However, with the popularization of the automobile,these events became accessible without interurban transportation. • Some interurbans began to focus on freight traffic to make up for lost passenger traffic. — Interurbans were not designed for the heavy loads of freight. This made it necessary to reduce the interurban operating speed. — Often, freight operations interfered with passenger service, causing even further dissatisfaction with interurban service.	• AHS must maintain market share sufficient to cover costs or suffer the market ramifications of limiting service.
• The primary influence of the interurban was to condition the rural population to a greatly increased mobility that was more fully realized with the acceptance of the automobile. • Since interurbans radiated outward from major cities, they also helped to influence urban development in many areas. — The distinction between urban and rural became blurred, and many smaller towns were faced with declining commercial industries, trends that were reinforced by the automobile. • Interurbans also were the first major challenge to railroad passenger service. — Previously, the railroads had held a monopoly on inter-city travel. — The advent of interurbans was the first step in the eventual decline of railroad service.	• Enhanced travel services along specified routes can influence commercial and private development along those routes. • AHS competitiveness must consider current and future alternative transportation modes and selection criteria (e.g., increased emphasis on reduced pollution).
• Almost all of the interurbans had ceased operations by 1933. The remaining lines shut down gradually through the 1940s and 1950s. — Some of the lines simply became integrated with the railroad system; however, most lines were simply abandoned. — Many of the interurban tracks were torn up to facilitate paving of streets and highways for automobiles.	• If AHS is not competitive with alternative transportation modes, over the long term, even initial successes may not be sufficient to ensure survivability.

The Railroad’s Decline and Recent Regional Successes

Although competition for the railroads had begun to emerge early in the 1900s, the railroads did not recognize the seriousness of the threat to their monopoly on long-distance transportation. During the 1920s, the railroads found themselves facing very significant competition from automobiles, trucks, buses, and airplanes for long-distance passenger and freight traffic. They were forced to improve their efficiency, or be forced out of business.

The railroads switched from steam locomotives to diesel locomotives between the late 1930s and 1960. The diesels were more efficient, required less maintenance, and had a longer range. However, the total number of trains in operation decreased throughout the 1940s, 1950s, and even through the 1960s. The railroads were not able to meet the increasing demand for short-distance trips. Passengers were choosing the automobile as their primary mode of transportation, and more and more commercial freight was transported by truck or air. Even for long-distance trips, the railroads refused to make any changes in their service, and passengers chose to drive or fly to their destinations.

By the late 1960s, the railroad industry was crippled. Railroad lines were forced to shut down throughout the nation, disrupting national railroad service. In 1970, the United States Congress established Amtrak. Amtrak was charged with reversing the decline in railroad passenger service, and with reestablishing a national railroad system. Although Amtrak has been relatively successful, it has been unable to obtain enough political support to get the funding that would be required to upgrade the nation's ailing railroad system. Amtrak is less subsidized than the other transportation industries, but the Government has been unwilling to allocate the necessary funds.

As congestion continues to increase on the highways and in the air, railroads are becoming a more attractive mode of transportation, especially for commuter lines. Amtrak has been quite successful in regional areas in establishing efficient commuter service; between New York City and Washington, D.C., as an example. Although better railroad technology exists worldwide, Amtrak has been unsuccessful in bringing this technology to the United States, even on a limited scale. Amtrak is obligated by law and politics to manage a national railroad system. Thus it is prevented from making further improvements to localized geographic areas.

Individual states, however, have been studying the possibility of bringing modern railroad technology to their areas. High-speed rail systems have been operating successfully in Europe and Japan for twenty years, and have proved to be safe, reliable, efficient, and cost-effective. All that remains is the question of how to fund and market similar high-speed rail systems in the United States.

For more information on the high speed rails, please refer to *Supertrains* (Vranich, 1991).

Table 30 describes milestones in the general decline and recent regional successes of the railroads. Also included are pertinent lessons for AHS.

Maglev Technology

The thirty-year history of magnetic levitation (maglev) technology has been a continuous, unsuccessful struggle for funding and implementation. The following discussions present a brief account of this struggle, along with lessons learned that may be applicable to AHS. Maglev is a comparable technology to AHS because it seeks to apply new levitation technology to a conventional rail transportation system with the objective of providing a higher level of service (higher speed, comfort, and reliability). It is also perceived by some as a transport system for the transportation rich. It differs from AHS in several important areas. It doesn't have improved safety as a main objective, and it has no consumer component except for the actual end-purchase of transportation. In addition, suggestions for maglev and high-speed ground transportation (HSGT) in general may be applicable to AHS, as discussed in this section. But first, a short description of maglev technology will be presented.

Maglev systems consist of magnetically levitated vehicles which transport passengers at high speeds (in excess of 300 mph in some cases) on fixed guideways. The vehicles may be levitated by either magnetic repulsion or attraction (explained below), and they are propelled by a linear induction motor. This motor "creates a traveling electromagnetic field that interacts with magnets on the vehicle to generate the thrust forces for vehicle acceleration, maintenance of speed, and deceleration." (Transportation Research Board (TRB), 1991)

Table 30. The Railroad's Decline and Recent Regional Successes Milestones: Lessons Learned Worksheet

Recent Regional Successes Milestones	Lessons Learned for AHS
• During the 1920s, railroads found themselves facing serious competition from automobiles, trucks, buses and airplanes for long-distance passenger and freight traffic. — To compete, they needed to improve efficiency, reduce costs, and increase flexibility.	
• Diesel locomotives were considered as a substitute for steam locomotives. Diesel offered numerous advantages over steam for the railroad industry: — The steam locomotive was diffucult to start, and it was difficult to regulate and maintain speed. Stopping was also difficult, and caused brake shoes to wear out quickly. Steam engines needed to stop every 100 miles for fuel and water, and often could not operate at maximum efficiency. Also, maintaining steam locomotives was difficult and time-consuming. Replacement parts needed to be custom made. — On the other hand, diesel locomotives could be started and stopped on command. Speed could be easily regulated and maintained. The diesel could run for 500-600 miles between fueling stops, and could run at maximum efficiency. Also, diesel engines used standardized parts, and required much less time for maintenance and repairs. (Klein, 1991)	• Standard parts and efficient maintenance should be included in AHS design and evaluation criteria. • The ability of AHS to maintain constant speed will improve travel efficiency (i.e., mileage) and reduce wear and tear on brakes and other vehicle components. These benefits should be considered in cost benefit analyses.
• In 1941, there were 41,911 steam locomotives and 1,517 diesels in service. • By 1961, there were 30,123 diesels and only 210 steam locomotives. • The reduction of locomotives in operation between 1940 and 1960 was due to the inability of the railroads to meet increasing passenger demands for short-distance trips. — Passengers switched to other modes of transportation (primarily automobile), reducing the load on the railroads. (Klein, 1991)	

Table 30. The Railroad's Decline and Recent Regional Successes Milestones: Lessons Learned Worksheet (continued)

Recent Regional Successes Milestones	Lessons Learned for AHS
• By the late 1960s, both the passenger and freight railroad systems were in serious decline. — This decline led to reduced service, which further discouraged railroad traffic. • In June 1967, the National Association of Railroad passengers was formed as a national organization to represent consumers of rail passenger service, together with all who believed that trains were an essential element of a truly balanced national transportation system. • In 1970, Congress passed the Rail Passenger Service Act, which established Amtrak. — Amtrak was charged with reversing the decline in railroad passenger service. — Amtrak took over almost all remaining intercity passenger trains on May 1, 1971.	• Unsuccessful commercial transportation systems can become a Government responsibility.
• By 1990, Amtrak was able to cover 72% of its operating costs, with the remaining funds subsidized by the Federal Government. • Amtrak does not have strong political support, and must constantly fight to maintain operations. For example, the administration tried annually, from 1986 to 1991, to abolish Amtrak, while each year, additional funds were allocated to aviation and highway interests. • Amtrak receives less Government subsidy than either aviation or the highway industries. For each dollar spent by the transportation industry: — Fifty cents is subsidized for the aviation industry, thirty-nine cents is subsidized for the highway industry, and twenty-eight cents is subsidized for the railroads. — In addition, aviation and highway industries receive additional financial support from trust funds, as well as state and local agencies. Amtrak has no such sources of financial support.	• Competitiveness of transportation systems is enhanced by secure sources of Government funding and political support.
• Although Amtrak is decreasing its dependence on Federal funding, it has had a difficult time overcoming its reputation as a loser. — Usually, Amtrak's Federal funds are referred to as subsidies, while aid to aviation and highway interests is referred to as investments. – The prejudicial treatment often causes people to call for an end to Amtrak.	• AHS image will be an important factor in achieving political support. Care must be taken to promote AHS as a successful, viable, competitive, and reliable transportation system.
• Amtrak has strong public support, especially in areas supported by Amtrak's commuter service. • Congress, however, has been reluctant to provide the necessary funds to expand and upgrade passenger service. • Amtrak has few organized, national groups that are able to fight on its behalf. The groups that do exist have nowhere near the clout of the aviation and highway lobbies.	

Table 30. The Railroad's Decline and Recent Regional Successes Milestones: Lessons Learned Worksheet (continued)

Recent Regional Successes Milestones	Lessons Learned for AHS
• Better train technology exists worldwide, but Congress has been unwilling to commit to the capital investment necessary to upgrade the railroad industry in the U.S. — Amtrak is obligated by law and politics to manage a national railroad system. Thus, improvements in service to particular geographic regions may elicit charges of favoritism and intense controversy.	• Regional biases in AHS applicability and investment may limit AHS political and public support. This may lead to opposition from areas of the country not receiving AHS investments and benefits.
• High-speed rail systems have been operating in Europe and Japan for twenty years. They have proved reliable, safe, efficient, and cost effective. • High-speed trains could reduce the amount of congestion on the highways and in the air by transferring some travel to the rails. — Some leaders of the airline industry concede that high-speed trains could eliminate the less cost-effective short haul air routes, and reduce congestion at airports. — Amtrak also believes that a high-speed rail system would not be competition for Amtrak's service, but instead would complement the rail services currently operating.	• AHS could complement other transportation services. An inter-modal view is needed to allow AHS implementation where most beneficial.
• Many states have explored the idea of constructing high-speed rail systems. — Only a few, like Texas, Florida, and California, have established specific plans. — Some states are hindered by the need of a rail system to cross state borders. Thus, approval from two or more state Governments is necessary before any plans can be made.	• Interstate/inter-region AHS will need to address inter-jurisdictional issues. The requirement of obtaining cooperation from multiple operating jurisdictions can slow implementation and hinder operation.

The "attraction" approach, developed in Germany, is known as electromagnetic suspension (EMS). "The lower portion of the vehicle wraps around and under the guideway and is suspended by attractive magnetic forces that lift it up toward the underside of the guideway." (TRB, 1991) The vehicle contains electromagnets; the guideway contains ferromagnetic rails. This type of system requires a sophisticated gap control system, given its inherent instability: the attractive forces become stronger as the 3/8 inch gap closes. For this reason, the guideway must adhere to very close tolerances.

The "repulsion" approach, developed in Japan, is known as electrodynamic suspension (EDS). In this system, "superconducting magnets in the vehicle push away from magnets induced in guideway conductors to suspend the vehicle at a gap of about 4 inches from the guideway." (TRB, 1991) Although EDS systems are inherently more stable than EMS systems, EDS requires the use of wheels at low speeds (where the levitation force is inadequate). EMS systems can levitate at a standstill.

The origination of the modern maglev concept is generally attributed to Dr. James R. Powell in 1960. It was not until 1966, however, that Dr. Powell and Dr. Gordon T. Danby, both researchers at Brookhaven National Laboratory, presented the first paper on superconducting maglev transportation at an engineering conference. The High Speed Ground Transportation Act of 1965 was later changed to add maglev funding, and grants were awarded to Ford

Aerospace and the Stanford Research Institute. Development work on maglev began in 1974, when Dr. Henry H. Kolm of MIT directed the construction of a 1/25 scale model known as the "magneplane." (Moynihan, 1989)

Maglev research was dealt a crushing blow in 1975, when the OMB canceled all Federally funded work. (Thornton, 1991) Given the supposed adequacy of America's air network at the time, maglev was no longer declared a priority Throughout the 1980s, the Germans and Japanese developed their respective systems. In addition, the British opened the world's first maglev system in public service in 1984. In their Birmingham Airport system, "vehicles carrying up to 40 passengers shuttle between the airport terminal and the railway station--a distance of 620 meters—without a driver or attendant, under central computer control." (Riches, 1988) This system operates at low speeds. To date, no high-speed maglev system has been put into revenue service. It should be noted that during the 1980s, several regions within the U.S. spent millions of dollars studying specific maglev corridors, but lack of funding and political opposition blocked implementation. (Thornton, 1991)

The U.S. re-entered the maglev race in 1988, when Senator Daniel Patrick Moynihan (D-NY) and others introduced maglev-oriented legislation. That same year, the Senate Committee on Environment and Public Works established the Maglev Technical Advisory Committee, whose report helped to launch the National Maglev Initiative (NMI), a Federal interagency group. The NMI was also spurred on by the May 1990 "Maglev Forum," sponsored by the Department of Transportation (DOT), the U.S. Army Corps of Engineers, and the Department of Energy. In February 1991, the DOT issued a "concept definition request for proposals." (Thornton, 1991)

The Clinton Administration presently supports the development of a maglev prototype. According to a report released by the DOT, the potential benefits of maglev justify a $700 million development program in the U.S. (PR Newswire, 1993) The NMI recommends that $800 million in Federal seed money be granted to both public and private think tanks, contractors, and consultants for the development of a maglev prototype. (Field, 1993) The conclusions of a report being prepared by the NMI "should provide direction for future U.S. research and development efforts, including opportunities not only to increase speed but also to reduce costs, particularly in guideway construction." (TRB, 1991) In addition, New York Governor Mario Cuomo recently announced that a maglev system may run from New York City to Albany. Given maglev's past track record, however, one may be justified in having a less than optimistic attitude toward these recent developments.

There are many lessons that can be learned from these experiences with maglev.

Maglev Lesson 1: Get a Long-Term Commitment. Opponents of maglev have objected to its implementation on the grounds of cost, complexity, environmental friendliness and political viability. (Glanz) Throughout maglev's history, lack of funding has been the chief obstacle to implementation, and some contend that this lack of funding is chiefly due to opponents in Congress (Wheeler, 1993). In many cases, a project would be initiated, then stall a year or two later because of financial difficulties. For example, the proposed maglev corridor from Anaheim to Las Vegas was shelved because the corporation in charge of the enterprise, Bechtel, could not raise the necessary $200 million from private investors. In addition, California Governor Pete Wilson vetoed funding for the California-Nevada Super Speed Train Commission. (Del Valle, 1992)

Proponents of AHS should realize, then, that they should not rely upon short-term financial commitments for the development of an AHS system, in the hope that the project's momentum will somehow garner additional funding after the original grant monies have been depleted. In other words, a regional AHS system should be an all-or-nothing proposition: Either the necessary funds are committed for the long haul, or no funds should be committed at all. Of course, the funds referred to here do not include those earmarked for corridor feasibility studies or basic R&D; these monies must be provided in order to determine whether AHS is even viable. We are referring to funding for implementation.

Maglev Lesson 2: Recruit a Political Proponent; i.e., get a strong Congressional leader. At the Federal level, it should be noted that Senator Moynihan has been instrumental in the maglev funding effort. As an outspoken maglev proponent, Senator Moynihan was responsible for the inclusion of a $700 million maglev demonstration project in the 1991 transportation bill. (Wheeler, 1992) As noted above, Senator Moynihan proved vital to renewed U.S. political commitment to maglev technological development.

AHS proponents should learn from Senator Moynihan's efforts that it would be worthwhile to spend considerable time and effort either to "convert" an individual of comparable political pull to the AHS cause or to elect such an individual. This is easier said than done, but the resulting benefits would almost certainly justify the effort.

Maglev Lesson 3: Form an AHS Initiative. In a similar vein, the National Maglev Initiative represents the Federal Government's long-term commitment to maglev development. The formation of a similar interagency organization for AHS would be worthwhile if the political climate would allow it. The importance of a long-term orientation must be stressed: some have "blamed a lack of foresight for the U.S. failure to implement projects with longer-range payoffs, as Germany and Japan have done with their maglev projects." (Cortes-Comerer, 1988)

Maglev Lesson 4: Don't Exaggerate Benefits. With the objective of obtaining a favorable political climate for AHS in mind, a few do's and don'ts may be provided based upon maglev experience. Promoters of AHS should not exaggerate the potential benefits and feasibility of the system. One maglev fanatic is audacious enough to make the claim that "airports...are clearly more land-intensive than magways," citing the 17,800 acres occupied by the Dallas-Fort Worth airport as "enough land to create a maglev corridor 100 feet wide and 1466 miles long." (Thornton, 1991) Never mind the far greater origin-destination flexibility of the airplane! This same author would have us believe that a 10,000-mile national magway "skeleton" is currently feasible. (Thornton, 1991) In short, making such statements only fuels the opposition and disillusions the public. These exaggerations, in addition to broken promises (including that of Florida's Epcot Center maglev proponents, who claimed that the project could be completely privately funded), can only damage a technology's political viability.

Maglev Lesson 5: Think Small (But Plan for the Long Term). AHS promoters should think small, given the relative infancy of the technology. The feasibility of the system must be proved through prototypes and relatively insignificant implementation. A great amount of publicity is generated every time a prototype is successfully tested or even a small system is put into operation. This publicity helps garner political support for more extensive implementations. One author contends that the chief advantage of the German maglev system is its feasibility, basing his contention on the fact that "Transrapid (a German corporation) has been operating a 20-mile prototype in Elmsland, Germany." ("Magnetic Levitation Trains", 1990) On the other hand, an unsuccessful prototype run may generate much negative publicity. Japanese maglev efforts as a whole "suffered a setback" when a test train burned out during a demonstration run in October 1991. (Field, 1993) Hence, extensive testing is warranted before AHS supporters show off their technology.

Maglev Lesson 6: Focus Cost Containment Efforts on Most Costly Components. With respect to cost-containment, it has been noted that the capital costs of maglev "are dominated by the costs of construction of the guideway; the cost of the vehicles is a considerably smaller part of the total." (TRB, 1991) Recently, researchers at Argonne National Laboratory have found a way to simplify construction of the guideway, saving considerable sums of money. ("Savings for Maglev Trains", 1993) Similarly, AHS research should emphasize cost reduction in the most costly AHS components.

Maglev Lesson 7: The Simpler, The Better. With respect to AHS longitudinal and lateral control, maglev experience teaches us, "the simpler, the better." One major fault of the German EDS system is the necessity of a complicated gap control system (as noted above), while the Japanese EMS system suffers from its reliance on vehicle-mounted superconducting magnets.

Several suggestions offered with respect to maglev may also be applicable to AHS. Currently, no safety or environmental regulations exist in the U.S. pertaining to maglev. Such regulation areas as fire safety, vehicle crashworthiness, emergency braking, and earthquake impact must be developed if maglev is to be implemented. (TRB, 1991) Similarly, these types of regulations should be developed for AHS. These regulations would aid implementation as well as demonstrate the Federal Government's willingness to implement AHS.

Environmental reviews have presented a major roadblock to maglev implementation. The delays and uncertainties associated with these reviews "can adversely affect project timing, increasing costs and discouraging private investors." In addition, these delays create opportunities for opponents to stall the project. Hence, according to the Transportation Research Board's Special Report 233, "streamlining public reviews is critical if private investment is to be secured for infrastructure projects with long lead times and long paybacks." (TRB, 1991) The TRB recommends that "the U.S. DOT create a clearinghouse to facilitate environmental permitting in order to coordinate and streamline the approval process for proposed HSGT systems." (TRB, 1991) A clearinghouse of this type should also be formed for AHS.

The TRB further recommends that "HSGT systems be evaluated in a broad framework that considers the full range of potential impacts of HSGT and alternative transportation investments." (TRB, 1991) In this manner, perhaps Congress could overcome its short-term orientation; House lawmakers have been "strongly opposed to moving forward with a costly high-tech transportation project that has no prospect of an immediate payoff." (Wheeler, 1992)

In the area of public funding, the TRB has recommended a theoretically elegant solution: Public support should equal the system's losses under marginal cost pricing. (TRB, 1991) These are losses because the system's increasing returns to scale means that marginal cost is below average cost at modest levels of usage and beyond. The TRB cautions that the total value of the system to society must at least equal its total costs (of course). As an alternative to public financing, it is suggested that differential pricing be used: The most price sensitive users could be charged the marginal cost, while the least price-sensitive would be charged more. (TRB, 1991) Of course, this pricing scheme may not be politically viable. Whatever the case may be, these suggestions also apply to AHS.

One author recommends that maglev vehicles and guideway should be standardized, so that the systems built in the near future (if this happens) may be linked in the more remote future. This standardization should also apply to AHS: the vehicles should be fitted with one (preferably passive) apparatus, and all AHS highways should utilize this apparatus. This standardization would minimize both cost and confusion, and it would lead to a more integrated AHS in the distant future. This same author suggests that public information is vital; "travel professionals should achieve a general understanding of maglev and know how it will be integrated into America's transportation infrastructure." (Baker, 1991) Doing the same for AHS would probably enhance its political viability and social acceptance.

In short, the lessons we learn from the frustrations of maglev may lead to a more efficient and rewarding effort to make AHS a reality. Table 31 summarizes maglev development and the applicable lessons for AHS.

Table 31. Maglev Development Milestones: Lessons Learned for AHS

Maglev Development Milestones	Lessons Learned for AHS
• Dr. James R. Powell first originated the idea of the modern magnetic levitation (maglev) concept in 1960. — However, Powell and Dr. Gordon T. Danby did not present their first paper on superconducting maglev transportation until 1966. • The High Speed Ground Transportation Act of 1965 was later changed to include funding for maglev research. — Research grants were awarded to Ford Aerospace and the Stanford Research Institute. • Development work on maglev began in 1974, when Dr. Henry H. Kolm of MIT directed the construction of a 1/25 scale model known as the “magneplane.”	

Table 31. Maglev Development Milestones: Lessons Learned for AHS (continued)

Maglev Development Milestones	Lessons Learned for AHS
• The Federal Government (OMB) canceled all funded work on maglev in 1975. — Maglev was no longer considered a priority, given the supposed adequacy of America's air network. • During the 1980s, several regions within the US spent millions of dollars studying specific maglev corridors, but funding limitations and political opposition blocked implementation.	• Projects with high cost infrastructure, like AHS, face political uncertainties. • AHS should secure long-term funding commitment and/or take an evolutionary development approach.
• During the 1980s, both the Germans and the Japanese developed technology for maglev systems. • The British opened the worlds first operational maglev system in 1984. — The system is used to shuttle passengers between the Birmingham Airport terminal and a nearby railway station. — The system operates at low speeds; to date, no high-speed maglev system has been put into revenue service.	
• The U.S. re-entered the maglev race in 1988, when Senator Daniel Patrick Moynihan (D-NY) and others introduced maglev-oriented legislation. • The Maglev Technical Advisory Committee was formed in 1988, which led to the establishment of the National Maglev Institute (NMI). • The NMI recommends that $800 million in Federal seed money be granted to public and private think tanks, contractors, and consultants for the development of a maglev prototype. — The conclusions of a report being prepared by the NMI "should provide direction for future US research and development efforts, including opportunities not only to increase speed but also to reduce costs, particularly in guideway construction."	• AHS should secure political champions to help ensure US political commitment to the development of AHS technology. • The formation of an interagency organization for AHS (similar to the NMI) would be worthwhile if the political climate would allow it.
• Governor Mario Cuomo (NY) recently announced that a maglev system may be established between New York City and Albany.	• The feasibility of AHS must be proved through prototypes and relatively insignificant implementation. A great amount of publicity is generated every time a prototype is successfully tested or even a small system is put into operation.
• The Japanese maglev program was severely set back when a maglev demonstration project failed.	• An unsuccessful prototype may generate much negative publicity for AHS. Hence, extensive testing is warranted before AHS supporters show off their technology.

Table 31. Maglev Development Milestones: Lessons Learned for AHS (continued)

Maglev Development Milestones	Lessons Learned for AHS
• Many maglev plans and recommendations can also be applied to AHS.	• Special regulations for AHS may be needed (e.g., vehicle crashworthiness). • Plan for streamlining of public reviews (e.g., environmental), to avoid schedule impact. • Standards for vehicle and guideway designs need to be developed. This will allow early systems to be linked with future systems.

3.2.3.4.4 Issues

The major issues and recommendations for AHS based on an analysis of railroads, interurbans, and maglev are summarized in Section 4.1.

;3.2.3.5 The Introduction of Commercial Flight

3.2.3.5.1 Introduction

Since the 1930s, commercial flight has become an increasingly important mode of transportation worldwide. From its first introduction, air travel offered time savings over all competing modes of transportation. The public, however, needed to be convinced that the advantages gained in travel time were worth the extra cost and the personal risk of flying.

The public had to be sold on flying as a routine mode of transportation. The airline industry had to repeatedly demonstrate the safety and reliability of new technology, and to offer incentives to the public to attract passengers. Although it took many years, commercial flight has become accepted worldwide as a viable, safe, and convenient mode of transportation. In this section, we discuss the development of commercial flight, and some of the reasons why it was successfully integrated as a mode of transportation.

3.2.3.5.2 Approach

The approach taken during this part of the study relied exclusively on a review of available literature that documents the history of commercial flight worldwide from a social perspective. For more information, refer to *Conquest of the Skies (Solberg, 1979)* and *Air Travel (Hudson, 1972).*

3.2.3.5.3 Results

When the Wright Brothers invented the first powered airplane in 1903, they showed the world that flying could be a viable mode of transportation. Passenger flying began in 1908, although it did not become widely accepted until the 1920s. The initial acceptance of air transport was for goods (i.e., mail), not people. The first airlines were hired by the U.S. Post Office, in 1925, to fly mail along designated routes. The planes being flown were two-seaters, and the airlines realized that they could make extra money by selling the extra seat to a passenger. They also seemed to recognize that the only way to ensure profitability in the future was to become involved in passenger service.

In early 1933, Boeing introduced the Boeing 247, the first of the modern airliners. This plane could carry ten passengers, faster, and with fewer refueling stops than the older planes. The 247 was also more aerodynamic, and more comfortable for passengers. To compete with the Boeing 247, Douglas was commissioned to develop the DC-1 later that year. The DC-1 flew slightly faster that the Boeing 247, and revolutionized the airline industry by using only two engines. (All earlier planes, including the Boeing 247, had three engines.) Slight modifications, including increased passenger capacity (fourteen passengers), led to the introduction of the Douglas DC-2 in 1934. The DC-3 was developed in 1936, improving upon every aspect of the DC-2. The DC-3 was considered the first plane that could succeed financially on passenger traffic alone.

Throughout the 1930s, businessmen were the backbone of the airline passenger industry. They were attracted to air travel because of the time savings it offered , and their companies were willing to pay the extra expense for the savings in travel time. The airlines were still struggling to convince the general public that flying was a safe mode of transportation.

In 1930, Steve Stimpson, of Boeing, realized that it was necessary to add a crew member specifically to deal with passengers. He quickly realized that using young women as stewardesses would provide a psychological boost to the passengers (most of whom were male). Stimpson believed that men would be less fearful seeing that the stewardesses were not afraid to fly. In addition, much of the public's apprehension of flying was health related, so Stimpson decided that the hiring of registered nurses as stewardesses would be appropriate. The nurses' medical training, as well as their experience in caring for people, made them ideally suited for the job. Stewardesses were utilized by almost every airline by 1935, and the registered nurse requirement stayed in effect until World War II. Passengers responded favorably to the stewardesses, and even seemed grateful for their constant attention.

During World War II, airlines were used primarily for military transport. They carried military personnel, equipment and supplies. New technologies were developed to sustain the trans-Atlantic routes made necessary by the war. After the war, these new technologies were adopted by the commercial airlines, and offered passengers the luxury of international flights. In the 1940s, the airline business boomed. Many Americans had experienced flight during the war (as military personnel), and the general public had witnessed the military accomplishments of aviation. Public trust in aviation increased, and flying became more widely accepted as a reliable and safe mode of transportation.

In 1948, competition from non-scheduled airlines (Non-Skeds) forced the regular airlines to consider air travel for the masses. The Non-Skeds offered fares up to thirty percent lower than the regular airlines, but would not take off until most of the seats were sold. This practice allowed people who could not afford to fly on the regular airlines a chance to travel by air. The regular airlines soon recognized that the public was willing to make sacrifices in service for a low-cost opportunity to fly. They realized that if they increased passenger capacity on their flights (by increasing the number of seats), they could offer lower fares. This was the origination of "coach service" or "tourist class," and it opened up a whole new market for air travel. Air travel became an important contributor to the tourist industry worldwide.

Jetliners were introduced into commercial service in 1959. The jets were larger than earlier planes. They allowed the airlines to carry more passengers, at higher speeds and at higher altitudes than with previous planes. The increased altitudes led to smoother, more comfortable rides for the passengers. The Boeing 707, the first jetliner to be purchased by the airlines, was sold on the basis of a demonstration; once the airlines could see first-hand how the 707 could perform, they were eager to replace their older planes with the new jets.

In recent years, air travel has become almost a routine mode of transportation. However, it is still relatively expensive to fly, as compared to other modes of transportation. In order to maintain adequate levels of passenger service, the airlines are constantly working to improve service, to lower fares, and to offer more conveniences to passengers.

The development of commercial flight is summarized in table 32. We have identified the milestones, as well as applicable lessons for AHS.

Table 32. Development of Commercial Flight Milestones:
Lessons Learned Worksheet

Commercial Air Flight Development Milestone	Lesson Learned for AHS
• The first use of flight for public transport employed dirigibles. — In 1909, Ferdinand Graf von Zeppelin established dirigible air passenger service. — Between 1909 and 1937 many airships were lost in accidents, but no commercial passengers were ever injured. — On May 6, 1937 the Hindenburg burst into flames after making a trans-Atlantic crossing, killing 36 of the 98 people on board. — After this accident, dirigibles were never again used for passenger service. The public became wary of the dangers associated with dirigibles, and the Germans did not have access to helium, a safer gas that could be used in dirigibles.	• Safety or reliability problems, especially those that are sensational in character, can scuttle emerging systems intended for public use.
• In 1919, ex-military pilots acquired planes and sought to earn a living by flying them. — They offered "joyride" flights to the public for a nominal fee. These rides allowed the public to experience flying.	• Allowing the public to try AHS on a small scale may help make them more receptive to a large scale implementation.

Table 32. Development of Commercial Flight Milestones: Lessons Learned Worksheet (continued)

Commercial Air Flight Development Milestone	Lesson Learned for AHS
• The initial acceptance of air transport was for goods (i.e., mail), not people. — The US House Post Office Committee introduced a bill in 1925 which allowed private contractors to fly the mail. — Contracts were awarded to Colonial Air Transport, Robertson Aircraft Corporation (later part of American Airlines), National Air Transport, Varney Air Lines (later part of United Airlines), Western Air Express (eventually a founding unit of TWA), and to Henry Ford. — Airmail service was begun on June 18, 1926. — Many of the mail carriers had an extra seat in the plane, which provided an opportunity to earn extra money through passenger service.	• Commercial implementations of AHS could provide applications and serve to demonstrate AHS safety and reliability prior to widespread use by the public.
• As public concerns over air flight reliability were addressed, public acceptance increased. — In 1927, Charles Lindbergh made the first non-stop flight between New York and Paris. His flight attracted much public interest and demonstrated that flight could be made reliable. — The Ford Trimotor was introduced in 1927, offering more passenger seats per plane, and the inherent reliability of three engines. The Ford name also helped to inspire public confidence.	• Demonstration of AHS reliability and safety is an important factor in public acceptance. • Obvious fail-safe features will help sell AHS to a wary public.
• Businessmen were attracted to air travel first because it saved time. — By 1929, over eighty US. companies allowed their employees to put air fares on their expense accounts. They realized that the air fares were worth the time saved by their employees on business trips.	• Commercial markets for AHS will require definable financial or efficiency benefits.
• In 1926, Colonial Air Transport began to actively recruit passengers. They were one of the first airlines to do so. They established booking offices in major cities and offered transportation to and from the airports. — In 1929, Colonial offered discounts on blocks of airline tickets. Customers could save 20% by purchasing ten tickets, and could save 50% by purchasing fifty tickets simultaneously. These "commuter" tickets were quickly purchased by businesses for use by their employees.	• Aggressive marketing and innovative pricing strategies can be considered to stimulate the AHS marekt.
• During the late 1920s, planes were often forced to make emergency landings, due to mechanical problems and adverse weather conditions. — The planes lacked instruments to fly in any weather. They also lacked the pressurization to allow them to fly above the weather. — Due to the difficulties of flying in poor winter weather, the early airline business was erratic. Air travel peaked in the summer months, and declined to 1/3 of this level during the winter.	
• During the late 1920s and early 1930s, there was much pressure by local business communities to establish modern airports in the larger US cities. — These airports would provide better access to air travel and could encourage inter-city flying for business purposes. — The National Aeronautics Association of the U.S.A. set up chapters in major cities nationwide to act as lobby groups for the construction of commercial airports at public expense. They felt this would prevent private companies from obtaining too much control over air service.	• If AHS provides significant, cost-valued benefits to travelers, public pressure for the expansion and improvements of the service will follow.

Table 32. Development of Commercial Flight Milestones:
Lessons Learned Worksheet (continued)

Commercial Air Flight Development Milestone	Lesson Learned for AHS
• In 1933, Boeing introduced its Boeing 247, a ten- passenger all metal airplane (previously planes were wooden and subject to rotting). This new plane was more aerodynamic and less noisy than any previous plane. • Douglas was commissioned to develop the DC-1 as competitor to the Boeing 247. — The DC-1 flew slightly faster than the 247 and revolutionized the airline industry by using only two engines. Douglas was required to demonstrate the reliability and safety of the two-engine plane before the design was accepted. — Slight modifications led to the introduction of the DC-2 which entered service in 1934. • The Douglas DC-3 was placed into service in 1936, and immediately changed the industry perception of what constituted an adequate airplane. The design of the DC-3 improved upon every aspect of the DC-2. — The new plane had wing flaps, improved brakes, more horsepower, new cockpit radio aids, and was easier to inspect, repair, and maintain than earlier models. — The design of the DC-3 also considered the needs of passengers. The plane had more noise-absorbing material built into the frame. Also, the cabin decor was chosen to minimize airsickness and to emphasize security and safety. — The DC-3 had seating for 22 passengers (almost twice as many as the DC-2), and flew 10% faster than the DC-2. Because it was more efficient than earlier planes, it was the first plane that could make money solely on the operation of passenger service.	• It is necessary to demonstrate the safety of AHS before the system will be accepted.
• Boeing Air Transport was the first airline to hire female stewardesses. These stewardesses, first hired in 1930, were all required to be registered nurses. — The airlines felt that registered nurses were already trained to care for people, and would be able to handle any medical emergencies that could arise on a flight (especially airsickness). — The public enthusiastically accepted the stewardesses and seemed grateful for their services. — The ability of young women to fly without fear set an example for potential customers. Their example helped overcome people's natural fear about flying.	• Obvious facilities and/or design features for dealing with AHS malfunction contingencies will help sell AHS to a wary public.
• In 1932, Franklin D. Roosevelt used an airplane to travel from New York to Chicago to accept the Democratic nomination for President. — His flight gave the public confidence in flying, and helped call attention to the availability of air transport as a routine mode of transportation.	• Political support for AHS, even on a symbolic level, can enhance public support.
• Prior to 1935 most American film stars were contractually barred from flying. When the clause was deleted, many film stars began to fly, indicating to the public that flying did not pose a significant risk. • Some European airlines published, each month, a list of all the famous and influential people who had flown with them that month. They were attempting to gain public confidence.	• Like most products, AHS (and transportation products) can be marketed with endorsements from rich, famous, and influential people.

Table 32. Development of Commercial Flight Milestones: Lessons Learned Worksheet (continued)

Commercial Air Flight Development Milestone	Lesson Learned for AHS
• In 1936, the airlines joined together to form the Air Transport Association. — One of the Association's first acts was to introduce the Air Travel Card, a credit card that allowed travelers to fly now and pay later. — The card could be used on any airline, and offered a 15% discount on all tickets bought with the card. • Airline tickets could be reserved by telephone, a convenience not offered by the other major forms of transportation. — It was then possible to start writing the tickets as soon as reservations were received, reducing the amount of last-minute paperwork that had to be completed.	• AHS should be easy and convenient to use, in order to gain public support. • Aggressive marketing and innovative pricing strategies can be considered to stimulate the AHS market.
• Airlines used comforts and luxuries as selling points, and competed in terms of the service, food, and amenities offered to customers.	• AHS convenience is one selling point.
• Between 1935 and 1938, many airline accidents occurred, with the blame often attributed to the pilot. The public began to lose confidence in flying. • This led to Federal regulation of the airline industry in 1938.	• As AHS use expands, new problems may emerge. Inadequately dealing with these problems could negatively impact public acceptance and AHS success.
• The Boeing 307 was introduced in 1938, as the first pressurized passenger plane. This allowed the plane to fly "over" the weather, increasing the comfort of the passengers. — The extremely high altitude flight alarmed some passengers. Ridership was not reduced, however, because the pressurization offered a more stable, less turbulent ride.	• AHS improvements, even after the system has been implemented, need to be test marketed and implemented as appropriate and feasible.
• During World War II, airlines were used mainly for military transport applications, carrying passengers, equipment and supplies. — Seats on commercial flights were assigned in order of military priority. — Civilian passengers were allowed to take any remaining empty seats, but could be "bumped" off the plane, even at the last minute, by the arrival of a priority passenger. — The airlines operated with little consideration for the needs and opinions of passengers, since the planes were operated at full capacity for the war effort.	• The potential role of AHS in supporting national defense objectives can be noted in arguments for public support/investment.
• After the war, the airline business boomed. — Over one million Americans had flown as military passengers, and the general public witnessed the military accomplishments of aviation. -— Public trust in aviation increased, and air travel became a widely accepted form of transportation.	
• In 1944, airlines from all nations (except the Soviet Union) joined together to form the International Air Transport Association (IATA). — ATA set international standards for safety, navigational controls, air maps, and the setting of international air fares.	• International standards for AHS design will be needed to facilitate success in the global market.
• The airlines continued to be swamped with reservations, and began to face a problem of "no shows." They began to overbook their flights, to ensure that each plane would be filled to capacity. — In 1946, IATA announced that "no shows" would only receive a 75% refund of their fare. Although this was standard practice on Pullman trains, the public was angered. -— US air travel declined after this announcement, and the airlines began not enforcing the policy.	• AHS pricing and access policies need to be carefully considered within the pre-vailing market environment. • It cannot be assumed that the public will want to use AHS; the service must be sold to them.

Table 32. Development of Commercial Flight Milestones: Lessons Learned Worksheet (continued)

Commercial Air Flight Development Milestone	Lesson Learned for AHS
• Competition from non-scheduled airlines (Non-Skeds), in 1948, forced the airlines to consider air travel for the masses. — Non-Skeds offered fares up to 30% lower than the established airlines, and did not take-off until the plane was full. People who had never before been able to afford to fly were willing to sacrifice the scheduled departure for the experience of air travel at an affordable price. • To compete, the airlines began to offer "tourist class" fares, and actively went after the low-cost coach business of the railroads. — The airlines moved the seats closer together and offered less amenities to the "tourist class," to compensate for the lower fares. — The airlines were successful in regaining lost market shares. The Non-Skeds were driven out of business, or forced to become scheduled airlines. — The introduction of tourist class significantly increased the number of people who traveled by air.	• AHS pricing and access policies need to be carefully considered within the prevailing market environment. • Transportation products, like AHS, can benefit from a competitive marketplace.
• In 1954, airlines offered installment payment plans, making air travel financially attractive to the general public.	
• In 1959, jetliners were introduced to the commercial market. They were able to carry more passengers, faster than the earlier planes. They also offered non-stop flights, as they had a range of about 6,000 miles. — The Boeing 707 was the first of the jetliners. It was sold to the airlines on the basis of a demonstration. — The benefits of high-altitude jet travel (smooth, quiet, fast) were obvious, and sales of the Boeing 707 and its competitor, the Douglas DC-8, were immediately forthcoming.	• The marketing of AHS should include demonstrations of the benefits.
• Businessmen continue to make up 2/3 of the airline business. • Airlines must still actively compete to attract customers. They often offer incentives and amenities to their customers. — Airlines offer fare discounts to passengers who are willing to purchase non-refundable tickets well in advance. — Airlines offer frequent flier programs, which offer free tickets to people who fly a large number of airlines. Usually, all miles must be flown on one airline, and the free ticket is only good for that airline. — Recently, airlines have introduced a new class of flying, the business class. This class falls between tourist class and first-class in terms of seat size and services offered. — The airlines also offer preferential treatment for their frequent fliers, allowing them use of a separate waiting room at airports, and quicker reservation and check-in procedures.	• It cannot be assumed that the public will continue to use AHS after the system is implemented. The system must be sold to the public. • Aggressive marketing and innovative pricing strategies can be considered to stimulate the AHS market. • Transportation products, like AHS, can benefit from a competitive market place.

3.2.3.5.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of commercial flight development are summarized in Section 4.1.

3.2.3.6 Supersonic Transport (SST)

3.2.3.6.1 Introduction

As planning for the implementation of AHS proceeds, it may prove helpful to examine the failure of America's Supersonic Transport Program (SST). In the 1960s and early 1970s, the SST program was designed to provide American travelers with a high-speed aircraft for commercial use. The AHS program aims at innovating highway transportation just as the SST program proposed to change air travel thirty years ago. Many of the institutional, societal, and economic features of the SST program that led to the eventual collapse of the program can serve as warnings to the proponents of the AHS program.

3.2.3.6.2 Approach

The approach taken for this analysis was to review available literature about the SST Program in the United States. Emphasis was placed on identifying the reasons why the SST Program did not succeed, and the relevant lessons for AHS. We would recommend Horwitch's *Clipped Wings: The American SST Conflict*, 1982, for a complete history of the SST program.

3.2.3.6.3 Results

The concept of the commercialized supersonic transportation was first introduced in the United States in the 1950s by political and technical proponents. The advocates for an American SST program resisted working with other countries despite the advances made by the British in these years. (Horwitch, 1982) In June of 1963 President Kennedy formally announced the creation of America's SST program in a quick response to the decision of Pan American World Airlines to buy six Concordes, supersonic planes built by a joint venture of the French and British airline industries. (Doty, 1970) In an effort to compete with the technology abroad, an American SST program was designed by FAA administrator Najeeb Halaby. (Horwitch, 1982)

After this event, the SST program entered a "design phase" from 1964 to 1966. (Doty, 1970) During this phase, an 18-month design competition was held, resulting in contracts to Boeing and General Electric awarded on May 1, 1967. Technological difficulties arose soon after as the Boeing design was rejected by the FAA because of structural weight problems with the variable-sweep wing in their design. (Doty, 1970) A new design with an alternate wing structure was submitted by Boeing in 1969. The investigation of the SST designs by Transportation Secretary John Volpe conducted that same year advocated beginning construction of the SST in 1969. However, as this report will discuss, the national campaign against the SST program was already growing in the late 1960s. On March 24, 1971, Congress voted to terminate the American SST program.

As one of the first large, Federally funded, civilian projects after World War II, the SST program exposes many of the problems associated with a program dependent on Government money. Without military justification or a clear mission to raise national pride as with the Apollo mission, finding grounds to support Government funding of the SST program was a problem for SST proponents. Government funding of this project was seen by many as an inappropriate use of Federal money. Senator Walter Mondale (D-Minnesota) criticized the funding, noting that $290 million was requested in 1971 for the SST program while only $200 million was spent in the United States to feed the hungry that same year. (Horwitch, 1982) In addition, the SST would eventually lead to commercial use of a product developed with Government money. Senator J.W. Fulbright (D-Arkansas) called funding of the SST program in 1970 “socialism...bringing the Government in to sponsor a questionable project, so that if it fails, it goes on the taxpayers.” (Watkins, 1970) If AHS receives most of its funding from the Federal Government, the AHS program may face similar resistance. The AHS program could become a controversial national topic just as SST was in the 60s and 70s. When the research and development of many projects, not only in the field of transportation, is too expensive for private firms to conduct, Government funding is supplied. However, if it cannot be shown that the project will serve the national interest, then, as in the case of the SST program, justification of Government funding becomes increasingly difficult.

Najeeb Halaby, former FAA administrator and the first head of the SST program, described the SST aircraft as "a political plane", stressing the influence of political players on the development of the program. (Loomis, 1986) When the SST program was introduced by President Kennedy in 1963, he ardently supported the program. (Horwitch, 1982) However, the change in administration after Kennedy's assassination jeopardized the stability of the SST program. Under Johnson's administration, SST skeptics such as FAA administrator Robert McNamara and his aide, Joseph Califano, weakened the program further through the President's Advisory Committee on Supersonic Transportation. The SST program was divided and placed under the jurisdiction of other agencies beyond the control of the FAA, causing more complications for the program. Without the backing of major political players, the program faced major difficulties. Halaby warned proponents of a second (renewed) American SST program as follows: “Make sure you have champions on the Hill, at least four on each side, and get them lined up before you start touting something to the public.” (Loomis, 1986) This is equally true of the AHS program. While the AHS program gained a major endorsement from Congress in the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA), it will be very important in the coming years to maintain this political support. If the AHS program is funded by the Government, political battles similar to those surrounding the SST may arise.

The Federal funding of the SST program also exposed the program to other complications. By 1970 the program had become a national issue; the environmental threats of a supersonic aircraft mobilized strong protests by environmental advocacy groups. The 1970s were a time of changing views on technology, and the SST program became for many another example of the evils of technology. The year 1970 was the year of the first Earth Day, raising national awareness of environmental issues. (Horwitch, 1982) Strong political opponents of the SST program, such as Minnesota Senator Walter Mondale and Illinois State Treasurer Adlai Stevenson, used Earth Day as an opportunity to question the tremendous amount of Government money being spent on the SST program. This criticism weakened national support for the SST program and sparked further debate over the Government's role in such projects.

Furthermore, the exhaust fumes and the sonic booms produced by the SSTs sparked much debate and concern. (Dunn, 1990) The sonic booms produced when the planes broke the sound barrier became a target of protest from organized environmental groups as well as from people living near airports or along potential SST flight paths. Groups such as the Sierra Club, Friends of the Earth, and Citizens League against the Sonic Boom were concerned about potential pollution of the upper atmosphere and destruction of the ozone layer. (Horwitch, 1982) After the defeat of the American SST program, environmental lobbyists even attempted to stop the Concorde from flying to US cities. In 1977 their appeal was lost in the courts, and the Concorde began flights to Kennedy International Airport. (Feldman, 1985)

Advocates of the AHS program will be given the challenge of presenting automated highways as a help to the environment by showing the potential reduction in fossil fuel consumption and increase in air quality.(Saxton, 1993) If these benefits are not stressed, the AHS program may encounter the same strong resistance that led to the defeat of the SST program.

The failure of the SST program can also be attributed to the economic problems associated with a supersonic commercial aircraft. Opponents of the SST program doubted the claim that revenue earned from selling SST aircraft would be enough to repay the Government investment. The FAA had estimated in 1970 that the SST program would result in $6.6 billion in Federal and state taxes. (Watkins, 1970) Yet, skeptics wondered if the SST program could even be profitable at all with its high operating costs, limited seating capacity, and restricted routes.

As noted by former FAA administrator Najeeb Halaby, a project funded by taxpayers must appear to benefit the taxpayers. (Loomis, 1986) Yet, the operating costs of such a plane were too large to enable the SST to offer service to consumers at fares competitive with subsonic aircraft. In 1985, the cost per trip on the Concorde, from New York to London, was $5,358. That same trip cost $2,126 in business class and $837 in coach on a subsonic plane. (Loomis, 1986) Supersonic transportation is just not an option for most travelers; it was described by Senator William Proxmire (D-Wisconsin) in 1970 as “a plaything for the jet-set.” (Watkins, 1970) The infrequency of high-speed travel by the average taxpayer made it difficult to justify Government funding. Automated highways aim at a larger market and, therefore, may have greater success in the public arena. It will be important for proponents of the AHS system to stress the services provided by AHS to the taxpayers.

In addition, the SST Program was established to compete with foreign competition, in order to preserve the American role as a leader in aeronautic technology. The development was not initiated or driven by demands and/or needs of the American public. Much of the public opposition was raised because the Government was spending large amounts of money on a project that did not satisfy the general population, when other projects were left unfunded. AHS must be sold as a system that meets the needs of the general public. It must offer service that is equal or superior to the current modes of transportation, while still being within economic reach of the public. As with SST, it is the relative appeal of a combination of speed, comfort, convenience, and price that will determine the success of AHS.

At a conference on the possibility of a second generation of SSTs, Najeeb Halaby concluded his speech with this warning: “Don't take all of my experience as applicable today, but please, let's not relive history. Let's not mislead anyone as to what is reality; let's find that reality and go forward on that basis.” (Loomis, 1986) Twenty years have passed since the failure of the SST program, and things have changed. While much of the distrust of technology may be less prominent in today's society, the importance of lobby groups in determining the fate of Government projects is still strong. Opponents of the SST program emphasized the negative effects of the planes on the environment and significantly lowered public opinion of the program and weakened support within the Government. Environmental lobby groups have even more power today, and therefore, AHS will be more viable if marketed as a benefit to the environment, rather than a threat.

The AHS program may meet many of the same political and economical problems that plagued the SST program. Much of the debate over Automated Highway Systems is centered on the potential sources of funding for such an expensive program. If the AHS program is going to be funded in part by the Federal Government, the proponents of AHS should stress the potential jobs created in the AHS industry. The creation of jobs, especially military conversion jobs, could promote national interest. Thus, Federal funding of AHS might be justified from this angle. In conclusion, to ensure the success of the AHS program, the factors that led to the defeat of the SST program should be considered.

Table 33 summarizes the milestones of the SST Program in the United States and applicable lessons for AHS.

Table 33. Supersonic Transport Program Development Milestones: Lessons Learned Worksheet

Supersonic Transport (SST) Development Milestones	Lessons Learned for AHS
• In 1958, the airline industry had not yet begun to routinely use jet planes. Even so, Douglas and Lockheed, two of the biggest airplane manufacturers, had begun research on a supersonic (faster than the speed of sound) transport (SST). • England, France and Russia were all reported to be developing an SST before 1960.	
• In May, 1960, the Special Investigating Subcommittee of the House Committee on Science and Astronautics held hearings devoted to SST. — They concluded that the US needed to initiate a national SST program to keep up with foreign competition and maintain the US position as the world leader in aviation. — The need for substantial Government financing for the plan emerged during these hearings, as the airline industry claimed it could not afford to invest heavily into the development of such radically new technology. (The airlines were still struggling to update their planes to subsonic jets.)	

Table 33. Supersonic Transport Program Development Milestones: Lessons Learned Worksheet (continued)

Supersonic Transport (SST) Development Milestones	Lessons Learned for AHS
• Debate over the real need for the SST, the amount of Government funding that should be allocated, and the role that various Government agencies should play in overseeing the program continued for over two years. • In June 1963, President Kennedy formally announced the establishment of a Government funded SST program in the US. — The announcement was a direct response of the administration to the decision of Pan American Airlines, the flagship of all American airlines, to purchase six supersonic jets produced by the British. — Kennedy's plan called for initial development phases to be conducted to ensure that the SST would "produce an aircraft capable of transporting people and goods safely, swiftly, at prices the traveler can afford and the airlines find profitable." He also called for the Government to simply assist the airline industry by providing development funds, only up to 75 % of the total cost, and not subsidizing production, selling prices, or operating costs.	• High level political support can get a program started, but ongoing support is needed to keep it on track.
• After initial research was conducted, it was determined that the sonic boom caused by the planes was a significant problem that needed to be addressed. — The sonic boom is produced when an airplane flies faster than the speed of sound. The air cannot move fast enough, causing the air in front of the plane to be compressed. The compressed air causes a shock wave, which causes a change of air pressure on the ground that is perceived as a thunderous noise. • In 1964, the FAA decided to conducta series of supersonic tests over Oklahoma City to determine what, if any, effects were caused by the sonic booms. — They expected to show that the typical sonic boom was not overly annoying to the public, and that no physical damage resulted because of the boom. — After the tests began, the FAA received over 15,000 complaints about the noise, and 5,000 damage claims. Surveys indicated that almost 25 % of the population felt that they would never be able to adjust to the sonic booms. • The FAA believed that the test results from Oklahoma City were not reflective of future responses to sonic booms. They felt that the sonic boom problem was being exaggerated by the media, and that technical solutions would eliminate the problem, or reduce it to tolerable levels.	• If AHS produces higher noise levels than current highways, this could be a source of contention and opposition. Accurate assessments and tests of this possibility need to be made so the final AHS design can avoid this potential problem.

Table 33. Supersonic Transport Program Development Milestones: Lessons Learned Worksheet (continued)

Supersonic Transport (SST) Development Milestones	Lessons Learned for AHS
• In 1966, after further sonic boom tests, the FAA was forced to consider that sonic booms would be a serious obstacle to the acceptance of SST. — They announced that SST may never be acceptable for commercial, overland operations. (Horwitch, 1982) Supersonic flight, as restricted by 1960s designs, would be limited to over-water flights. This would minimize public annoyance, but would severely limit the economic viability of SST. • SST proponents believed that the sonic boom problems could be resolved in the technical design of the SST, and that sonic booms would not interfere with SST introduction. • Engine noise was also a major concern. The SST needed bigger engines, and thus would produce increased engine noise. This was a concern for community acceptance near airports. • The debate over sonic booms and excessive engine noise caused significant delays in the SST program. By the time the issues were under control, it was too late. New doubts about the program had arisen, and new opponents to SST had emerged; specifically, the Citizens League Against the Sonic Boom was established.	• AHS problems need to be identified and dealt with early and up front. If not, they could hurt the project later.
• Between 1964 and 1966, design efforts continued. Airline and engine manufacturers were encouraged to enter a design competition, to see who would eventually build the SST prototypes. • In the fall of 1966, the manufacturers submitted their proposals for the design of the SST prototype. Technical evaluations began immediately. — Two designs were under consideration, one from Boeing, with the engine designed by General Electric; and the other by Lockheed, with the engine designed by Pratt and Whitney. • Both designs exceeded Government sonic boom limits, further emphasizing the need to restrict supersonic travel to over-water or unpopulated regions. • In December 1966, the Boeing-General Electric model was selected.	
• The funding for the next phase of the SST program, prototype development, needed to be approved by Congress for fiscal year 1968. — Congressional opposition to SST had grown, due to increasing concerns over Government funding of a commercial project, the excessive funding needed to continue (and eventually finish) the project, and the need to reallocate funds for the Vietnam War and various social programs. • The funding was approved, due to an active pro-SST campaign in Congress. The airlines committed financial support to the SST program, which reassured the Congress that the Government was not providing all of the financial backing for a commercial project.	• Financial support from private industry may help to reassure the Federal Government about the commitment to AHS. This could be a factor in securing continuous financial support.
• By May 1967, contracts for prototype development had been signed with Boeing and General Electric. • Technical difficulties arose, as Boeing realized that its proposed design would not meet the structural weight limits specified by the FAA. — Boeing asked for an extended design period to redesign their plane. Plans for a new design were submitted in 1968. Evaluations of the new design were favorable, and the design was accepted in 1969.	• Plan for schedule contingency. Time may be needed to deal with unforeseen technical problems.

Table 33. Supersonic Transport Program Development Milestones: Lessons Learned Worksheet (continued)

Supersonic Transport (SST) Development Milestones	Lessons Learned for AHS
• The SST had been designed to be compatible with existing airline and airport operations. — The SST could use the existing runways, and could access most existing airport terminals. They could also be serviced with equipment used for subsonic jets. Thus, the airlines would have little difficulty integrating the SST into their fleets. (Wooley, 1970)	• AHS should be designed to be as compatible as possible with existing systems. The less new infrastructure or new technologies needed, the easier it will be to implement AHS.
• Throughout the first half of the 1960s, important SST activities and decisions were more or less contained within Government agencies. However, toward the middle of the 1960s, the SST slowly emerged as a matter of public concern. • In 1966 and 1967, the media published many anti-SST articles. The FAA worked hard to counter all negative publicity, especially concerning the social impact of sonic booms. • In May 1967, Boeing had organized a public relations plan for its subcontractors. The plan was designed to sell the SST to the general public, to Government decision makers, and to the financial and technical communities.	• It is wise to keep the general public educated and informed throughout the AHS planning, design, and development phases. Build coalitions with opposition groups and deal forthrightly with public concerns.
• In 1966, the Citizens League Against the Sonic Boom was established. — The League published fact sheets, ran newspaper advertisements, and wrote anti-SST letters to influential groups and individuals. — Members of the Citizens League comprised a dedicated network of SST protesters nationwide, and by 1969 had transformed the SST program into a widespread issue of public concern.	• Lobbying groups may influence support for AHS, positively or negatively. • Environmental issues are very sensitive and need to be dealt with directly.
• In 1969, newly elected President Nixon voiced his support for the SST program. In addition, Congress approved additional funding for the SST in the fiscal 1970 budget. — $80 million was allocated for SST prototype design. • The anti-SST movement, however, was continuing to grow.	
• In 1970, the Coalition Against the SST was formed. The Coalition united fourteen organizations (including the Citizens League, Sierra Club, National Wildlife Federation, and Friends of the Earth) into one unified consortium against SST. • The Coalition was determined to prevent any additional funding for the SST. • The Coalition raised environmental, economic, and social issues surrounding the SST. They published literature, publicized negative items on the SST, lobbied Congress, and provided support for local anti-SST groups. • Members and friends of the Coalition actively worked to sway individual Congressmen to vote against the SST.	
• Congress voted, in 1971, not to allocate any additional funds to the SST program. — By this time, $623 million had been funded by the Government for SST development. — An additional $315 million was being requested for prototype construction and to complete the SST program. However, this funding was not approved. • SST supporters tried to reopen the matter in Congress after the defeat of the budget, with little success.	• Opposition from lobbying groups can be very influential in stopping AHS. Maintain dialogue and build coalitions with the environmental groups and other groups that could work against AHS.

Table 33. Supersonic Transport Program Development Milestones: Lessons Learned Worksheet (continued)

Supersonic Transport (SST) Development Milestones	Lessons Learned for AHS
• In 1974, the British and French Governments informally advised the FAA of their intention to begin regular Concorde service to the United States in early 1976. • On February 1976, after holding public hearings, Secretary of Transportation William T. Coleman, Jr., permitted limited scheduled commercial flights of the Concorde into two United States cities (New York and Washington, D.C.) for a trial period of 16 months. • However, the Concorde did not fly into New York City until October 1977. The New York Port Authority had banned supersonic flight into its airports in 1976, but the ban was ruled illegal in 1977.	
• By 1980, many of the Concordes had been taken out of service worldwide, and both the British and the French halted Concorde production lines. (Horwitch, 1982) • By the end of 1980, the plane had sustained a $200 million operating loss since beginning commercial service. The high losses were attributed to rising fuel costs and low passenger demand.	• AHS must offer improved service over traditional transportation systems, and the benefits must be worth any additional costs to potential passengers.

3.2.3.6.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of SST development are summarized in Section 4.1.

3.2.3.7 Planning and Building Mass Transit Systems

3.2.3.7.1 Introduction

AHS has the following requirements in common with mass transit:

- Must have substantial user market
- Requires a preferential travelway
- Involves large front-end costs
- Needs Government assistance and subsidy
- Must be financially feasible
- Must be accepted by the public and politically

For mass transit the first requirement drives the remaining requirements in the order listed. The planning process is iterative, addressing all requirements until each is fully defined and quantified.

This comparative analysis outlines the items to be addressed for each of the listed requirements, together with lessons for AHS.

3.2.3.7.2 Approach

The information assembled here was drawn from recent experience in developing a technical and financial feasibility study for a downtown elevated light rail system now being implemented by a development consortium.

3.2.3.7.3 Results

Table 34 summarizes guidelines for mass transit and corresponding lessons for AHS.

Table 34. Guidelines for Mass Transit Lessons Learned for AHS

Guidelines for Mass Transit	Lessons Learned
User Market • Potential ridership—commuter, intra city, transfers = Passengers Per Day. • Fare structure—unlimited/zone, cash/token/card = Revenue Per Day • Growth—inter-modal connections, extensions, city development = Ultimate Design Capacity	Define the market so that the design can be appropriately tailored. Each segment of the AHS network may have different needs.
Travelway • Route selection-at-grade/underground/aerial, within street/new right-of-way (ROW)= Alignment • Entry/Exit - destinations, walking distances, vehicle travel time/loading volume, station costs, development potential = Station Spacing • Operation/maintenance-side tracks/cross-overs/turnarounds, storage yards, administration/ maintenance depot = Support Facilities	Size the product to meet service requirements. Consider requirements for support facilities.
Implementation Costs • Right-of-way—land acquisition, utility relocation, demolition = Land Costs • Mainline—street tracks or cut-and-cover/bored tunnel or viaduct = Guideway Costs • Passenger service—ticketing, loading platforms, stairway/elevators = Station Costs • Rolling stock—train units, power and signal system = Vehicle Costs • Support—buildings, yards, equipment, staff = Facility Costs	Quantify capital, operating and maintenance costs.
Government Support • ROW Use - develop rights to use public ROW = Public Service • Competition—license to operate without competition = Exclusive Rights • Operating Partner—provide direct financial input = Subsidy	Establish or make development package dependent upon receipt of Government support.
Financial Feasibility • Government implementation—capital and operating costs are lost within general funding. Revenue accounts for less than 50% of operating costs. • Private implementation—If front end capital costs are financed by loans, revenue cannot break even due to interest cost. Majority of capital costs must be financed from deferred dividend bonds.	Develop and test acceptability of financial package.
Public/Political Acceptance • Advantages—inexpensive and reliable service, commercial and housing development, etc. • Disadvantages—construction & operating disruption, neighborhood changes, burden on Governmental services, etc. • Costs—rate tables, concessions, property values	Bring the public and politicians into the planning early to make the design a partnership.

3.2.3.7.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of mass transit development are summarized in Section 4.1.

3.2.3.8 Elevators

3.2.3.8.1 Introduction

The elevator is the safest form of modern transportation, with only one serious accident for every 65 million miles traveled. (Ford, 1982) Generally, most people feel comfortable riding on elevators, even though most modern elevators are completely automated. It is therefore useful to AHS to consider the history of the elevator, and how it evolved into one of the most important forms of transportation in modern society.

The introduction of the elevator revolutionized major cities in the United States by making it possible to build taller buildings and therefore allowing more efficient use of valuable urban land. Before the elevator, buildings were limited to five floors or less, which was the highest people could be expected to walk up. But, with the introduction of the elevator, building height seemed almost unlimited. In addition, the elevator caused a change in the well-established property value structure in US cities. Prior to the elevator, the ground floor of a building was considered to be the most valuable, since access to this floor did not require climbing stairs. However, after the elevator, the top floors of buildings became the most valuable.

Over time, the elevator has progressed from a manual device, with two or more operators, to a completely automated device. The elevator was the first form of automated transportation encountered by the general public. This section discusses the development of the elevator, and the relevant lessons that can be applied to AHS.

3.2.3.8.2 Approach

The approach taken in this part of the study relied on a review of available literature. We especially recommend *The Elevator* . (Ford, 1982)

3.2.3.8.3 Results

Although elevator-like lifting devices were used by almost all ancient societies, the elevator, as we know it, was not invented until the late eighteenth century. At that time, steam became a widespread source of power, eliminating the need for animal or human muscle power to operate the lifting device. The first public elevator was installed in London in 1829, and, by 1850, a steam elevator was installed in the United States.

In 1852, Elisha Otis invented the safety elevator to help move materials safely between the two floors of the factory at which he was employed. Otis' safety elevator incorporated a spring loaded engagement mechanism that automatically engaged a metal track to prevent the elevator from falling if support from the cable was lost. It was the loss of cable support itself that caused the spring to release and the mechanism to engage. Otis dramatically demonstrated his invention at the Crystal Palace Exhibition in 1854. Soon after the public demonstrations, the safety elevator became an accepted mode of transportation. Continual improvements to the elevator made it a more efficient transportation system; in fact, new technologies were applied to elevators as soon as they became available.

The early elevators were controlled entirely by human operators, who were responsible for scheduling the elevator cars, for starting and stopping the elevator, for opening and closing the elevator doors, and for leveling off the elevator car at each floor. Over time, the elevator became increasingly automated. Eventually, in the late 1940s, automatic elevators were invented. These elevators (and most elevators in use today) simply require the passenger to press one button to call the elevator, and another button to indicate his/her destination. All other functions are performed by the elevator automatically.

The elevator has changed the face of US cities by encouraging the construction of skyscrapers in urban areas. In addition, the elevator has provided the general public exposure to a reliable form of automated transportation. Table 35 presents milestones in the development of the elevator, as well as applicable lessons for AHS.

Table 35. The History of Elevator Milestones: Lessons Learned Worksheet

Elevator Development Milestones	Lessons Learned For AHS
• Most early societies developed, or adapted, devices to lift heavy objects with less effort than would be needed if there were no device Almost all of these devices were run by human or animal muscle power. (Ford, 1982) • Ancient Egyptian tomb paintings illustrate the use of a counterweight to facilitate the lifting of heavy objects. The Assyrians used pulleys to help lift heavy loads, while the ancient Chinese may have invented the windlass to aid in lifting. • The ancient Greeks and Romans combined pulleys and windlasses to lift heavy loads (e.g., ships) high in the air. • During the sixth century, monks at the Convent of St. Catherine on Mt. Sinai used a net and a windlass to reach their monastery. (Ford, 1982) — Similarly, in 1203, an "elevator" was installed at the Abbey of Mont St. Michel in France. This device used a windlass attached to a treadmill to pull up a large basket. Both materials and people rode up in the basket to the Abbey. (Ford, 1982)	Good ideas sometimes take time to perfect.
• In 1743, one of the earliest known passenger elevators was built for Louis XV, at the Versailles Palace. — This elevator was used by the king to travel from his first floor apartment to the 2nd floor apartment of his mistress. (d'Estaing, 1986) • The Versailles elevator was essentially a "flying chair." It moved by means of a rope passed over a pulley and a counterweight. Two vertical guide rails were installed to prevent the chair from bumping around. (Ford, 1982)	

Table 35. The History of Elevator Milestones: Lessons Learned Worksheet (continued)

Elevator Development Milestones	Lessons Learned For AHS
• The development of the steam engine, by James Watt in the late 18th century, reduced the manual effort necessary to raise an elevator. • The first public elevator was built in the Regent's Park Coliseum in London in 1829. This elevator could carry ten passengers simultaneously. (d'Estaing, 1986) • By the early 1850s, steam elevators were in operation in many US factories. — The standard steam elevator consisted of ropes, a drum on which the rope was wound, pulleys, guide rails, and a counterweight. — As a steam engine supplied power, the rope was wound up on the drum, pulling the platform upward. The guide rails kept the platform from moving sideways, while the counterweight made the lifting easier. • Most of these early elevators were used only for hauling freight, because of safety concerns.	Concepts for safety can create a reluctance to accept AHS.
• Initially, some elevators were equipped with mechanical safety devices to prevent the elevator from falling if the rope broke. These devices required some quick action by the elevator operator to engage. (Ford, 1982) — The operator was often not able to react fast enough to prevent the elevator from falling in an emergency. • In 1852, Elisha Otis invented the safety elevator to help move materials safely between the two floors of the factory at which he was employed. — Otis' invention required no action on the part of the operator in an emergency. — The safety device was triggered automatically by a heavy spring connected to the rope that lifted the elevator platform. When the rope was taut, as in normal operations, the spring remained compressed. However, if the rope were to go slack, i.e., if the rope were to break, the spring would snap out and force two iron bars into notches in the vertical guide rails, locking the elevator in place. (Inventive Genius, 1991) • Otis dramatically demonstrated his invention at the Crystal Palace Fair in New York City in 1854. — Otis stood on an elevator platform, which was loaded with freight, as it was raised 40 feet in the air. His assistant then cut the rope supporting the platform. The platform jerked downward slightly, then stopped. — Otis repeatedly performed this demonstration, each time stunning the crowd. — After Crystal Palace, business improved for the newly formed Otis Steam Elevator Works.	• The demonstration of AHS safety will facilitate public acceptance. • The simplicity and understanding of AHS fail-safe features will enhance the facilitating effect of safety features.
• Otis installed his first passenger elevator in 1857. — This elevator was installed in a five story department store, and featured an enclosed platform. This permitted a number of people to ride up on the platform without the danger of falling off. — The elevator was steam powered, and could carry up to 1000 pounds at a rate of 40 feet per minute.	

Table 35. The History of Elevator Milestones: Lessons Learned Worksheet (continued)

Elevator Development Milestones	Lessons Learned For AHS
• In 1867, Leon Edoux installed the first hydraulic elevator. — Hydraulic elevators are supported by a piston attached below the platform. When a steam pump forces water into the bottom of the piston, the plunger and the platform are pushed up. As the water flows out, the plunger and platform go back down. (Ford, 1982) • The hydraulic elevator was safer than the standard steam elevator, because it did not require ropes, and could travel much faster than the steam elevator. — Unfortunately, the hydraulic elevator required a piston to be installed below ground, as deep as the elevator was high. This drawback prevented the widespread installation of hydraulic elevators. (Ford, 1982)	AHS design and supporting technology selection can limit AHS growth and acceptability. AHS design should consider expandability and growth.
• In 1872, Cyrus Baldwin invented the roped hydraulic elevator. — This elevator used ropes, pulleys, anda short horizontal piston instead of the long vertical pistons of the older hydraulic elevators. — This elevator rose higher and traveled faster than the steam elevator. • The roped hydraulic became the most popular elevator by 1880. • In 1873, New York City approved plans for the construction of the two tallest buildings in the world. One was nine stories, the other ten stories tall. — These buildings were completed in 1880. — Elevators made it possible to get to the top of these tall buildings without a lot of effort, and even made the top floors more desirable. Henceforth, top floors would rent for more than bottom floors. (Ford, 1982)	AHS can impact property values as a result of improved transportation.
• The first electric elevator was built by the German firm Siemens and Halske for the Mannheim Industrial Fair in 1887. (d'Estaing, 1986) • In 1889, Otis Brothers (a company formed by the sons of Elisha Otis) installed the first electric elevator in a commercial building. — These early electric elevators were very slow, and worked exactly like the old steam elevators, except they could serve higher buildings than the roped hydraulics.	Design AHS to allow evolutionary improvements.
• In 1903, the Otis Company—a new firm created when Otis Brothers merged with 14 other firms—developed the gearless traction elevator. This was an electric elevator designed especially for skyscrapers. — The gearless traction elevator consists of a drive sheave (a large pulley with grooves cut in it) connected to the top of an elevator car by six to eight cables. The other ends of these cables are attached to the top of a counterweight. Another set of cables, attached to the bottom of the elevator car, pass through the bottom sheave, and are attached to the bottom of the counterweight. As the electric motor is running, the drive sheave turns, which causes the cables to move and the counterweight to slide down as the car moves upward. (Ford, 1982) • — The gearless traction elevator is designed with two different safety systems. — First, if the elevator begins to move too fast, a mechanism (governor) senses this and opens a safety switch that cuts the power and activates a brake. — Second, if the speed continues to increase, the governor pinches the safety cable, which activates two clamps beneath the car that wedge themselves between the vertical guide rails, stopping the car. (Ford, 1982)	• Design AHS to allow evolutionary improvements. • Safety devices that can sense and respond to out-of-control conditions would be valuable for AHS.

Table 35. The History of Elevator Milestones: Lessons Learned Worksheet (continued)

Elevator Development Milestones	Lessons Learned For AHS
• In 1920, the first elevator safety code was introduced by the American Society of Mechanical Engineers (ASME). All elevators must meet the minimum specifications described in the safety code. ASME completely revises its code every three years. (Ford, 1982)	• AHS should consider development of a safety code for AHS products.
• Until 1920, elevators were controlled by a starter and an operator. — Starters told the operator when to leave, and where to bring the car at the end of a run. Starters were responsible for scheduling the cars to give the best possible service, especially during busy periods. — Operators were responsible for the movements of the elevators. They opened and closed the doors, started and stopped the cars, announced floors to the passengers, and leveled the car with the floor. • As elevators became faster, and buildings became taller, it became increasingly difficult for starters and operators to keep up with the demands for elevator service.	• AHS design should consider the ability to adapt to increasing demand.
• In 1924, Otis Elevator Company developed Signal Control, an automatic system for commercial buildings. The automatic system controlled speed, stopped at the right floors, and leveled itself with the floor. — Operators were still required to push the floor buttons, open and close the doors, and start the car. — Starters were still required to schedule elevator service.	Design AHS to allow evolutionary improvements.
• By the late 1940s, both Otis Elevator Company and Westinghouse Elevator Company (a division of Westinghouse Electric Corporation) had developed completely automatic elevators. (Ford, 1982) — These elevators weigh the car load so the car will know when to start; they stop the car on the right floors, level it correctly, and open and close the doors automatically. The car cannot start unless the doors are closed, and the doors will automatically slide back if someone tries to board the elevator as the doors are closing. • Soon after the introduction of the automatic elevators, better systems for scheduling the elevators in a building were developed. — Instead of running on fixed schedules, the elevators were able to respond to changing needs of the passengers, and operated in an on-demand mode.	Design AHS to allow evolutionary improvements.
• As new, improved technology has been introduced, it has been applied to elevators. Solid state devices and printed circuits were introduced in the 1950s and 1960s, and were utilized to improve elevator service. • Elevator service continues to be improved, as faster and more reliable technologies become widely available. — Elevator scheduling has become efficient, allowing much faster response times, and thus reducing passenger waiting times. — Some elevators have devices which permit only people with special access cards to stop the elevator at certain restricted floors. (Ford, 1982)	Design AHS to allow evolutionary improvements.

3.2.3.8.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of elevator development are summarized in Section 4.1.

3.2.3.9 Denver International Airport

3.2.3.9.1 Introduction

The headlines in table 36 summarize the progress of the Denver International Airport (DIA) project. In recent months, the only publicity about the project (through the media) has been extremely negative. The public has begun to view the project as a huge fiasco, and the DIA has become the subject of intense criticism.

Table 36. Current Headlines About the Denver International Airport

Headline	Date of Publication
Denver Aims For Global Hub Status With New Airport Under Construction	March 11, 1991
Denver Airport Delayed Until December	May 10, 1993
Delay Likely in Denver Opening	September 6, 1993
Denver Fails to Meet Deadline For Opening	March 7, 1994
Automation Off Course in Denver	March 18, 1994
Denver Airport Opening Delayed Fourth Time	May 7, 1994
Denver Airport Still Months From Opening	August 8, 1994

When the DIA project was first proposed in the late 1980s, it was hailed as the answer to all of Denver's economic problems. City officials saw the project as a large scale public works project, which could introduce jobs and revive the ailing economy. The airport, the first new airport built in the United States in almost twenty years, was intended to serve as an international commercial and industrial hub, by making the city more accessible to airline traffic. (Brown, 1991)

As of September 1994, Denver has not yet opened the new airport. February 28, 1995 has recently been established as the new target date for the opening of DIA. The delay in opening the airport is costing the airport, and the airlines, one million dollars per day, in interest on bonds, and operational costs. Denver's bond ratings have been downgraded severely, and many Denver residents are questioning whether the new airport was really needed in the first place.

This section will discuss the problems experienced by the Denver International Airport, as well as the relevant lessons for AHS.

3.2.3.9.2 Approach

The approach used in this section was to conduct a review of current literature about the Denver International Airport project.

3.2.3.9.3 Results

The Denver International Airport (DIA) project was conceived in the late 1980s by Denver city officials. They hoped that a new airport would entice the airlines to make Denver a central hub for both domestic and international flights. They also hoped that the new airport would attract new investors to the Denver area, and help to improve the ailing economy. City officials sold the project as a necessary investment in Denver's future. In 1989, voters approved the two billion dollar project by a two-to-one margin.

Airport officials in Denver stated that the old Denver Airport, Stapleton Airport, was unable to handle the airline traffic that was expected in the 1990s and beyond. They felt that although Stapleton was meeting the short-term needs of the city, it would be unable to serve the long-term needs. In addition, Stapleton is severely limited in its ability to cope with poor weather conditions, which occur often in Denver. During bad weather, planes must land using an instrumented landing approach. Stapleton is only able to handle one instrumented landing at a time. Thus, although in good weather Stapleton is able to land 80 planes per hour, in bad weather only 25 planes can land per hour.

DIA is expected to land 100 planes per hour under all weather conditions. It has more runways than Stapleton, and is designed to be more flexible in how the runways are used. It also is planned to be expandable, as needed in the future. Denver officials feel that DIA will be able to handle airline traffic well into the next century.

The new airport plans to implement the most sophisticated automated baggage system ever designed. The system, designed by BAE Automated Systems, Inc., is intended to carry 1,400 bags per minute, using 4,000 automated baggage carts. By comparison, previously implemented automated baggage systems are able to transport 100 bags per minute. (Myerson, 1994) The Denver baggage system is the first automated system designed to: serve the entire airport, load and unload baggage carts without stopping them (they will be slowed down), allow for last minute gate changes, and handle oversized baggage (e.g., skis). It is intended to be five times as fast as a traditional conveyor belt system. (Nordwall, 1993)

BAE Automated Systems, Inc. began implementing the baggage system in mid-1992, after construction on the airport was well underway. This forced the company to work on a tight schedule, in order to meet the original October 1993 opening date. However, Denver officials repeatedly altered the plans for the baggage system, which caused further delays in the installation of the system. (Myerson, 1994) The \$193-million system has been blamed for the most recent delays in the opening of the airport.

Testing of the baggage system was conducted in March 1994. These tests showed that the system was not reliable. Some baggage was damaged during the test, and the system was unable to reliably route the baggage to its proper destination. Currently, BAE Automated Systems, Inc., is working to fix the problems with the system.

In August, 1994, Denver officials decided to implement a conventional baggage handling system, using tugs, carts, and conveyor belts. (Hughes, 1994). The city will then be able to open the airport in February, without depending on the automated baggage system. As the automated system becomes available, the conventional system will be maintained as a back-up system. (Hughes, 1994)

Due to the year long delays in opening the airport, Denver officials, and the entire project, have been under intense scrutiny. Airline traffic has not been expanding at the rate predicted in the late 1980s, when the project was sold to the public. The current traffic through Denver is well within the capabilities of Stapleton Airport. In addition, the current cost of the new airport is approaching four billion dollars, twice as much as was approved by the voters in 1989. Thus, DIA must produce revenues of $350 million per year in order to break even. Stapleton produced revenues of only $164 million in 1992. It is expected that the operating costs at DIA will be between $14 and $20 dollars per passenger. However, costs at Stapleton airport are only $7 per passenger. (Miller and Nayyar, 1993) Finally, the new airport is located almost 25 miles outside of the city. It takes 45 minutes to reach by car, and costs $45 dollars to reach by taxi. The old airport is much more convenient for most passengers. It takes only 15 minutes to reach from downtown, is a $20 dollar cab ride, and is almost an hour closer to Colorado’s ski resorts. All of these reasons have begun to turn public opinion against the project. The general public is beginning to question whether the airport should ever have been built, and many air travelers are thankful for the delays. (Johnson, 1994a)

The milestones in the development of the Denver International Airport, as well as relevant lessons for AHS, are described in table 37.

Table 37. Milestones in the Development of the Denver International Airport: Lessons Learned Worksheet

Milestones in the Development of the Denver International Airport	Lessons Learned for AHS
• In the late 1980s, Denver city officials proposed the construction of a new airport. — The new airport was sold as a necessary 2 billion dollar project, to revitalize Denver’s economy. — The old airport, Stapleton, was approaching capacity, and could not be easily expanded and upgraded. — Voters approved the project in 1989, by a two-to-one margin. • Construction of the new airport began in 1990, with an expected completion date of October 1994.	

Table 37. Milestones in the Development of the Denver International Airport: Lessons Learned Worksheet (continued)

Milestones in the Development of the Denver International Airport	Lessons Learned for AHS
• Early progress on the airport was well ahead of schedule, and the opening date was pushed up to October 1993, in order to hasten construction. • Airport plans included the implementation of the most sophisticated automated baggage system in the world. — The baggage system was expected to carry 1,400 bags per minute, and to move baggage five times faster than a conventional conveyor belt system. — System installation was not begun until April 1992, and was expected to be complete by the October 1993 opening date. The system developers were forced to work under intense time pressure in order to meet that schedule.	• Develop realistic schedules for system development. Rushing a project may lead to serious consequences, which may result in more serious delays.
• In September, 1993, airport officials announced that the airport would not be ready to open until December 1993. — They announced that most of the construction would be complete by the end of October, leaving two months for system testing. — Airport officials also announced that the delay was requested by the airlines, who did not want to switch airports during the Christmas travel season. • In November, 1993, airport officials announced that the opening of the airport would be delayed until March 1994. — They stated that additional time was needed to finish construction, to train airline personnel, and to allow for the completion and testing of the automated baggage system.	
• In March, 1994, testing of the automated baggage system was conducted. — The system failed to route many of the bags to their correct destinations, and even caused damage to some pieces of luggage. — The media had been invited to watch these demonstrations, and were able to witness first hand the failures in the system. • Due to these problems with the baggage system, the opening date for the airport was pushed back to May, 1994.	• It is important not to hold public demonstrations of a technological system too soon. Developers should ensure that the system is reliable before it is shown to the public. Otherwise, developers risk allowing the public to develop negative impressions of the system. Such negative associations are often difficult to overcome.
• In May 1994, airport officials announced that they were unable to open the airport by their deadline. They decided not to announce a new opening date until they were better able to predict when all systems would be operational. • By this point, the total cost of the project was over 3 billion dollars, because of the interest on the bonds used to finance the airport.	• Establish realistic budgets and schedules for system completion. Schedules and budgets must be carefully calculated. Unmet schedules can cause cost overruns just due to debt interest alone. Other cost increases may also be incurred when schedules slip (e.g., staff costs). Public acceptance may be hindered if unrealistic schedules and budgets are set, requiring large delays or cost overruns.

Table 37. Milestones in the Development of the Denver International Airport: Lessons Learned Worksheet (continued)

Milestones in the Development of the Denver International Airport	Lessons Learned for AHS
• As of September 1994, the DIA has not yet begun operation. It was recently announced (in August 1994) that the airport would open in February, 1995, whether or not the automated baggage system was ready. • Airport officials, together with the airlines, have decided to install a conventional baggage system. This system, using carts, tugs, and conveyor belts, can be used until the automated system is proved reliable and efficient. In the future, the conventional system will serve as a backup to the automated system.	
• Public opinion of this project is not as strong as it was when the project was conceived. — The new airport location is not as convenient for many passengers as the old airport. — Airport traffic has not increased as expected, and current traffic through Denver is well within the capabilities of Stapleton Airport. — The new airport will be at least twice as expensive as Stapleton to operate. — Costs associated with the delays are approaching one million dollars per day, and continue to rise. • The public, and the media, is beginning to question whether Denver really needed a new airport.	• The negative publicity surrounding this project will be difficult to overcome. It is important to maintain a good public image on publicly funded projects, in order to maintain public support.

3.2.3.9.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of the Denver International Airport development are summarized in Section 4.1.

3.2.4 Non-Transportation Related Systems

3.2.4.1 Office Automation

3.2.4.1.1 Introduction

One of the most profoundly technologically impacted environments in the history of our nation has been the office. The work performed in our nation's offices has changed extensively over the years in terms of tasks performed, tools applied, skills required, as well as the underlying social structure itself. These changes have not always been smooth and easy to accomplish. Much resistance and many difficulties have been encountered and overcome.

In this section, we look at three technologies that have caused many of these changes: the typewriter, photocopiers, and computers. Lessons for AHS have been drawn from the introduction of these technologies. The types of roadblocks and difficulties encountered in the transitions resulting from the introduction of these technologies have been evaluated to provide lessons learned for AHS.

3.2.4.1.2 Approach

The high-level approach applied in the study of these comparable systems has included review of relevant literature and interviews with persons who were personally involved in the changes.

Our study of the typewriter involved review of a single article which provided an overview of the typewriter's invention, evolution, and travails leading to its ultimate acceptance and ubiquitous use. Lessons learned for AHS are based on the insights of this article. A few articles and books were found describing the invention and integration of the photocopier within the office. Insights and lessons for AHS were developed on the basis of these sources.

Insights concerning the recent infusion of computers into office work is based on review of several books and the personal experience of individuals involved. Structured interviews were conducted with several secretaries at the Calspan Advanced Technology Center to identify the issues and difficulties involved with their personal transition from typewriter to computer. We also asked these secretaries for their thoughts on the acceptability of AHS for their own personal travel. The structured interview used in soliciting these views is reproduced in table

3.2.4.1.3 Results

Although the results of this study are based on high-level analysis and a limited review of available literature, insights provided for AHS are informative, as discussed in the following sections.

The Introduction of the Typewriter

In the 1880s the typewriter changed forever the way offices operated and were organized. Before the typewriter, offices employed large numbers of clerks and copiers (those schooled in penmanship who made copies of letters and documents by hand). After the introduction and acceptance of the typewriter, each office had a small pool of typists who performed the tasks of letter and document preparation and reproduction. Office managers and their assistants were able to give typists hand-drafted documents for rapid production on the typewriter. One typist was able to do the work of several clerks, and the output was of substantially better quality. The requirement for large staffs of clerks was eliminated, high school and college penmanship programs were abolished, the organization of office staffs was dramatically changed, and the quiet atmosphere of offices was replaced with the day-long tapping sounds associated with the new typewriters.

Despite the benefits and potential offered by the typewriter, the introduction and acceptance of the typewriter was a long and difficult process. The typewriter's history is summarized in table 38. Lessons that could be applied to AHS are noted in table 38, along with relevant AHS tasks.

Table 38. Invention and Introduction of the Typewriter and Lessons Learned for AHS

Typewriter Development Milestone	Lessons Learned for AHS
• First patent for "an artificial machine or method for impressing letters ..." was made in England in 1714. It was not until the late 1800s that a typing machine suitable for efficient office use was available. • Several patents for improved techniques of impressing letters followed during the 1700s in Europe. None of these inventions survive today. • During the early 1800s U.S. inventors struggled with several early versions of the typewriter as well.	• Sometimes good ideas take time to take root.
• A patent for a "new and useful improvement in typewriting machines" was patented in 1868 to Christopher Sholes, Carlos Glidden, and Samuel Soule. This was the precursor to modern typewriters.	
• Major financial backing for the typewriting machine was obtained from Remington & Sons in 1872. Remington & Sons was an arms manufacturer very interested in finding domestic products following the Civil War. Only small investors were previously involved.	• Private sector support for AHS (and generally IVHS) products may be sought from defense contractors interested in diversification to commercial markets following the Cold War.
• The initial typewriter looked a lot like a sewing machine (another new Remington product). It was sold with a sewing machine-like stand. This appearance did not facilitate association with its purpose and was thought by some to hinder the marketing message.	• Issues of how AHS looks can impact acceptance. • The appearance of AHS needs careful design and evaluation.
• The unrelenting, persistent support and salesmanship by one of the typewriter's original financial backers, James Densmore, kept the idea alive through periods when public interest and sales were not forthcoming.	• Someone needs to keep stirring the pot (for systems that are difficult to sell).

Table 38. Invention and Introduction of the Typewriter and Lessons Learned for AHS (continued)

Typewriter Development Milestone	Lessons Learned for AHS
• The typewriter was initially marketed to clergy, writers, and scholars. This market resisted the typewriter's introduction. In fact, those few "men of letters" who did purchase and use the typewriter found that those with whom they corresponded were insulted at not receiving more personal hand-written correspondence. Typed letters seemed impersonal and the question of authenticity (forgery) was raised. It was years later when the practice was instituted of personally signing typed letters and using personalized letterhead to provide a more personal touch. • Communication was such in the 1800s that most communication between individuals separated geographically was via letters. Letter writing was a major medium of information exchange, and norms of writing etiquette evolved. Colleges of Penmanship existed to teach the important skills of fashionable writing. The typewriter was seen as a disruption to this etiquette.	• While change is more a part of our society today than in the past, it is important to consider the driving and transportation norms that will be impacted by AHS. These may become stumbling blocks to AHS acceptance.
• The original typewriter sold for $125. This made it an expensive gamble for many potential buyers, especially during the early and middle 1870s when there was a recession (and when $125 could really buy something). • Until 1878 the typewriter offered only upper case and had several technical problems. Sales lagged even after these shortcomings were resolved.	• Market success of AHS will be affected by its cost and the prevailing economic conditions.
• Although the early typewriter was marketed to the clergy and writers, there was a growing need for such a device within the business community. The telegraph and railroad had led to large national-scale businesses (previously businessmen were thought of as being local proprietors of small businesses). These large companies had a growing need for internal documentation and communication not subject to the same writing norms as externally distributed documents. But the early promoters of the typewriter did not recognize this burgeoning market until the 1880s.	• Consider all potential AHS markets -- for example consider commercial highway users as well as the larger motoring public.

• In the 1880s when the typewriter finally took-off, it was the business market that drove sales. • Those who believed in the future of the typewriter predicted the demise of the pen. A new class of professional emerged, the typist, and office organization changed forever; but the pen continued to be used (and still is). •The large benefits available from the typewriter facilitated its success. It was faster (75 vs. 24 words/min.), and allowed production of multiple copies when used with the newly patented carbon paper. • Sales exceeded production capacity and new companies entered the market. Many patent infringement lawsuits ensued. • By 1886 every office had at least one typewriter and resident typist. The look and sound of offices was changed dramatically.	• AHS may produce significant changes in the way we use our national highways, but the full impact of the changes is difficult to predict.

The Development and Introduction of the Copy Machine

Machines that copy or duplicate documents are considered essential today, but the introduction of document reproduction technology into the office environment was difficult and fraught with many setbacks. This section explores the history of this experience, the difficulties encountered, and causal factors underlying the setbacks and successes experienced. Table 39 traces the history of document reproductive technology within the office.

Table 39. Invention and Introduction of the Copy Machine and Lessons Learned for AHS

Copy Machine Development Milestones	Lessons Learned for AHS
• Early techniques for reproducing documents are summarized below: — armies of clerks were employed to produce copies of documents by hand, one at a time (mid-1800s). — the letter press was used to roll letters whose ink was still wet between two sheets of blotting paper to transfer the image to one of the sheets (mid- 1800s but very inefficient). — carbon paper was invented in 1869 and used with the typewriter to produce multiple copies of documents when produced.	
• The mimeograph machine was invented to provide the ability to produce many copies of a document. It required ink, a stencil with the typed or handwritten image, the cylinder, and an impression roller to reproduce the image on paper. It was relatively expensive and messy and produced poor copies.	
• Offset printing presses offered similar capability as the mimeograph but with better quality. Its limitations were that it was expensive and required the preparation of a special "master" copy. Its use was limited to high volume reproductions. • Devices applying photographic principles to the copying process were available in the 1950s, but these were very expensive and limited to specialized commercial markets.	• If AHS requires expensive vehicle components its market may be limited to high volume users (e.g., commercial trucking)
• In the early 1950s several devices using wet chemical technology came on the market (e.g., Thermo-Fax, Autostat, Verifax). These were slow, required special paper, and produced copies of varying quality (usually poor). These devices were expensive ($400) and enjoyed only limited markets.	
• Chester Carlson saw the need for dry copy technology as early as the 1930s and set out to invent such a device. His efforts ultimately led to the development of the Xerox copy machine. — He received his first patent for his electrophotographic process in 1937 and successfully demonstrated the technology in 1938. — Carlson was unable to interest a corporate sponsor despite repeated and persistent attempts. GE, RCA, IBM, and many others refused before Battelle finally stepped forward. By the mid 1940s Battelle could no longer support the development effort, and Haloid Company (now known as Xerox) was convinced to add their support. They were unable to find other sponsors, so went it alone (with Battelle).	• Sometimes good ideas take time to take root.
— The first commercially marketed copy machine was marketed in 1958. It was primitive, expensive, and difficult to use. It found little market support.	

Table 39. Invention and Introduction of the Copy Machine and Lessons Learned for AHS (continued)

Copy Machine Development Milestones	Lessons Learned for AHS
• In 1960 the Xerox 914 copy machine was introduced. Despite some initial mechanical problems, the strong maintenance support provided by the company together with fast, high quality copies ultimately made it a success. • Its biggest stumbling block was its price, $29,500; much more than the $400 being charged for the lower quality chemical copiers. — The price disadvantage was overcome by offering the Xerox 914 on lease for $95 per month which included a maintenance contract and 2000 free copies after which they were charged at five cents per copy. For the first time the company made money on the product line. — Within 5 years of the introduction of the Xerox 914, more than 40 other companies entered the copier business. • Carlson died a wealthy man in 1968.	• If initial costs for AHS equipment are high, a leasing approach can be considered to gain market penetration. • If there are technical problems with AHS, immediate maintenance support will be essential to avoid waning of public support.

The Introduction of Personal Computers within Modern Offices

There are many parallels between the introduction of desktop computers and AHS. In addition to significantly affecting the way office work is accomplished, desk-top computers provide a recent example of the rapid development and evolution of technology-based products and markets. Issues of compatibility/standardization, the role of competition, and market shake-out are informative. Table 40 shows relevant issues.

Table 40. Introduction of Computers within the Office Environment

Computer Development Milestones	Lessons Learned for AHS
• Initially, many relatively small computer manufacturers entered the personal computer market. There were few standards, and the models offered were largely incompatible with one another.	
• Efforts to develop industry standards enjoyed only limited success. For example, the CPM operating system served as a standard for a few years, but was only adopted for a few machines. As technology advanced, this standard was unable to adapt (i.e., it was not upward compatible). It was abandoned after a few short years.	
• When IBM entered the personal computer market late in the game, their design became the new de facto standard. Incompatible machines were ultimately displaced with machines based on the IBM (PC) standard.	
• The Macintosh offered advantages over the IBM standard. These included an integrated software environment (e.g., data could be shared across software applications) and user friendliness. These advantages of usability were sufficient to enable Macintosh to gain significant market share.	• Ease of use will help attract users to AHS.

Table 40. Introduction of Computers within the Office Environment (continued)

Computer Development Milestones	Lessons Learned for AHS
• The IBM-based standard was supported by numerous vendors. This market was very competitive. Computers meeting this standard were lower cost than the Macintosh line. Macintosh offered a superior, more user friendly system but was based on proprietary software. The lower level of competition led to higher prices.	
• As IBM and Macintosh machines were improved, the improvements were implemented in a way so as to allow the new machines to use all the previous software.	• As AHS markets are developed, and AHS evolves, provisions for accommodating earlier users must be considered.
• IBM and Macintosh are finally working together to develop machines that will be able to use software from both IBM and Macintosh environments.	

An even more interesting aspect of infusing computers within our nation's offices is the impact on office workers. New skills had to be developed and new ways of organizing and accomplishing tasks had to be put in place. We interviewed three secretaries working at the Calspan Advanced Technology Center to identify difficulties in adjusting to the infusion of computers replacing the previous and more mechanical typewriters. We also asked about their initial thoughts regarding AHS. The questions put to our secretaries and a synopsis of their responses are shown below. Secretary 1 has 27 years' experience, secretary 2 has over 20 years' experience, and secretary 3 has over 15 years' experience. Keep in mind that only three secretaries were included in this very brief survey, and that the results cannot be considered definitive or reflective of the ideas of the larger population. A more complete and scientific survey is needed.

Questions Concerning Transition from typewriters to personal computers for general typing (which occured in the mid 1980s):

1.Did you find the transition from typewriters to personal computers easy or difficult? Why?

Secretary 1
It was initially scary, but I eventually learned not to be intimidated and that I am in charge. Hands-on is the only way to go.

Secretary 2
It was difficult. Needed someone close by to help. Used the manual when needed.

Secretary 3
Relatively easy and a great improvement. I had used word processors in the past.

2.Were you concerned or uneasy about the pending change when you first heard about it? What specifically concerned you?

Secretary 1
Yes, I was concerned about learning the commands. Formatting was different, and it was necessary to learn shortcuts for the commands. This was not easy at first.

Secretary 2
Some apprehension. Some of the older secretaries didn't want a computer at first.

Secretary 3
Not really. Had already used a computer-based word processor at a previous job. This made the transition relatively easy.

3. How did you make the transition? Was it gradual, or did you do it "cold turkey"?

Secretary 1
I gradually learned, and I am still learning. Training would have helped. Used typewriter for labels and as back-up at first.

Secretary 2
Some apprehension. Used the typewriter as back-up and for small jobs at first. But once you see the benefits, you never want to go back.

Secretary 3
Gradual, had already used computer-based word processors. Did have to learn to use a mouse, but this was easy.

4.What were the most difficult aspects of making this change? Was it having to think in new ways, or was it not having specific skills needed to operate the computer?

Secretary 1
File management and remembering commands and procedures. Used a notebook to help remember commands.

Secretary 2
Dealing with situations when you don't know what to do (e.g., can't get the computer to do what you want, or having the computer "crash"). Also, using new features not previously available (e.g., tables and columns in the word processor) and new software (e.g., spreadsheets).

Secretary 3
Learning to use new software (beyond just word processing).

5.Were there training programs offered to help? Were they helpful? How?

Secretary 1
No, but the manuals were useful for looking up items to get help.

Secretary 2
On-line tutorials helped, but I mostly learned by doing.

Secretary 3
Used on-line tutorials. Also, learned enough to use the system and gradually increase understanding over time.

Questions concerning the potential for the development of an AHS:

1.Do you think you would use an AHS if it were made available?

Secretary 1
Might have been good when we traveled a lot but now wouldn't want to spend the money. Might be good for use in bad weather. Would also like the improved safety.

Secretary 2
Perhaps for longer trips, but not to commute—I live too close to need it.

Secretary 3
Need to be assured about safety. Is it Government certified?

2.Are there any concerns you have about using such a system? Are these concerns sufficient to influence your decision about using such a system? In what ways?

Secretary 1
Concerned about system failure. What are the options? Continue manually or wait for help?

Secretary 2
Concerned about putting people in a daze.

Secretary 3
As stated above, need to be assured about safety.

3.What conditions would be necessary before you would be completely comfortable (or willing) to use an AHS?

Secretary 1
After it is proven—would not be the first to use it.

Secretary 2
Would wait until it is proven—probably would wait 2 to 3 years until the "bugs" are worked out.

Secretary 3
As stated, need to be assured about safety.

4. Are there any aspects of AHS design that would make it more attractive to you? For example, if it were separate from other lanes and non-AHS traffic, would you feel more comfortable?

Secretary 1
Would want a rail between automated lanes and other lanes. Also, would want to see it first.

Secretary 2
Would wait until it is proven.

Secretary 3
Would want to be separated from other traffic.

5. Would you be interested in AHS for local travel (e.g., to and from work), or would you be more inclined to use it for less frequent, but longer distance, travel (e.g., intercity)?

Secretary 1
Intercity.

Secretary 2
More for trips on interstates and pleasure driving.

Secretary 3
On long trips. Like to use cruise control. It is more relaxing. Would look at AHS in this way.

6. How much would you be willing to pay on your next car (in today's dollars) to be able to have AHS (assuming AHS were available on all interstates, including beltways (like the Youngman) and intercity radials (like the Kensington))?

Secretary 1
$2,000 would be too much, $500 would be better.

Secretary 2
$2,000 would be ok.

Secretary 3
Would have to be less than $1,000 unless I was commuting a long way each day (e.g., 50 miles or more).

7.Would you consider paying a monthly fee for this service? How much?

Secretary 1
Perhaps $10 to $15 per trip, but it is too difficult without knowing more about it.

Secretary 2
$50 per month is ok.

Secretary 3
Don't know.

Tables 41 and 42 summarize the results of this very limited survey. They are included not as definitive conclusions, but rather as initial considerations for AHS based on personal experiences and perceptions of the Calspan secretaries interviewed.

Table 41. Calspan Secretary Survey Regarding Transition to Personal Computers from Typewriters

Transition Issue	Lesson Learned for AHS
• Transition to computers caused some apprehension. — Needed help at first. — Used the typewriter as a back-up during transition. — Older secretaries may have been more apprehensive than younger secretaries.	• There will be some apprehension about AHS at first. • Apprehension can be reduced if AHS operates and appears like previous vehicle systems (e.g., cruise control).
• Previous experience with computer-based word processors helped reduce apprehension and ease transition difficulty.	• Consider an evolutionary approach to AHS development and deployment.
• Secretaries tended to learn basic capabilities first and then to learn more over time.	• Consider an evolutionary approach to AHS development and deployment.
• The most difficult aspects of the transition was learning to use those things that were a lot different from previous experience (e.g., going beyond word processors and typing such as using a spreadsheet).	• Consider an evolutionary approach to AHS development and deployment.
• On-line tutorials were helpful but mostly learned to use the new computers by doing.	• Make AHS use obvious and consider including embedded training for more involved procedures.
• Once benefits are experienced you never want to go back.	• Emphasize and demonstrate AHS benefits. Make benefits as obvious as possible.

Table 42. Calspan Secretary Survey Regarding Views about AHS*

Comments aboutAHS	Lesson Learned for AHS
• All three secretaries were concerned about the safety of AHS and getting the initial "bugs" out.	• Demonstrate AHS safety and make safety features obvious.
• What happens if the system fails? Are you stranded on the highway?	
• Would feel better if there were a physical separation between automated and normal manual traffic.	• Consider use of barrier or buffer between automated lanes and manual lanes.
• Related AHS to cruise control.	• Stress evolutionary development of AHS. Make it obvious where "proven" technology is included.
• Two out of the three secretaries would want to pay less than $1000 extra to have an AHS-equipped car.	• Keep AHS costs as low as possible.
• If AHS carries a monthly or per trip charge, suggested reasonable amounts are $50 per month or $10 to $15 per trip.	• Keep AHS costs as low as possible.

* Note that only three secretaries were interviewed. The results presented here are not conclusive and cannot be considered to reflect the views of the larger population. A more extensive and scientific survey is required.

3.2.4.1.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of office automation are summarized in Section 4.1.

3.2.4.2 Foot Race Finishes

3.2.4.2.1 Introduction

AHS must be able to handle vehicle flow rates far greater than those experienced on today's highways. Approaches for efficiently managing these high traffic flow volumes, especially at entry and exit points, will be important. The recent popularity of foot races has led to the requirement for efficiently handling large numbers of runners (each moving independently within the stream) over very short periods of time.

Foot race finishes, especially those for short to moderate length races, must deal with large numbers of runners moving en masse. Especially critical is the finish, when all runners cross the finish line and enter the finish chute. Race finish processing must be done in a way that preserves the order in which runners finished, and in a way that allows finishing times to be recorded and runners to be processed, all without backing-up into the race. Table 43 shows how foot races are similar to AHS. In this analysis, we studied only foot race finishes. Other lessons can be gained from studying other aspects of foot races (e.g., techniques for starting large races using multiple starting lines).

Table 43. The Foot Race Analogy to AHS

Foot Race Tasks	AHS Analogy
• Getting people registered and lined up to start	• Vehicle qualification, certification, and check-in
• Moving runners through the city en masse (dedicated lanes, police enforcement)	• Moving vehicles on AHS—must keep lanes clear, traffic moving, clear incidents
• All runners going to the same place (the finish)	• Urban AHS applications and exits to activity centers
• Must perform finish line processing without backing-up into the race (finish chutes and time logging process)*	• Vehicles must exit without backing up into AHS lanes • Check-out
• Race finished, racers and well-wishers milling around the finish*	• Drivers leaving AHS, entering manual traffic, reaching destination

* Aspects of foot races studied during this analysis.

The flow rates experienced in popular foot races far exceed flows that will be experienced by AHS. Nevertheless, by examining how such large numbers of runners are handled during the critical race finish process can provide insights for design of AHS. This analysis was conducted to provide these insights.

3.2.4.2.2 Approach

The approach taken involved observation and analysis of the 98th Annual Turkey Day Race (the oldest continuous foot race in the United States), held on 25 November 1993 in Buffalo, New York. The race finish was videotaped, finish results were analyzed, and race planners were interviewed. Insights for AHS exit designs were identified.

3.2.4.2.3 Results

The 8-kilometer 98th Annual Turkey Day Race experienced extremely high flows of runners at the finish line during peak periods, reaching as many as 174 runners in one minute. Over 3,000 runners participated, and all finished within a 46-minute period. Each runner was processed as he/she passed through the finish chute, and his/her finish time and finishing order were recorded. This was done without causing back-ups into the race. Figure 3 shows the distribution of the number of runners finishing per minute.

The approach for processing runners within these extreme flow rates was efficient, intense, and instructive. The finishing time for each runner was entered into a computer as he/she crossed the finish lines (two identical finish lines and processing systems were set up and the results integrated with the computer following the race—runners selected one of the finish lines). Entering each runner's time involved hitting

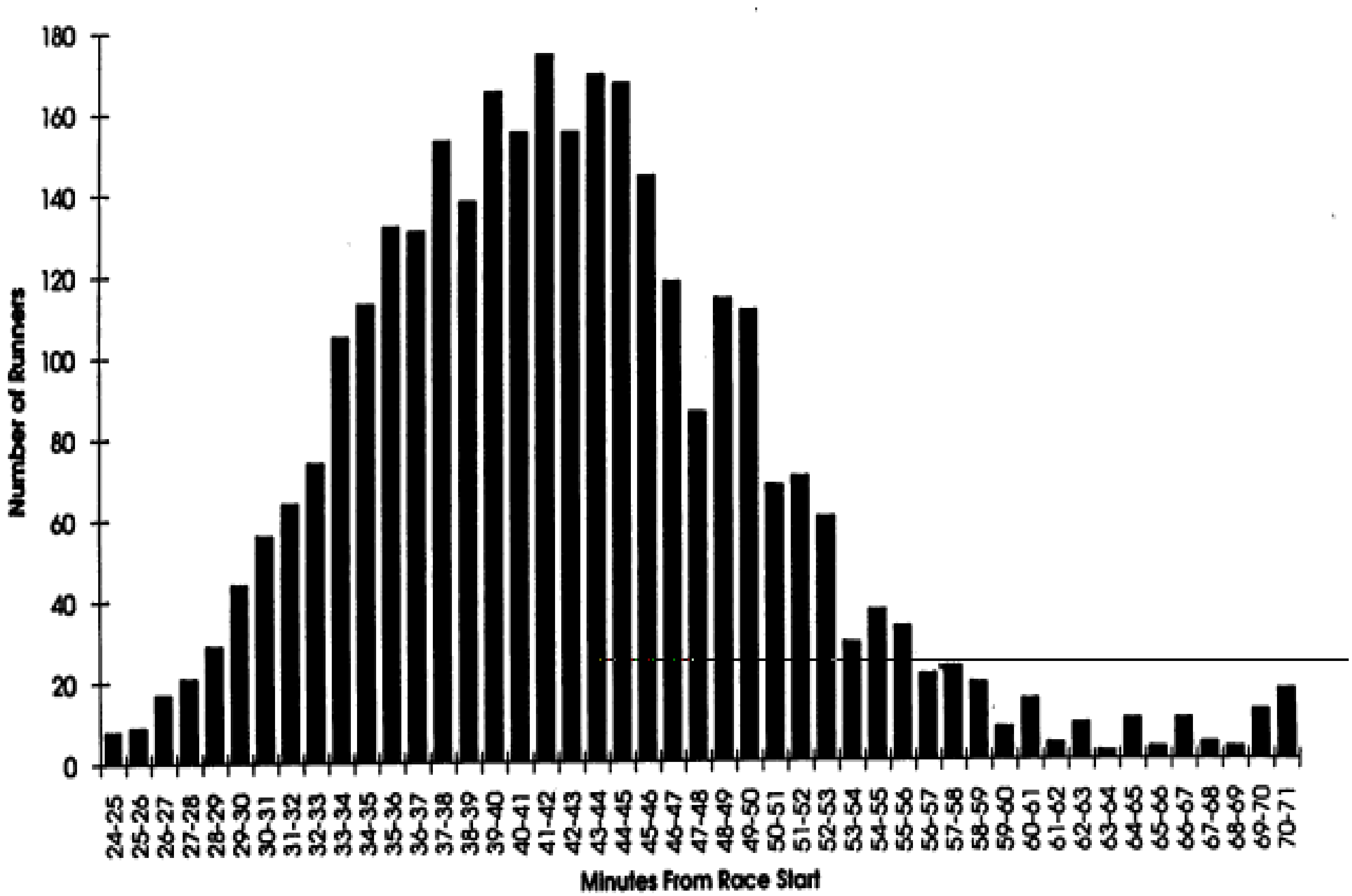


Figure 3 Frequency Distribution of Runners Finishing the 98th Annual Cameron Turkey Day 8 km Road Race as a Function of time

Figure 3. Frequency Distribution of Runners Finishing the 98th Annual Cameron Turkey Day 8 km Road Race as a Function of Time

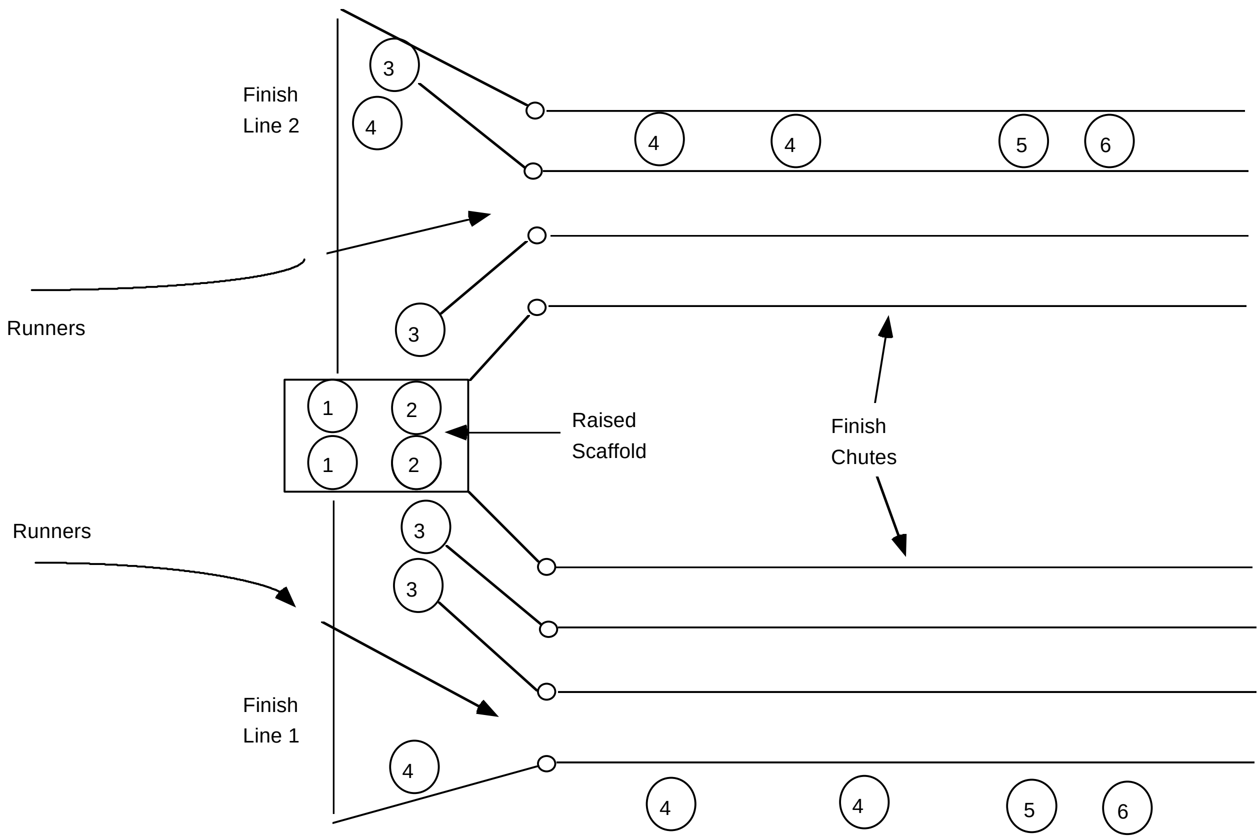


Figure 4. Race Finish Configuration

the space key as the runner crossed the line. This was done without regard to the runner's number. The time and runner's number were entered by a second person for every 5th or 6th runner. After runners crossed the finish line, they were channeled into one of six finish chutes. The order of finishing was preserved within the chutes. The runner's finishing order was recorded as he/she walked through the chute. This was done by removing and reading a bar code worn by each registered runner. The runners' time was associated with finish order, integrating the two finish lines (and associated chutes), by the computer after the race. The race results were printed and posted about one-half hour after the race, and awards were made to the winners of each age group. Figure 4 shows the race finish configuration for the 98th Annual Turkey Day Race.

The staff employed at each of the two finish lines to support in the race finish process and their responsibilities are summarized in table 44.

Table 44. Staff Employed for Processing Finishers at the 98th Annual Turkey Day Race

Station	Position	Description of Duties
1	Timer	Stationed on a scaffold above the finish line. Enters the time for each runner crossing the line by hitting the space bar each time a runner crosses the line. Does not enter the runner's identification number.
2	Timer/Recorder	Stationed on the scaffold. Enters each runner's time (by hitting the space bar) and the runner's identification number for approximately every 5th runner.
3	Chute Directors	Direct all runners into the currently operating finish chute, preserving the order of finish. Also, responsible for closing finish chutes about to back-up into the race and opening the next empty chute.
4	Screamers	Keep tired runners moving through the chutes by screaming and gently pushing.
5	Bar Code Collectors	Collect bar code from each runner traversing the chute, preserving the finishing order.
6	Bar Code Readers	Read all bar codes collected from the runners into the computer. This must be done in the order in which they were collected.
7	Race Results Computer Operator	Runs race results software, which integrates race results based on the data collected at the race finish and finishing chutes. Prints race results for whole race.

Table 45 highlights relevant features of the foot race finishes and identifies associated lessons and insights for AHS.

Table 45. Foot Race Finishes Lessons Learned Worksheet

Feature of Foot Race Finish	Lessons Learned for AHS
During peak finish periods, the efficient handling of runners involves an intense, hectic, and highly structured process.	AHS exit efficiency will be critical for handling high AHS flow rates. An efficient process will be required.
Multiple finish chutes are used to prevent runners from backing up into the race.	Multiple (parallel) exits and buffer areas can be used for AHS if check-out/exit demands exceed capability. This could be considered for special exits at activity centers and CBD areas.
Finish chutes designed for single file to preserve race finish order.	This is less important for AHS. However, drivers can be upset if they are not processed fairly. AHS should try to process vehicles in the order in which they reached the exit if parallel exit configurations are used.
Bar codes containing runner identification number are employed to speed processing at the finish line.	Vehicle and driver testing can be accomplished just prior to check-in or check-out and the results recorded on a computer storage medium. These results can be read as the car crosses the check-in/check-out point. This approach can be considered if tests take too long to accomplish at check-in/check-out.

3.2.4.2.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of foot race finishes are summarized in Section 4.1.

3.2.4.3 Domestic Appliances

3.2.4.3.1 Introduction

There have been many new products that have, over time, had a significant effect on our society. Electrical appliances have revolutionized housework, reducing the amount of physical labor required and improving the standards of efficiency and cleanliness that can be achieved. The electric companies and appliance manufacturers successfully developed a new technological system. From 1920 to 1940, the percentage of homes with electricity increased from 34 percent to 80 percent. Consumers were convinced to replace their old, "out-dated," non-electrical appliances (which still worked) with new electrical appliances (which worked better). There is a similar issue facing AHS: how to convince drivers to give up their traditional transportation for a newer, more efficient system.

The video cassette recorder (VCR) is a specific example of a new technology that was successfully accepted by the general public in a relatively short period of time. Sony found commercial success by developing a product that met the needs of the customers, was easy for the public to operate, and was reasonably priced. The sewing machine is a product that took a long time to be accepted by the general public. People feared the new invention, and felt that the sewing machine would ruin the lives of all the tailors, seamstresses, and needlewomen. By examining the history of domestic appliances including the VCR and the sewing machine, we can identify factors that played a role gaining public acceptance for new technology. In this section, we discuss the development of domestic appliances, the VCR, and the sewing machine, and identify relevant lessons for AHS.

3.2.4.3.2 Approach

The approach was to review available literature, including books and articles that document the development and introduction of domestic appliances (including the VCR and sewing machine) in the United States.

3.2.4.3.3 Results

The results of this study are organized into three sections. The first traces the development of electrical domestic appliances in the United States. The second section discusses the history of the video cassette recorder, and the reasons behind its successful introduction in the US. The third section provides a brief history of the sewing machine, and discusses why it was not immediately accepted by the public.

Domestic Appliances

Electricity first became commercially available in the 1880s, although it was expensive to produce the small quantities of electricity originally demanded by industry. Large quantities of electricity could be produced cheaply by large centralized plants, but only if there was adequate demand. Therefore, the electric companies actively campaigned to expand their market to increase demand, which would allow them to lower prices. Private homes represented the biggest potential market for electricity.

By 1920, only 34 percent of private homes had an electrical supply, since only the wealthy could afford to install the necessary electrical wiring. Through the 1920s, the cost of electricity decreased to a point where it became more widely used in private homes. By 1930, all new buildings in the United States were wired for electricity.

Until the late 1930s, electrical supply to homes was not standardized. Some electrical companies supplied alternating current, while others supplied direct current. Also, the voltage of the supplied current differed by location. This forced appliance manufacturers to produce two models of every appliance, one for use with AC, the other for DC. Each type of appliance was designed for use with a different optimal voltage; with the lack of industry standards, the result was customer confusion, increased appliance prices, and inconsistent operation of appliances.

The electrical industry continued to strongly promote the use of electricity in the home. They developed advertisements promoting the use of electrical appliances, claiming that the appliances would substitute for the dwindling number of servants, improve the efficiency of the household, improve health and hygiene standards, and reduce the drudgery of household chores. The advertising campaign was directed at women from all socio-economic levels, and implied that electrical appliances were necessities for the health and happiness of families.

In the 1920s, the electric iron was the first electrical appliance to become widely accepted by American housewives. The electric iron reduced the amount of physical labor needed to iron clothes, and thus reduced the amount of time spent ironing. The vacuum cleaner was also widely accepted during this time. The early vacuum cleaners were not especially easy to operate nor did they reduce the amount of time spent cleaning carpets. However, vacuum cleaners were much better at cleaning carpets than any traditional cleaning method.

The electric washing machine was introduced in 1914. The only automated function was the agitation; the machines still required a significant amount of manual intervention to operate. Electric washers did not reduce the amount of time spent doing laundry, but did reduce the amount of physical labor involved. The fully automatic washer was introduced in 1938, but was priced out of reach of the general public. When prices were lowered slightly after World War II, the public generally had more money to spend, and the automatic washer was one of the most frequently bought appliances. The manufacturers successfully convinced consumers to replace their old appliances, which still worked perfectly well, with the new appliances.

Other electrical appliances were introduced throughout the 1920s and 1930s. Most of these appliances simply electrically duplicated tasks performed with little inconvenience without electricity. For example, coffee makers, hot plates, heating pads, toasters, and room heaters were all introduced. These appliances did not become popular until the 1940s (or later), when the public was more financially secure. Many of these electrical appliances claimed to reduce the time and labor of household tasks. However, the labor and time saved with electrical appliances is often used to perform even more household chores, and to adhere to higher standards.

Milestones in the development and acceptance of domestic appliances, as well as relevant lessons for AHS, are summarized in table 46.

Table 46. Domestic Appliances Development Milestones: Lessons Learned Worksheet

Domestic Appliances Development Milestones	Lesson Learned for AHS
• Gas companies in the 1820s and 1830s began to establish distribution systems in most major cities. Gas lines did not reach the smaller towns until the 1840s and 1850s. • Domestic use made up only a small percentage of the gas used. Gas was primarily being used for lighting in public places (industrial and commercial).	
• Electricity became available commercially in the 1880s, and was introduced as competition to the gas companies. • During the 1890s, there was a thirty-fold increase in the amount of electric power being used in the US. This increase was due mainly to the widespread electrification of industry. — Many industries chose to use electricity to produce incandescent light, since it is inherently safer than gas lighting. • Large quantities of electricity could be produced cheaply by large centralized plants, but only if there was an adequate demand for it. To increase the demand for electricity, the electricity suppliers tried to expand their market. — Through advertising, they encouraged customers to use electricity for more than just lighting. One advertising campaign, in 1917, encouraged consumers to use more energy-efficient light bulbs, so that there would be enough current left over to operate electrical appliances without increasing the month's electric bill. — Private homes represented the biggest potential market for electricity. However, this market was not widely tapped until the 1920s. In fact, by 1920, only 34% of homes in the US had an electricity supply.	• For greatest market potential, don't limit potential AHS users (i.e., consider commercial and personal markets in AHS design).
• Before 1920, only the wealthy could afford to have electricity in their homes. However, during the 1920s, the price of electricity was lowered, and it became more widely used. • Starting in the 1930s, all new buildings in U.S. cities, including houses, were wired for electricity.	• As AHS becomes more widely used, the operating costs will decrease, leading to lower per use costs. In turn, the lower user costs may lead to an increased number of AHS users.
• Through the 1930s, electrical supply to homes was not standardized. Some electricity companies supplied alternating current (AC), others supplied direct current (DC). The voltage of the current also differed by location. — Appliance manufacturers needed to produce two models of every appliance, one for use with AC, the other for use with DC. — Each type of appliance (i.e., stoves, refrigerators, irons) also required a different voltage. • The lack of standards created customer confusion, and often resulted in appliances working differently in different homes.	• AHS, nationally and internationally, should be standardized. This will prevent confusion, and make equipment and skills transferable between systems.

Table 46. Domestic Appliances Development Milestones: Lessons Learned Worksheet (continued)

Domestic Appliances Development Milestones	Lesson Learned for AHS
• In 1924, a British group, the Electrical Association for Women (EAW) was founded to promote the wider use of electricity. They collected and distributed information on key areas of interest to women. — EAW published a journal to help women learn how to manipulate the new electrical technologies, and to give confidence in its use through a technological understanding. — EAW also ran campaigns to gather information in order to report to the electrical appliance industry on the attitudes of women toward their products. — EAW encouraged installation of electrical outlets in all new construction, and encouraged standardization of all outlets and appliance types.	• AHS will be more widely accepted if people are well informed about the system. Public education about the technology behind AHS and especially those concerned with safety features will facilitate public acceptance.
• During the 1920s and 1930s, the electric industry actively promoted the idea that electric appliances could: — substitute for servants and household help — improve the efficiency of households — improve health and hygiene standards — reduce the drudgery of household chores • The advertising campaigns were focused on all economic levels in society, and were designed mainly to appeal to women. • The three main tactics used in the ads were celebrity endorsements, guilt (e.g., for not reaching the highest possible standards for cleanliness), and implications for social status. — The ads appealed to women and carried the message that electrical appliances were necessities for health and happiness. — They also emphasized that failure to meet the new standards of cleanliness (achieved only through electrical appliances) could be embarrassing, and potentially dangerous to the familiy's health.	• Aggressive advertising campaigns can influence consumers, and can encourage them to use an AHS system.
• The electric iron was the most popular electric appliance during the 1920s. It was inexpensive, and could be run off the lighting circuits. — The electric iron reduced the amount of time spent ironing; it eliminated the need to continuously reheat a non-electric iron on a stove. — The adjustable thermostat was introduced in 1927, offering a further advantage over early electric irons. Early electric irons were either on or off. — According to a market survey done in Zanesville, Ohio, in 1926, almost 60% of the households owned an electric iron.	• Consumers welcome new innovations which can lessen the physical demand of a task, and offer greater convenience. AHS will reduce the physical demands of driving. This should be emphasized in marketing.
• The vacuum cleaner was another popular electric appliance during the 1920s. — The two most popular vacuum cleaners were the Hoover, introduced in 1908; and the Electrolux, introduced in 1924. The Hoover used a power-driven brush to beat the rug, while the Electrolux was a canister type cleaner which could even vacuum something above the floor. — The early vacuum cleaners were not easy to operate. They required as much, or even more, work to operate as it took to simply clean the carpets with a broom. — However, vacuum cleaners were much better than brooms, or even carpet sweepers, at removing dirt from a carpet. — According to the Zanesville study, over 50% of the households owned a vacuum cleaner in 1926.	• If AHS offers better (more efficient, more convenient) service over other transportation systems, the public may be willing to use it, even if it does not offer faster service. • Time is not the only factor that is important to consumers.

Table 46. Domestic Appliances Development Milestones: Lessons Learned Worksheet (continued)

Domestic Appliances Development Milestones	Lesson Learned for AHS
• Although other electrical appliances were introduced in the 1920s and 1930s, none sold as well as the iron and the vacuum cleaner. • Most of the new appliances offered were simply electrified appliances which duplicated tasks done with little inconvenience without electricity. — Hot plates, heating pads, grills, percolators, room heaters, fans, electric waffle irons, chafing dishes, coffee makers, egg cookers, corn poppers, baby-bottle warmers and toasters are some examples. — Only 20% of the Zanesville households owned a toaster in 1926, far outstripping all of the other small household appliances.	• AHS should offer some definable benefits over currently used transportation systems, or the public will be reluctant to spend money to try it.
• The washing machine was first introduced in the late 1800s, although the early models did not reduce the amount of time or physical labor required to do laundry. • Electric washers were developed in 1914. — They required a significant amount of manual intervention. (The operator needed to start and stop the machine, add and remove water, and put each item through the wringer.) — Laundry in the electric washers took as much time as doing it by hand. However, the amount of physical labor was reduced, since users no longer had to agitate the load by hand. — By 1926, over 25% of the Zanesville households owned an electric washer. • The automatic washing machine was developed in 1938, but was expensive, and therefore inaccessible to the general public. — After World War II, families found themselves with more money to spend, and the automatic washing machine was one of the most frequently bought appliances. — The manufacturers needed to convince consumers not simply to buy a new appliance, but to move up from an old-fashioned appliance (electric washers) to the newest kind (automatic washers), replacing machines that worked perfectly well.	• AHS must demonstrate benefits over alternative/traditional forms of transportation that are perceived as worth the price.
• The electric refrigerator became popular during the 1930s, replacing the iceboxes found in most American homes. — In 1930, only 10% of American families owned refrigerators; this had increased to 56% by 1940. — Aggressive advertising campaigns assumed that consumers could recognize the superiority of refrigerators over iceboxes. The ads focused on how families could afford to buy a refrigerator, which kind to buy, and how to use it correctly once they owned it. — Refrigerator manufacturers offered installment plans to encourage families to buy, even during the Depression.	• AHS must offer some definable benefits over currently used transportation systems, or the public will be reluctant to spend money to try it.
• By 1941, 80% of American homes had an electrical supply. • During the 1940s and 1950s, manufacturers continued to introduce appliances which claimed to reduce the time and labor of household chores. • The labor and time saved by the use of electric appliances is often used to perform even more household tasks, and to adhere to even higher standards of cleanliness and efficiency.	

Video Cassette Recorder Development

The video cassette recorder (VCR) was first developed for industrial/commercial use in the 1950s. The television industry recognized a need for a device that would allow them to record live programs for later broadcasting. Ampex, an American company who had worked on developing audio tapes, began working on a videotape recorder that could be used to record and play back video images. The early machines were introduced in 1960, and were sold to television stations and professional studios for $75,000 each.

Early in the 1960s, several companies developed video recorders for home use, but they were overpriced, bulky, and unreliable. They did not succeed in the market. The Japanese also recognized the potential for using video tape technology to produce machines for use in private homes. They believed the public would be receptive to a device which allowed them to record television programs for later viewing, at their own convenience, if they were reliable and low priced. Sony began mass producing video recorders for the public, which sold for $1000 each.

In 1975, Sony introduced the Betamax, the first VCR designed especially for the home. JVC then introduced the Video Home System (VHS), to compete for market share with the Betamax. The VHS cassette tape allowed up to six hours of recording, as compared to the five hours permitted on Beta cassettes. VHS and Beta co-existed in the market for a few years, although VHS has become the industry standard for home VCRs.

The development of the video cassette recorder, as well as lessons learned for AHS, are summarized in table 47.

Table 47. Video Cassette Recorder Development Milestones: Lessons Learned Worksheet

VCR Development Milestone	Lesson Learned for AHS
• In the early 1950s, the television industry recognized a need for a device that would allow them to record live programs for later broadcasting. This initiated research into video recording. • Concentration was focused on magnetic tape recording, similar to that used in audio recording.	
• By January 1956, Ampex had developed a videotape recorder (VTR) that could be used to record and play back video images. • By 1960, Ampex had sdd about 950 machines, mainly to television stations and other professional studios, at a cost of $75,000 each.	
• Ampex was content with its dominance in the high-scale end of the market in video recorders. • In the early 1960s, Japanese companies (Sony, in particular) began to use their expertise in miniaturization to mass produce smaller video recorders, selling for around $1000. • Sony intended to produce machines that could be used in private homes for recording television shows for later viewing.	• Don't overlook potential markets. • Specialized markets are generally small, keeping prices high. Large public markets are needed to achieve low-cost high participation for AHS.

Table 47. Video Cassette Recorder Development Milestones: Lessons Learned Worksheet (continued)

VCR Development Milestone	Lesson Learned for AHS
• Eventually, in 1966, Ampex did attempt to compete in the consumer market. The machine they produced was quite complicated to operate, and recorded only in black and white, although television was now broadcasting in color. In addition, the Ampex machine was priced considerably higher than the Sony model. • The Ampex machines were successfully sold to institutions (schools, hospitals, etc.) that had large budgets for new audiovisual equipment. • Sony, however, was marketing machines that were easy to operate, and that were within the price reach of consumers for home use.	• If AHS is expensive to use, the potential market will be limited.
• In 1975, Sony introduced the Betamax, thefirst VCR designed especially for the home. Sony sold about 100,000 of these machines. • JVC, another Japanese company, introduced the Video Home System (VHS) to compete with the Betamax. The VHS cassette allowed six hours of recording, as compared to the five hours permitted by Beta cassettes. • Although VHS and Beta co-existed in the market for a few years, VHS has become the industry standard for home VCRs.	
• During the 1970s, Sony was successful in marketing its product in the US, and other US companies tried to develop video recorders for the consumer market. None were successful in taking a product to market. • RCA was the last US company to give up on the video recording market. They discontinued work on VCRs in 1978, and continued to work on the development of the videodisc. However, the videodisc could only play programs; it could not record. -— By the time the videodisc was released in 1980, hundreds of thousands of VCRs that could both play and record had already been sold in the US. Movies were already being released on videotape for consumers to buy or rent. Even at competitive prices, the videodisc could not overcome the head start of the VCR in the home video market. The videodisc market remains very small relative to the VCR market today.	• AHS must offer significant improvements over existing technology, at competitive prices, to allow it to gain market share. • AHS must anticipate what features will be desired by consumers.
• In general, US businesses were less prepared to match the long-term patience and foresight of the Japanese. US companies were less willing to take risks and accept the probable sacrifice of profits in the short term, in order to meet success in the long term.	• US industry will be more receptive to support long-term AHS goals if short-term profits are possible. Consider an evolutionary approach to AHS deployment to allow early product sales.

Sewing Machine Development

Before the 1930s, clothes were made to measure by a tailor, a dressmaker, or someone at home. Industrial clothing manufacturers were limited by the speed of needlewomen, who could not sew fast enough to keep up with the power looms making the cloth. The need for an automated sewing machine was readily apparent to the manufacturers.

The first patented sewing machine was introduced in France in 1830 by Barthelemy Thimonnier. By 1841, he had outfitted a Paris shop with 80 working sewing machines. However, the tailors and seamstresses, fearing that the machines would ruin their livelihood, broke into the shop and destroyed all but one of the sewing machines. Thimonnier never again succeeded in making his sewing machine known to the public.

In the United States, Walter Hunt, a well known inventor, began work on a sewing machine in 1832. By 1834, he had two working machines in his shop. How-ever, Hunt was convinced by needlewomen not to market his invention. Hunt did not want to be responsible for ruining the livelihood of the needlewomen. (Fenster, 1994)

In 1835, Elias Howe began working on developing a sewing machine. In 1845, he had a working machine. Coincidentally, Howe’s machine was similar to that previously designed by Hunt. Machinery, in general, was established in many industries by 1845. Howe’s sewing machine was not immediately rejected as previous models had been. However, Howe was unable to sell his machines to the public. He did patent his invention in 1846.

By 1849, various sewing machine models were on sale or on display in the United States. In 1850, Isaac Merritt Singer examined one of the poorly made sewing machines offered for sale under the name Lerow and Blodgett. (Fenster, 1994) Singer reworked the machine into the first practical, versatile, and dependable sewing machine.

Early sewing machine manufacturers had concentrated on selling their machines to men, the ones who owned the factories. Singer recognized that there was another large market for the sewing machine. He marketed his machine directly to women, dressmakers, seamstresses, needlewomen, and housewives. Singer and his partner Edward Clark introduced an installment payment plan for their sewing machines. This allowed almost everyone to afford a sewing machine.

The Civil War was an impetus to the acceptance of the sewing machine in industry. The immediate need for large numbers of uniforms encouraged garment factories to purchase large number of sewing machines. In industrial use, the sewing machine reduced the amount of time needed to make a fine shirt from 14 hours to one-and-a-quarter. Needlewomen were not hindered by the introduction of the machine. In fact, the sewing machine created hundreds of thousands of new jobs by reducing the price of ready-to-wear clothing, and turning the garment industry into a larger and steadier industry than it had ever been before. (Fenster, 1994)

Milestones in the development of the sewing machine, as well as lessons learned for AHS, are summarized in table 48.

Table 48. Sewing Machine Development Milestones: Lessons Learned Worksheet

Sewing Machine Development Milestones	Lesson Learned for AHS
• Barthelemy Thimonnier patented the first sewing machine in France, in 1830. — Previous inventors had worked to build a sewing machine that imitated the hand movements of human seamstresses. — Thimonnier's machine was the first to break away from the imitation of human movement. — By 1841, Thimonnier had outfitted a Paris shop with 80 working sewing machines. — All but one of these machines were destroyed by a mob of angry tailors and seamstresses, who felt that the sewing machines posed a serious risk to their livelihood. — Thimonnier's machine gained support in London in 1848, and was to be entered in a competition of new inventions at the Crystal Palace Exhibition of 1851. However, due to a clerical error, the sewing machine could not compete, and did not become widely known.	• Innovations and breakthroughs are sometimes achieved when new ways of looking at problems are applied.
• In 1834, Walter Hunt introduced a sewing machine in the United States. — As Hunt's invention became widely known, it attracted the attention of needlewomen advocacy groups. Representatives from these groups encouraged Hunt to destroy the machine. — The sewing machine was never promoted or marketed, because no one wanted to face the groups campaigning against the machine.	• Special interest groups can scuttle projects.
• Elias Howe began work on a sewing machine in 1840. His machine was quite similar to Hunt's machine, and was publicly introduced in 1845. — In general, by 1845, machinery had become established in many industries. There was less fear and opposition to the introduction of the new machine. — By 1849, Howe and a few competitors had succeeded in putting sewing machines on the market for use in industrial settings.	
• In 1850, Isaac Merritt Singer examined a poorly made sewing machine offered by Lerow and Blodgett, one of Howe's competitors. — Within two weeks, Singer managed to redesign the machine, and rework it into the first practical, versatile and dependable sewing machine. — Although previous sewing-machine manufacturers promoted their machines to the men who ran the factories, Singer realized that there were in fact two major markets for sewing machines. — Singer recognized that women would usually be the ones using the machines at home, and began marketing his sewing machines directly to them. — Singer and his partner Edward Clark introduced an installment plan in 1856. This allowed almost everyone to afford a sewing machine. — In 1857, Clark introduced a trade-in plan, allowing consumers to trade in old machines for a discount off the price of a new machine. Thus, he encouraged consumers to continually replace their machines. — Once the sewing machine came within reach of the general public, the sewing machine was widely accepted, and lost its ability to intimidate potential users.	• Don't overlook potential markets, (e.g., consider both commercial and non-commercial AHS markets). • As AHS evolves, consider incentives for people to upgrade their equipment.

3.2.4.3.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of domestic appliances development are summarized in Section 4.1.

3.2.4.4 Automated Teller Machines

3.2.4.4.1 Introduction

Prior to the development of the automated teller machines (ATMs) in the early 1970s, bank customers could gain access to their bank accounts only during bank hours. Now, almost 25 years after they were first introduced, automated teller machines make it almost totally unnecessary to ever go to the bank. Customers can access their accounts, quickly and easily, 24 hours a day, 7 days a week.

The drastic change in banking is due to two main factors. First, the emergence of the necessary technology made it feasible to build automated teller machines. Magnetic stripes containing scrambled information, machines to accurately dispense cash, and a mainframe to protect the system from fraud are examples of system components that made it possible to build ATMs. The second factor is that bank leaders recognized that consumer banking provided a previously untapped market which could provide increased revenues. They realized that they could increase their profits by improving customer services, and making their banking services more accessible to the public.

In a relatively short time frame (less than 20 years), automated tellers have developed from cash dispensers to electronic versions of the bank teller's counter. ATMs have recently provided the technology and the motivation for the current development of electronic point-of-sale (POS) networks. In this section, we examine the development of ATMs, and consider the factors that led to the immediate acceptance of the new technological system Lessons learned from the introduction and implementation of ATMs are then applied to AHS.

3.2.4.4.2 Approach

The approach taken during this part of the study relied exclusively on a review of available literature. We especially recommend "The Electronic Bankers: The Rise and Spread of Automated Teller Machines," in *The Innovators.* (Diebold, 1990)

3.2.4.4.3 Results

The first automated teller machines were installed in 1969, as a tool to dispense emergency cash to customers. Customers were generally impressed with the convenience offered by the machines, although the banking industry failed to recognize the huge implications for the long-term future of banking. These machines were feasible due to the introduction of the technology that allowed the ATM to be activated only by the insertion of a special plastic entry card, with a magnetic stripe on the back. The stripe contained encoded information about the card holder, including a personal identification number (PIN), known only to the card holder. Before accessing any bank account, the user was required to enter the correct PIN number, to verify that it was his card.

Chemical Bank was the first bank to establish an ATM network, although they faced many problems with account security. Chemical Bank did not connect its ATMs to a mainframe computer; they simply transferred information to and from the machines once or twice daily. Therefore, even if a customer reported an ATM card stolen in the morning, the thief would still have access to the bank account throughout the day. Also, customers could withdraw more cash than they had in their account, before it could be noticed when the machine's transactions were downloaded. Many of these security issues were resolved when the ATMs were put on-line in 1974. Transactions could be immediately posted to the account, and stolen cards could be locked out of the system as soon as they were reported.

Citibank was the first bank to realize that the introduction of a widespread ATM network would attract consumer business, and provide increased profits to the bank. They spent a year developing and testing automated tellers, and introduced a user-friendly ATM that satisfied the needs of their customers in 1978. They placed their machines in locked vestibules, which gave customers an added perception of safety. Customers began switching to Citibank in order to obtain the privilege and convenience of safe, electronic banking.

In 1985, other New York City area banks joined in developing the New York Cash Exchange (NYCE), which quickly became the largest ATM network in the US. NYCE allowed the banks to share operating costs, and provided even greater customer convenience. Customers no longer were limited to automated teller machines located at their own bank locations; they could access their accounts from any machine connected to their bank's ATM network. This trend has been further expanded, and many banks are now members of more than one national (even international) ATM network. This allows customers to access their accounts from anywhere in the world, at any time.

The number and types of transactions that can be performed on ATMs have also been expanded. Initially, ATMs simply allowed customers to withdraw funds from their accounts. Then, ATMs were expanded to allow withdrawals, deposits, payments, and balance inquiries. Now, many machines allow customers to transfer funds between accounts, to check the status of unpaid checks, even to get a statement of all activities on their accounts.

The technology used in ATMs is also being applied in the development of national POS networks. POS terminals allow customers to use their ATM cards as debit cards, from which the amount of purchases is automatically deducted from the bank account. Thus, the need to write checks or carry cash for purchases is reduced, or even eliminated.

Table 49 presents the milestones in the development of automated teller machines, as well as applicable lessons for AHS.

Table 49. Automated Teller Machines Development Milestones: Lessons Learned Worksheet

Automated Teller Machine Development Milestone	Lesson Learned for AHS
• The first automated teller machine was installed in 1969. A few bank leaders then applied automated teller machines (ATMs) on a small scale to dispense emergency cash to customers and as a general enhancement to customer convenience. • The banking industry, as a whole, initially failed to recognize the huge potential as a revolutionary innovation for the long-term future of banking.	• Small scale implementation of potentially revolutionary ideas can serve as a catalyst for market-driven larger scale applications.
• ATMs were not feasible until a method of securing them could be developed. It was necessary to restrict access by customers to their own bank accounts. • A new technology was introduced that allowed the ATM to be activated only by the insertion of a plastic entry card, with a magnetic stripe attached to its back. • The stripe contains intricately scrambled information, including the user's personal information number (PIN). The PIN, which is a code known only to the user, provides adequate account access security. • Customers did not seem to realize the security significance of the PIN system. They often wrote their PIN numbers on the back of their ATM access card, allowing the card to be used if stolen.	• The value and purpose of AHS safety features needs to be understood by AHS users.
• The first ATMs were easy to use, although they only allowed customers to withdraw funds from their accounts. • Once customers realized that cash withdrawals were coming from checking, rather than credit accounts, they had little trouble adjusting to the new machines.	
• Chemical Bank was the first bank to establish an ATM system, although they had many problems with account security. • These early ATMs were not immediately put on-line with a mainframe computer. This was not felt to be a major necessity for the ATM system. • However, many security problems with the ATMs were eliminated when the system was put on-line in 1974. For example, the mainframe was able to immediately update the ATM to prevent the use of stolen cards.	
• Citibank was the first commercial bank to realize that consumer banking was a possible source of significant revenue. Before this, commercial banking was considered to be the mainstay of the banking industry, with consumer banking a necessary, yet unprofitable sideline. • Citibank believed that the introduction of an ATM network would attract consumer business, by providing conveniences not offered at any other bank.	• All potential market segments for AHS need to be identified and targeted as appropriate. Don't overlook viable markets.
• Citibank spent almost a full year testing different configurations of ATMs in order to obtain consumer input into the design of the system. • The ATM system they eventually implemented, in 1978, reflected the preferences and needs of their customers. • Citibank realized that the public wanted a machine that was an extension of the teller's counter, not simply a cash dispenser.	• Work out the bugs and fully understand customer needs before final implementation.

Table 49. Automated Teller Machines Development Milestones: Lessons Learned Worksheet (continued)

Automated Teller Machine Development Milestone	Lesson Learned for AHS
• Citibank placed their ATMs in special locked vestibules that could only be entered with a valid ATM card. • The availability of ATMs in safe locations resulted in consumers viewing electronic banking as a viable, attractive alternative to standing in teller lines at the bank during banking hours. • Consumers began to switch to Citibank in order to obtain the convenience of electronic banking. This significantly increased Citibank's share of the consumer banking market.	• The perception of safety can be important for attracting customers and system success.
• To compete with Citibank,other New York City area banks formed a cooperative venture to create an ATM network, called The New York Cash Exchange (NYCE). NYCE began operations in 1985, and by 1988 was the largest ATM network in the US. • The network approach allowed the banks to share the startup costs, and to minimize equipment costs. Customers could access their accounts from any ATM connected to the network, reducing the number of ATMs each bank would need to provide.	• Cooperative consortium approaches to AHS development are recommended.
• In 1984, Citibank took measures to stay ahead of the industry by increasing the number of ATMs available at each of its branches, and by introducing new machines that were virtually able to replace the human teller. • The new machines were able to perform 55 separate functions, in three languages (English, Spanish, Chinese). These machines operated on a touch-screen principle, making them easier to use than previous machines.	• AHS needs to satisfy all users. • Special needs of specific user groups should be anticipated and considered (e.g., non-English speaking drivers).
• ATMs were originally developed simply to dispense cash, but the technology is being applied to encourage a "cashless" society. • Point-of-Sale (POS) networks are now being established that allow users to use their ATM cards as debit cards, from which the amount of purchase is automatically deducted from the bank account. • A POS system allows convenientaccess to banking services where and when they are most needed and eliminates the need to carry cash or to write checks for purchases.	• Efficient, unrestricted access to AHS may be important for its widespread acceptance by the public. • Don't limit the vision of potential AHS design applications.
• The automation of the entire retail and banking industries through ATMs and POS networks is not totally accepted as a positive benefit to society. It may be considered an invasion of privacy. • Some argue that the total dependence on electronic fund transfers could infringe upon the individual's right to privacy, since all transactions would leave an audit trail.	• The extent to which people's movements are tracked by AHS could raise right-to-privacy complaints.

3.2.4.4.4 Issues

The major issues, risks, and recommendations for AHS derived from the analysis of ATM development are summarized in Section 4.1.

4.0 CONCLUSIONS

4.1 SUMMARY CONCLUSIONS FOR INDIVIDUAL ANALYSES

Summary tables for all issues, risks, concerns, and recommendations are provided in this section. The tables include a unique number identifying the issue, a descriptive title and short description of the issue, identification of impacted RSCs, and a reference where more detailed discussion of the issue can be found.

Summary tables for the comparable systems analyses listed in table 50 are included in this section.

Table 50. Comparable Systems Summary Table

Table Number	Preliminary Issues and Risks Based on Analyses
51	HOVs
52	Ramp Metering
53	U.S. Interstate Highway System
54	Highway Tunnels
55	Electronic Toll and Traffic Management (ETTM) Systems
56	Automobile History
57	Cruise Control, ABS Brakes and Air Bags: Liability Issues
58	Automated Guideway Transit
59	Air Traffic Control
60	Aircraft Automation (TCAS, ILS, ALS)
61	Railroads, Interurbans, and Maglev
62	Commercial Flight
63	Supersonic Transport
64	Planning Mass Transit
65	Elevators
66	Denver International Airport
67	Office Automation
68	Foot Race Finishes
69	Domestic Appliances
70	Automated Teller Machines

Table 51. Summary and Conclusions for HOVs

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
HOV-1	Return from AHS can be achieved with transit vehicles, and with encouragement (e.g., through pricing strategies) or requirement for HOV use. These applications will be limited to urban corridors.	• Consider transit vehicle and/or HOV users for urban AHS applications within cost-benefit trades. Cost-benefit trades may favor this usage in congested corridors. In fact, AHS can out perform HOV and mass transit in terms of people moving capability if it includes large mix of HOV and transit use. • HOV facilities provide a critical service which can be greatly enhanced with AHS, but AHS cannot replace HOVs. • AHS can out perform HOV and mass transit if mix of transit and HOV use is high.	All RSCs	3.2.1.1

Table 51. Summary and Conclusions for HOVs (continued)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
HOV-2	Maximize instrumentation and minimize construction for rapid implementation at the least cost.	• Preference should be given to instrumentation over roadway construction. Emphasize evolution, building on existing infrastructure.	All RSCs	3.2.1.1
HOV-3	Guidelines for HOV development and operation appear to have direct application to AHS deployment.	• Evaluation of AHS benefits must consider entire trip, not just the AHS portion. Must collect before as well as after data. • Separated AHS (barrier or buffer) will improve flow because it will isolate AHS from effects of non-AHS incidents. Barrier is best for this purpose. • Barrier enclosed AHS incidents are best handled using counterflow travel to reach incident site, however this is a cumbersome operation. • AHS plans must involve interaction between highway planners, Government (all affected jurisdictions), and public. • Must provide resources and commitment for enforcement and incident management.	All RSCs	3.2.1.1
HOV-4	Non-AHS motorists will not support lanes lost to AHS unless they are used for improved people movement, not just vehicle movement.	• Early AHS deployment where existing freeway lanes are designated for (exclusive) AHS use must provide for increased people movement (not just increased vehicle movement). • Apparent AHS use level will impact public perception. Can consider evolutionary deployment to build user base. • Gains by AHS cannot offset lower level of service on other lanes.	All RSCs	3.2.1.1
HOV-5	AHS is one of many transportation solutions and should be considered within the larger transportation system.	Plan AHS as an integrated component of the overall transportation system. • Must be commitment to off-roadway support facilities (e.g., park and ride/intermodal transfer stations). • AHS benefits should be measured against alternative available modes, not just on the basis of cost benefit analysis.	All RSCs	3.2.1.1

Table 52. Summary and Conclusions for Ramp Metering

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
RM-1	AHS ramp design must accommodate all anticipated vehicle maneuvers (e.g., check-in/out, queuing, operation on ice/snow).	Identify scenarios associated with AHS ramp use including degraded operations and CVO use. Assess ramp design requirements including requirements for vehicle storage. Consult existing ramp design guidelines.	All I3	3.2.1.1
RM-2	New AHS displays should be consistent with existing conventions and standardized across all AHS implementations.	Design in-vehicle and highway mounted AHS-unique displays in consultation with existing published standards and conventions, and standardize across all AHS implementations.	All RSCs	3.2.1.1
RM-3	Initiation/termination of AHS operation must be accounted for in design.	Identify scenarios associated with AHS termination (e.g., due to weather, malfunction) and define safe, compatible displays, design geometries, and operational procedures.	All RSCs	3.2.1.1
RM-4	AHS design should consider requirements for enforcement of use restrictions.	Identify AHS scenarios requiring enforcement provisions and ensure AHS design can support (e.g., photograph license plates of vehicles illegally entering AHS, a way for police to apprehend those violating AHS rules).	All RSCs	3.2.1.1
RM-5	AHS design should consider impact of AHS on non-AHS roads and likely local public reactions.	Assess impact of AHS on non-AHS roads and initiate action to assess and mitigate likely public reaction (e.g., through community involvement). Consider incremental deployment.	All RSCs	3.2.1.1
RM-6	Public must perceive overall benefit of AHS.	Approach AHS design and deployment in ways that will make AHS benefits obvious (e.g., consider incremental deployment, eliminate excessive queuing, make faster AHS travel visible to non-AHS drivers).	All RSCs	3.2.1.1
RM-7	Make AHS status clear to drivers	Ensure that timely information about AHS status (e.g., exit and lane-slot availability) is conveyed to drivers.	I2 and I3 (and in-vehicle status for I1)	3.2.1.1
RM-8	Community outreach and public involvement will be important for AHS success	Ramp metering projects have failed because of community opposition. Public and community involvement in ramp metering projects has helped ensure success. This approach is recommended for AHS as well.	All RSCs	3.2.1.1

Table 53. Summary and Conclusions for U.S. Interstate Highway System

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
IHS-1	AHS funding should be sufficient and specific to the goals of AHS	AHS will require long term funding commitment. If funding is not sufficient or continuous, AHS development may be delayed or not accomplished at all. If funding is not AHS specific and focused to accomplishment of AHS milestones, it could be applied to porkbarrel projects.	All RSCs	3.2.1.3
IHS-2	AHS public acceptance will be facilitated if benefits are obvious and desired across many large constituencies.	Consider people's transportation needs and desires in designing and marketing AHS. If reduced trip time is most highly valued, then this should have high weighting in design trade-offs. The more constituencies satisfied, the more political support that will be available (e.g., consider national defense, commerce, personal travel, etc.).	All RSCs	3.2.1.3
IHS-3	Pay as you go financing is preferable to borrowing but needs to be broad-based if AHS is to be implemented in rural areas.	• Requirements for high levels of Government borrowing could scuttle AHS projects. • Toll-based funding for AHS could limit viable implementation to high traffic areas. • Support increased development.	All RSCs	3.2.1.3
IHS-4	Community and environmental concerns must be adequately addressed.	Highway projects that do not adequately address the concerns of impacted communities and environmentalists could be blocked.	All RSCs	3.2.1.3
IHS-5	AHS is one of many transportation solutions and should be considered within the larger transportation system.	Plan AHS as an integrated component of the overall transportation system. • Impact of AHS on surrounding facilities must be considered. • Consider intermodal travel where this makes sense.	All RSCs	3.2.1.3
IHS-6	The success of new innovative infrastructure intensive projects is greatly enhanced by high level support from influential persons in Government and industry.	Seek support and advocacy for AHS from senior levels of Government, particularly from executive and legislative branches of the federal Government. This support needs to be maintained over the long-term, and certainly over the life of AHS development and implementation.	All RSCs	3.2.1.3

Table 53. Summary and Conclusions for U.S. Interstate Highway System (continued)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
IHS-7	Evolutionary development and deployment offers advantages over all-at-once development approaches.	The interstate highway system was implemented gradually over many years. Pay-as-you-go financing was able to support development and ongoing demonstration of benefits was sufficiant to maintain public support. AHS will also benefit from an evolutionary development approach.	All RSCs	3.2.1.3

Table 54. Summary and Conclusions for Highway Tunnels

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
HT-1	Procedures for dealing with unauthorized AHS access need to be developed.	• Some AHS designs will not be able to tolerate unauthorized vehicles (e.g., when narrow lanes are used and/or barriers are placed close to the AHS lanes). In these cases fail-proof mechanisms for denying unauthorized access will be required. This may require long lead detection, special stations to prohibit unauthorized access, or an entry technique that physically requires AHS engagement (e.g., gate opens, barrier lowers only when vehicle is engaged/passes check-in). • Alternatively, AHS designs could be made to operate safely even when unauthorized vehicles enter AHS lanes (e.g., adjust control parameters adjusted to operate safely with non-AHS vehicles). In this case, a lower level of enforcement can be tolerated, but detection of unauthorized access will still be required. • If unauthorized vehicle enters AHS causing an unsafe condition, a last ditch approach would be to slow or stop all AHS traffic until the violator is dealt with.	I2, I3	3.2.1.4
HT-2	Traffic flow monitoring technology currently in use in tunnels can be applied for AHS.	• Consider using existing tunnel traffic flow monitoring technology for AHS. These include loop detectors, microwave, sensors, and video cameras/detectors. • Freeway segments (e.g., tunnels) with traffic management systems will form a strong base for introduction of AHS because they have in-place: traffic flow monitoring, CCTV coverage, Visual communication systems, and central control facilities.	All RSCs	3.2.1.4

Table 54. Summary and Conclusions for Highway Tunnels (continued)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
HT-3	AHS approaches to communicating information (e.g., status) to "drivers" will need to be more attention-getting than current non-AHS systems.	• Visual attentiveness of AHS "drivers" cannot be assumed. In fact, high levels of attentiveness in general cannot be assumed. AHS displays must incorporate attention-getting qualities. Consider auditory or other attention-getting approaches.	All RSCs	3.2.1.4
HT-4	High AHS development and/or operating costs will be passed on to AHS users reducing AHS cost/benefit advantages or requiring public sector subsidy.	• Keep AHS design as simple and low cost as possible. • Deploy AHS incrementally to develop markets and revenue streams before the full system is developed. • Tailor AHS marketing on the basis of initial deployment experience.	All RSCs	3.2.1.4
HT-5	An evolutionary development approach. Can help avoid cost and schedule problems.	• Incremental development allows systems to be tested and sold as you go along.	All RSCs	3.2.1.4

Table 55. Summary and Conclusions for ETTMs

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
ETTM-1	ETTM technology can be considered to support AHS data communication requirements.	ETTM systems provide communication of up to 256 bits of information in 100 milliseconds at highway speeds. This technology may applicable to AHS for data communication	All RSCs	3.2.1.5.3
ETTM-2	Develop AHS markets by building from pre-existing markets.	The NYS E-Z Pass system generated a large market penetration in a very short time frame by building from an already established market. AHS should consider market development approaches that build from already existing markets (e.g., those using ETTM).	All RSCs	3.2.1.5.3
ETTM-3	AHS should consider incentives to attract AHS customers.	Incentives have been successful for influencing motorists to car pool. AHS customers may be attracted with similar incentives (e.g., cost of AHS also covers tolls on conventional portions of highway).	All RSCs	3.2.1.5.3

Table 55. Summary and Conclusions for ETTMs (continued)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
ETTM-4	AHS developers must demonstrate that the system is safe.	Safety issues caused delays in implementing the E-Z Pass system and has been a concern of some users. AHS developers must design with safety in mind and be prepared to demonstrate that AHS is safe (free from accidents, health effects of radiation, affect on safety of other traffic, etc.)	All RSCs	3.2.1.5.3
ETTM-5	The introduction of AHS for commercial applications can raise concerns for job security.	AHS developers will need to consider the impact of AHS on employment and be prepared to address job security concerns. AHS facilitation of safety and efficiency should be emphasized, but job security should not be ignored.	All RSCs	3.2.1.5.3
ETTM-6	AHS outreach to affected communities and the public at large is needed.	Many communities are organized today and concerns for the impact of new technology and infrastructure development are prominent issues. AHS must provide outreach to affected communities and involve the public in AHS development planning and implementation or face community based opposition.	All RSCs	3.2.1.5.3
ETTM-7	Pay attention to public relations details.	Public acceptance of AHS will be an important factor in its success. Issues of public relations must be carefully addressed (e.g., communicate all AHS fees up-front, provide user responsive service centers, be very sensitive to privacy issues, avoid cumbersome billing and administrative procedures)	All RSCs	3.2.1.5.3

Table 56. Summary and Conclusions for Automobile History

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
AH-1	Organizations that see AHS as being in opposition to their own goals could become a force working against AHS development.	It is important to identify groups and organizations that may oppose AHS because its development could work against their own goals, or on a more theoretical basis. Identify potential opponents and build coalitions where possible. Consider multi-modal solutions.	All RSCs	3.2.2.1
AH-2	AHS design must plan for accomplishing ongoing maintenance.	Facilities, equipment, procedures, and plans for accomplishing ongoing AHS maintenance without disrupting AHS operations must be planned and implemented.	All RSCs	3.2.2.1
AH-3	AHS must serve long term traveler needs in terms of destinations served.	Once built, AHS destinations and routes will be somewhat fixed. Careful consideration of traveler origins and destinations will be important to ensure that AHS will provide continuing utility to users.	All RSCs	3.2.2.1
AH-4	Cost factors will be important determinants of AHS public acceptance.	AHS design and development efforts should proceed with final cost considerations in mind. AHS will need to compete with other travel modes and relative cost will be an important discriminator. Cost will determine level of market penetration which will affect AHS viability.	All RSCs	3.2.2.1
AH-5	An evolutionary implementation approach with successive demonstrations of success and safety will facilitate AHS public acceptance.	Public acceptance of novel ideas (like AHS) is enhanced when concepts can be experienced. An evolutionary approach to AHS development is recommended. Successful demonstrations of AHS safety and success (especially those involving the public) can also help ensure AHS acceptance.	All RSCs	3.2.2.1
AH-6	All feasible design alternatives for AHS should be considered.	By considering alternative approaches to AHS design and implementation, an evaluation and selection process can be implemented to allow optimal choices of technology and design.	All RSCs	3.2.2.1
AH-7	AHS impact on pollution will be a factor in determining public acceptance.	The impact of AHS on the environment needs to be carefully considered. Concerns about AHS caused pollution can negatively impact the public image of AHS and affect public acceptance.	All RSCs	3.2.2.1
AH-8	Support from advocacy groups can be a very positive force in AHS.	Advocacy for the development of the automobile and its supporting infrastructure was very influential in its successful development. Advocacy for AHS will also be important. Use by respected organizations can also help develop public acceptance.	All RSCs	3.2.2.1

Table 56. Summary and Conclusions for Automobile History (continued)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
AH-9	The impact of AHS on the structure of urban and suburban areas and on society are difficult to predict.	New transportation systems implemented on a large scale have had unforeseen impacts on the society they serve. The same can be expected for AHS. Attempts to predict the impact of AHS should nevertheless be made and planned for.	All RSCs	3.2.2.1
AH-10	AHS will be supported by manufacturers such as car makers if they perceive competitive benefits.	Drivers have been willing to pay for automobile enhancements that improve driving convenience and safety. Public acceptance of AHS technology can be expected to motivate private industry to develop and market AHS products.	All RSCs	3.2.2.1
AH-11	Don't overlook potential markets.	When automobiles were priced and marketed for sale to average Americans sales soared. Potential AHS markets should not be overlooked.	All RSCs	3.2.2.1

Table 57. Summary and Conclusions for Legal Issues

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
LI-1	Potential legal challenges to AHS should be anticipated and planned for; legal consultation should be sought.	Like any new product or system, AHS will face a wide range of legal challenges. These can stem from mismanufacture, defective design, failure to warn, and/or product/service misrepresentation. Steps to prevent legal challenges should be taken as AHS develops. • Extensive safety analyses must be conducted to support design decisions; and safety design features should be integrated. • Drivers must be educated and warned about system limitations. • Plans for updating AHS to avoid antiquated technology/designs should be included in the design. • Designs should use capable technology if it is available. Since legal foundations are built on precedents, legal issues not adequately addressed may be decided in court.	All RSCs	3.2.2.2
LI-2	The definition of defective products and dangerous conditions are based on the perceptions of the public (i.e., juries).	Educate the public about AHS operations and limitations, design warnings to avoid misunderstandings, and conduct demonstrations to demonstrate AHS safety.	All RSCs	3.2.2.2

Table 57. Summary and Conclusions for Legal Issues (continued)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
LI-3	Design and programatic approaches to limiting liability exposure should be applied when possible.	• Black box recorders may be able to avoid liability when products are misused (could be associated with check-in components). • Government design and safety standards can help reduce liability for private industry. • The more design redundancy the better. • Safety issues identified during design and development must be disclosed and dealt with appropriately. • User responsibility can help avoid technology-based liability. Make drivers responsible (e.g., for decisions) to the extent practical	All RSCs	3.2.2.2

Table 58. Summary and Conclusions for Automated Guideway Transit

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
AGT-1	The long term success of AHS will benefit from the support of high level Government officials.	The implementation of the Morgantown People Mover Project greatly benefited from the personal commitment from the Secretary of Transportation, John Volpe. The importance of influential support has also been very evident on other large projects. AHS will benefit from high level political support.	All RSCs	3.2.3.1
AGT-2	Budget and schedule estimates for the AHS program should be carefully assessed to ensure accuracy and realism.	Overly optimistic estimates of budget and schedule for large development projects like AHS look good at planning time, but lead to failure. AHS cost and schedule requirements should be carefully estimated and continually monitored to avoid dramatic cost overruns or schedule slippages. Success is measured against these estimates and failure to meet them can degrade political support. Additionally, when schedules or budgets are underestimated, design deficiencies are frequently experienced (e.g., as a result of hurried decisions and cost cutting measures).	All RSCs	3.2.3.1

Table 58. Summary and Conclusions for Automated Guideway Transit (continued)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
AGT-3	AHS objectives need to be clearly defined. These objectives should be realistic and achievable.	Successful demonstration of AHS will require clear objectives. Designers will need a clear understanding of the objectives in order to efficiently proceed, and the final demonstration will be less convincing without clear objectives against which to measure.	All RSCs	3.2.3.1
AGT-4	AHS must demonstrate safety and reliability from the outset.	AHS system failures can influence public opinion against the system, and people will be reluctant to use it. It takes time for technology to prove itself after receiving negative publicity. This could discourage additional AHS implementations.	All RSCs	3.2.3.1
AGT-5	Once initiated, AHS service should provide safe and reliable service on a continuous basis.	Once AHS service is initiated, further system development, enhancements, extensions, and/or maintenance should not require long term shut-down of service. Long-term breaks in service can force users to seek other travel means and to view AHS as not reliable.	All RSCs	3.2.3.1
AGT-6	Consistent political and financial support will be important for AHS long term success.	Inconsistent political and financial support for large infrastructure intensive transportation systems like AHS have led to reductions in achievable scope, only limited successes, and a general perception of poor performance. Firm financial commitments are needed throughout AHS development and implementation. AHS will need to contend with changes in political winds.	All RSCs	3.2.3.1
AGT-7	An evolutionary approach to AHS development offers advantages over higher risk all-at-once approaches.	Successful implementation of AHS for small-scale applications can facilitate future larger-scale implementation. By addressing achievable small-scale goals first, underlying technologies can be proven (and improved where needed) and public support can be developed. This approach also provides an opportunity to gain experience with alternative designs.	All RSCs	3.2.3.1
AGT-8	Technology developed for AGTs can be applied to AHS.	Technological issues dealt with for AGTs, and particularly PRTs, can be applied to support AHS development. Issues such as headway control, safety, switching, operations, system maintenance, and public acceptance have all been dealt with.	All RSCs	3.2.3.1

Table 58. Summary and Conclusions for Automated Guideway Transit (continued)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
AGT-9	Time and money invested in alternative technologies early in the design phase can provide relatively inexpensive insurance against the risk of implementing an inferior design.	All feasible alternative AHS technology and design approaches should be considered during the design phase. This will help ensure that the ultimate system implemented will best serve the ongoing AHS demands. At early stages efforts to explore all promising technology and design approaches should be undertaken.	All RSCs	3.2.3.1
AGT-10	Success of AHS will be facilitated if it is designed to serve large segments of the population.	Downtown People Mover (DPM) projects were less successful when they were designed to serve small portions of the population. AHS should not overlook potential markets and should be designed to serve as large a market base as reasonable.	All RSCs	3.2.3.1

Table 59. Summary and Conclusions for Air Traffic Control

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
ATC-1	A degree of centralized control in AHS can affect system efficiency and the ability to respond to local conditions.	• Alternative AHS control approaches should consider the effect on spacing requirements and flow achievable. Centralized control could create lags in the control system. • AHS vehicle control approach should allow enough local discretion to permit vehicles to deal with local events (e.g., take action to avoid object in the road). • The requirement for centralized human decision-making should be limited to global, non-time-critical parameters (e.g., setting overall speed)	I2, I3	3.2.3.2
ATC-2	Commands to AHS vehicles from the roadway that require immediate response must be rapid and unambiguous.	Requirements for driver assimilation and interpretation of messages will slow response. Consider sending commands requiring immediate response directly to the vehicle. Commands sent to the driver must be clear and unambiguous.	All RSCs	3.2.3.2

Table 59. Summary and Conclusions for Air Traffic Control (continued)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
ATC-3	The reduced workload associated with I2 relative to I1 will provide natural market forces for AHS evolution to I2 and I3.	Because AHS users on an I1 will be required to monitor and respond to manual traffic the full potential benefit of AHS will not be realized. There will be a natural desire to move to an I2 design. Workload will be reduced and comfort will be enhanced. This will provide market forces that will naturally facilitate AHS evolution from I1 to I2 and I3 (AHS segregated traffic).	All RSCs	3.2.3.2
ATC-4	Bottleneck problems associated with popular destinations can be mitigated through proactive planning.	If bottlenecks can be predicted (e.g., because of scheduled events or driver destination entries) the AHS can take actions to avoid the congestion problems. Alternative exits can be suggested to AHS drivers; exits in the vicinity of an event can be under the control of the AHS (i.e., driver indicates desire to exit and AHS selects specific exit within vicinity); vehicles entering the AHS with a given destination can be metered at entry points (this last approach requires drivers to pre-specify destinations and may be unpopular).	I2, I3	3.2.3.2
ATC-5	Selection of AHS design approach should consider the ability to make improvements later.	• An AHS design consideration should be ease of making design changes or improvements. Systems with vehicle-based components may be easier to change later than more centrally configured systems. • AHS should be thoroughly tested and alternative designs compared before implementation. It will be difficult to change later.	All RSCs	3.2.3.2
ATC-6	If operation of AHS is to be by private industry Government regulation should be considered to avoid preference for users more able to pay (e.g., commercial interests).	If AHS is to be operated as a for profit enterprise by private industry there could be a concern that preference might be given to those most able to pay. An extreme scenario is that the AHS would be used exclusively for trucks.	I2, I3	3.2.3.2

Table 60. Summary and Conclusions for Aircraft Automation (TCAS, Formation Flight, ILS, ALS)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
AA-1	Demonstration of benefits for AHS will be an important factor for securing political and financial support.	Political and financial support for AHS will require demonstration of the expected benefits. Demonstrated safety benefits of TCAS led to the requirement for its use on all large commercial aircraft.	All RSCs	3.2.3.3.3
AA-2	AHS reliability can be enhanced with design redundancies which can include human intervention.	The ultimate guarantee of reliability for in-flight automation is the human pilot and ground-based controllers. AHS can also consider human back-up as the ultimate reliability measure as long as design and operating conditions are permitting.	All RSCs	3.2.3.3.3
AA-3	AHS advisories and/or hard corrective actions should be limited to only the most serious conditions.	An AHS design that provides a large number alarms and advisories can cause dissatisfaction and limit public acceptance. AHS design should be fine tuned to avoid unnecessary alarms and advisories.	All RSCs	3.2.3.3.3
AA-4	Station keeping variance can be minimized if speed is referenced to the lead vehicle (of a platoon or vehicle string).	Station keeping performance of formation flight is enhanced by using a lead aircraft as reference. Distance to the nearest aircraft is monitored for safety, but speed is controlled relative to the lead aircraft. AHS inter-vehicle spacing can also be more accurately maintained by referencing speed to a lead vehicle.	All RSCs	3.2.3.3.3
AA-5	User discomfort with AHS can be mitigated by providing the driver information confirming that the system is operating correctly.	At least initially, AHS users will be likely to be apprehensive about AHS. Providing information confirming the proper functioning of AHS can help reduce this tension (e.g., a dynamic display showing the adjacent vehicles may reassure the driver that the system sees, and is tracking, these vehicles).	All RSCs	3.2.3.3.3
AA-6	The AHS-driver interface must be designed to avoid critical errors.	If it is possible for drivers to make critical errors the AHS-driver interface must be designed to avoid this possibility (e.g., if the driver is to take control under some situations, the system must make it very clear when these conditions exist and avoid communicating this message inadvertently).	All RSCs	3.2.3.3.3
AA-7	AHS design must consider the potential for the driver falling asleep.	Highly trained pilots sometimes experience sleepiness when using autopilot. This possibility must be considered for AHS with a less well trained population. Measures must be taken to avoid this if AHS design requires an awake driver.	All RSCs	3.2.3.3.3

Table 61. Summary and Conclusions for Railroads, Interurbans, and Maglev

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
RR-1	Variations of AHS design across regions or internationally can limit interoperability and require difficult or cumbersome work-arounds.	Consider AHS standards and/or cooperative design approaches (e.g., through the AHS Consortium) to avoid AHS incompatibilities.	All RSCs	3.2.3.4.3
RR-2	AHS development may benefit from an evolutionary approach in which familiar and trusted technologies are gradually substituted with more radical seeming approaches.	Consider implementing AHS in an evolutionary fashion, gradually adding technology and capability. For example, AHS can build from intelligent cruise to a lane-keeping warning system to full AHS, and from I1 to I2 to I3 as described in Section 2.1 of this report.	All RSCs	3.2.3.4.3
RR-3	AHS acceptance will be greatly facilitated if its benefits and reliability can be demonstrated.	• AHS demonstrations should be conducted under realistic conditions and widely publicized. • If AHS is developed in an evolutionary fashion only added features will need to be tested. Public acceptance will be facilitated. • The use of standard parts and efficient maintenance should be included in AHS design and evaluation criteria. • Keep AHS design as simple as possible. • AHS image will be an important factor in achieving political support. It must be seen as a desirable, viable, reliable, competitive transportation system.	All RSCs	3.2.3.4.3
RR-4	There may be regions in which conditions and/or markets favor AHS, while other regions may be less favorable.	• Consider initial AHS implementations and demonstrations in areas where geographic and market conditions favor its success. • Anticipate that political and public opposition to AHS may come from areas of the country not receiving AHS investments and benefits.	All RSCs	3.2.3.4.3
RR-5	Entrenched interests and other groups opposed to AHS could hinder AHS success.	• Identify groups that could represent organized opposition to AHS and work to build coalitions, overcome potential differences, and/or counter negative arguments. • Set-up mechanisms to streamline public reviews and facilitate environmental permitting.	All RSCs	3.2.3.4.3

Table 61. Summary and Conclusions for Railroads, Interurbans, and Maglev (continued)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
RR-6	Gaps in AHS funding and/or political support could scuttle AHS Projects and hinder AHS development.	• Once a commitment to develop AHS is made, secure and continuous funding should be obtained to ensure uninterrupted implementation. A long-term funding commitment will be important to the success of AHS. • Strong AHS proponents in Congress should be recruited for the long-term. • Form an AHS Initiative represented by an interagency organization whose role will be to promote and shepherd AHS development.	All RSCs	3.2.3.4.3
RR-7	AHS utility is enhanced by the personal and flexible transportation it offers. Origins and destinations should not be "locked-in".	• The marketing of AHS should emphasize its inherent origin-destination (O-D) flexibility. • Consider AHS within an intermodal environment to provide an efficient travel component with completely flexible O-D pairing.	All RSCs	3.2.3.4.3
RR-8	Unsuccessful transportation systems can become a Government responsibility (as was the case with Amtrak). Focus on reliable markets and control of development and operating costs will be important.	• AHS development plans must reflect realistic estimates of realizable market share and AHS design should be based on these estimates. • AHS marketability projections must consider current and future travel alternatives and selection criteria (e.g., increased emphasis on reduced pollution is likely). • Focus cost containment efforts on the most costly AHS components.	All RSCs	3.2.3.4.3
RR-9	The ability of AHS to maintain constant speed will reduce vehicle wear and increase mileage.	Consider the impact of more efficient vehicle operation on AHS costs (e.g., better highway mileage, reduced wear on brakes and other vehicle components).	All RSCs	3.2.3.4.3
RR-10	Improved transportation services along specified routes can impact commercial and private development.	• Plans for AHS implementation should be coordinated with all impacted regional planning organizations to assess and plan for potential impact on surrounding developments and facilities. • Interjurisdictional coordination and cooperation will be required.	All RSCs	3.2.3.4.3
RR-11	If the benefits and/or markets for AHS are overstated, a scenario for (at least) the perception of AHS failure will be likely.	• Don't exaggerate AHS benefits. Exercise modesty in documented claims for AHS. • Think small but plan for the long-term. Begin AHS deployment on a small scale and plan for expansion after initial successes have been realized.	All RSCs	3.2.3.4.3

Table 62. Summary and Conclusions for Commercial Flight

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
CF-1	Safety or reliability problems, especially those experienced in a sensational manner, can scuttle emerging systems intended for public use.	AHS must be demonstrated to be free of reliability and safety problems to ensure public acceptance. Transportation systems that have experienced obvious safety or reliability problems have been seriously hurt. When accidents are experienced in a very sensational and public way, public acceptance damage can be critical (especially for new forms of transportation).	All RSCs	3.2.3.5
CF-2	Allowing the public to experience AHS on a small scale can help facilitate public acceptance on a large scale.	New technologies, especially those associated with inherent dangers, are met with public skepticism. Opportunity for positive public experience with these systems (e.g., through public demonstrations) can help facilitate public acceptance.	All RSCs	3.2.3.5
CF-3	Commercial AHS applications can perhaps demonstrate AHS safety and reliability prior to widespread use by the public.	The use of commercial flight was first applied to moving goods (i.e., the mail) prior to moving people. This served to demonstrate the safety of air travel and helped attract passengers when passenger service became available. AHS may also benefit from an implementation strategy that first demonstrates viability and safety in the commercial (and perhaps transit) sector prior to marketing for individual use. This will require definable benefits to the commercial interests.	All RSCs	3.2.3.5
CF-4	Obvious fail-safe AHS features will help sell AHS to a potentially wary public.	The airlines were successful in attracting passengers to an inherently dangerous travel mode (flight) by making safety features obvious (e.g., multiple engines). AHS can also help demonstrate safety and gain public acceptance through obvious integration of safety features (e.g., visible roadway infrastructure, design redundancy).	All RSCs	3.2.3.5
CF-5	Aggressive marketing and innovative pricing strategies can be applied to stimulate the AHS market.	As with any competitive market, aggressive campaigns to promote benefits and safety, together with pricing approaches that appeal to target market segments, can help build a user base that is sufficient for market success. This approach has been applied successfully in the area of commercial flight. All benefits should be identified and communicated (e.g., benefits to national defense).	All RSCs	3.2.3.5

Table 62. Summary and Conclusions for Commercial Flight (continued)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
CF-6	Public pressure for AHS expansion will grow in response to the significance of the benefits provided.	The benefits air travel provided to communities led to community-based pressure to have publicly funded airports built. If AHS can offer valued benefits to travelers public pressure for its expansion can also be expected to follow.	All RSCs	3.2.3.5
CF-7	AHS will benefit from support and endorsement received from respected social and political leaders.	As with most competitive products, the marketing of AHS benefits can be enhanced through endorsements from influential political, community, and social leaders.	All RSCs	3.2.3.5
CF-8	As AHS evolves and expands problems encountered must be dealt with forthrightly.	• There will be problems experienced as AHS evolves and expands. Hopefully, by developing AHS in an evolutionary step-by-step fashion these will be manageable and even relatively minor in nature. Any problems encountered must be adequately dealt with and overcome to ensure continued success. Failure to do so could negatively impact AHS public support. • AHS improvements need to be test marketed and thoroughly tested.	All RSCs	3.2.3.5
CF-9	AHS standards will be required nationally and internationally to allow interoperability .	The worldwide growth of commercial flight required international standards. While AHS is better able to operate on a local level, standards will facilitate AHS market growth because vehicles will not require special adaptations and will not be restricted to regional AHS operation.	All RSCs	3.2.3.5
CF-10	A competitive marketplace for AHS can enhance AHS evolution and improvements.	The benefits of competitive markets to product improvements almost need not be mentioned in our society. However, its importance to the potential success of AHS is sufficient to warrant clear statement of this well accepted fact.	All RSCs	3.2.3.5

Table 63. Summary and Conclusions for SST

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
SST-1	High level political support can get a program started, but ongoing support is needed to keep it on track.	The SST was started as a result of support from President John Kennedy but lost favor in subsequent administrations. The SST was terminated when problems arose. Political support was not strong enough to maintain funding. AHS will also require continued political and financial support.	All RSCs	3.2.3.6
SST-2	AHS impact on the environment can affect public and political support.	Concern about environmental impacts from the SST (e.g., noise, ozone depletion) were important factors in its ultimate demise. Environmental groups lobbied hard against the SST. Environmental impacts of AHS must be carefully assessed. These need to be identified and (if negative) dealt with up-front. If not, they could hurt the project later.	All RSCs	3.2.3.6
SST-3	Financial support from private industry may help reassure the Federal Government about the viability of AHS.	Continued funding for the SST was maintained for a while after initial opposition in part because financial support was provided by the airlines. Commitment to AHS from private industry will help build political support within the Government.	All RSCs	3.2.3.6
SST-4	Plan for schedule contingency. Time will be needed to deal with unforeseen technical problems.	Problems with the initial SST design required redesign. This necessitated schedule slippage. AHS development plans should consider the possibility of schedule slippage, and have contingency plans ready.	All RSCs	3.2.3.6
SST-5	AHS should be designed to be as compatible as possible with existing systems.	The SST was designed to use existing airport and maintenance facilities. AHS will also benefit if it is designed for compatibility with existing infrastructure (e.g., can use existing roadway maintenance equipment, existing cars can be retrofitted, etc.).	All RSCs	3.2.3.6
SST-6	AHS must offer benefits that are considered to be worth the additional cost to potential users.	The Concorde (the British/French developed SST) has been a financial failure due to its high operating costs. AHS costs need to be competitive with alternative travel modes.	All RSCs	3.2.3.6

Table 64. Summary and Conclusions for Planning Mass Transit

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
MT-1	Define AHS market to support network design.	Planning for mass transit projects begins with market analysis. This drives requirements definition and quantification of initial, operating and maintenance costs. AHS should also carefully define user market.	All RSCs	3.2.3.7.3
MT-2	Include the public and politicians in AHS planning.	Planning for mass transit benefits from ongoing involvement from the public and Government leaders. Similar coalitions will also benefit AHS development.	All RSCs	3.2.3.7.3

Table 65. Summary and Conclusions for Elevators

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
EL-1	Good ideas sometimes take time to perfect.	Human and animal powered elevators have been in use since ancient Egypt, but because of safety concerns were most often used for hauling freight. Today they are the safest form of transportation used for moving people (1 accident per 65,000,000 miles traveled).	All RSCs	3.2.3.8.3
EL-2	Concerns for safety can create reluctance to accept AHS.	Until the elevator was made safe in 1852 it was used primarily for moving freight. With the invention of the safety elevator, it became an important tool for moving people. Demonstration of AHS safety will also be required to ensure public acceptance.	All RSCs	3.2.3.8.3
EL-3	The AHS design criteria should include the capability for expansion and improvement.	The elevator has experienced many technological improvements accomplished over many years. The ability to implement improvements to AHS technology should also be achievable and supported by the AHS design. In addition, AHS design should support system expansion (i.e., adding mileage to the AHS network and adding capability to handle increased demand).	All RSCs	3.2.3.8.3

Table 65. Summary and Conclusions for Elevators (continued)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
EL-4	AHS can potentially impact land use patterns and property values.	When the elevator was made safe and used for people movement, buildings were built taller and rent on higher floors was made the highest (previously, rents on lower floors were the highest). AHS can potentially lead to increased property values in communities further away from urban centers and stimulate development in these more remote areas.	All RSCs	3.2.3.8.3
EL-5	The AHS community should consider the development of a safety code to guide development of AHS products.	An elevator safety code developed by the American Society of Mechanical Engineers (updated every 3 years) serves as guidance for elevator developers. A safety code to guide the development and evolution of AHS products could facilitate AHS growth while ensuring ongoing safety.	All RSCs	3.2.3.8.3

Table 66. Summary and Conclusions for Denver International Airport

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
DIA-1	Develop realistic schedules for system development and allow for contingencies.	Schedule slippage can cause and exacerbate budget overruns (as has been the case with DIA). AHS must carefully plan schedules and budgets to ensure they are realistic and achievable. Allowance for contingency should also be made.	All RSCs	3.2.3.9.3
DIA-2	Make sure the system is reliable and fully functional before public demonstrations are held.	If AHS is demonstrated before all problems have been worked out, failures and mishaps can occur causing negative public perceptions which are often difficult to overcome. Dry run demonstrations can be conducted to identify problems before public demonstrations are held.	All RSCs	3.2.3.9.3
DIA-3	An evolutionary development approach can help avoid cost and schedule problems	Incremental development allows systems to be tested and sold as you go along.	All RSCs	3.2.3.9.3

Table 67. Summary and Conclusions for Office Automation

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
OA-1	Issues of how AHS looks can impact public acceptance.	The appearance of early typwriters are thought to have been a factor in their poor public acceptance. It is certainly true that appearances can affect perceptions of desirability and usability of products in general. AHS designers should consider the affect of AHS design on public reaction.	All RSCs	3.2.4.1.3
OA-2	Strong advocacy for AHS will facilitate public acceptance and success.	The typewriter was poorly received when first introduced. The persistance of the typewriter's most ardent supporter ultimately led to its success. Advocacy for AHS should be sought.	All RSCs	3.2.4.1.3
OA-3	The impact of AHS on driving and social norms should be considered.	The typewriter met with strong, unforeseen resistance because of the etiquette associated with handwritten communication. AHS designers should look for hidden social factors that could create opposition.	All RSCs	3.2.4.1.3
OA-4	Market sucess of AHS will be affected by prevailing economic conditions.	The reccession in the mid 1870s affected the success of typewriters being introduced at that time. AHS developers should consider the possible effects of changing economic conditions and plan accordingly.	All RSCs	3.2.4.1.3
OA-5	Consider all potential AHS markets.	The typewriter was initially marketed to clergy and writers. Only after the business community was included in sales efforts did the typewriter succeed. AHS should not overlook potential markets (e.g., consider commercial highway users as well as the general motoring public).	All RSCs	3.2.4.1.3
OA-6	AHS may produce significant changes in the way we use our national highways.	The typewriter, a very new idea at the time, had very profound affects on the business community and society in general. AHS may also have a profound affect on the way we use our highways. These may be difficult to predict, but attempts to anticipate changes resulting from successful implementation of AHS should be made and planned for.	All RSCs	3.2.4.1.3
OA-7	If AHS is expensive its market may be limited to high volume users (e.g., commercial trucking) unless innovative pricing approaches are used.	Early forms of document reproduction were very expensive and were limited to large institutions. The cost of using AHS can have a similar affect on market potential. The original Xerox machine overcame market limitations due to high price through a leasing approach. AHS developers should consider a leasing approach to gain market penetration if initial costs are high.	All RSCs	3.2.4.1.3

Table 67. Summary and Conclusions for Office Automation (continued)

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
OA-8	As AHS markets are developed, and AHS evolves, provisions for accomodating earlier users must be considered.	The personal computer industry has been successful in building their market base by introducing new products that are downward compatible with previous software. AHS will also need to evolve in a way that continues to serve previous users.	All RSCs	3.2.4.1.3
OA-9	An evolutionary approach to AHS development will help lower the apprehension of initial users.	There will be some apprehension about initially using AHS as there has been with the introduction of other new technologies (e.g., personal computers in the office). Gradual approaches to AHS introduction can help reduce this apprehension.	All RSCs	3.2.4.1.3
OA-10	Make AHS benefits obvious.	Demand for AHS will be facilitated if the benefits provided are clear and significant as has been the case with office automation.	All RSCs	3.2.4.1.3

Table 68. Summary and Conclusions for Foot Race Finishes

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
FR-1	AHS exit efficiency will be critical for handling high AHS flow rates.	If traffic exiting the AHS is not handled efficiently vehicles could back-up into the AHS lanes (or require closing the exit). An efficient process for accomplishing check-out and exit will be required.	All RSCs	3.2.4.2.3
FR-2	Multiple parallel exits can be considered for high demand AHS exits.	A multiple parallel exit configuration (or buffer area) can be considered for exits where check-out demands exceed processing capacity. This (more expensive) approach can be considered for special exits with high demand (e.g., near activitiy centers and CBD areas). This approach has been applied successfully at foot race finishes.	All RSCs	3.2.4.2.3
FR-3	The process of vehicle check-in or check-out can be made faster if time demanding tests are conducted ahead of time and the results are simply read.	Vehicle and driver testing can be accomplished just prior to check-in or check-out and the results recorded on computer storage medium. These results can be read as the car crosses the check-in/check-out point. This approach can be considered if tests take too long to accomplish at check-in/check-out. Items such as vehicle inspection can also be handled using this approach.	All RSCs	3.2.4.2.3

Table 69. Summary and Conclusions for Domestic Appliances

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
DA-1	Consider all potential markets for AHS. A large market base will allow more competitive pricing strategies.	Electricity prices were greatly reduced when the market was expanded to include private homes. This experience was repeated in the VCR industry. Similarly, lower, more competitive prices for AHS services will be achievable as infrastructure costs are spread over a larger base. With lower more competitive prices it will be possible to further expand the AHS market, and perhaps, even further reduce costs.	All RSCs	3.2.4.3.3
DA-2	Make AHS benefits obvious and emphasize these benefits in marketing.	The benefits derived from electric appliances, when first introduced, were emphasized in advertising campaigns with positive results (for consumers and sellers alike). AHS must also provide obvious benefits (e.g., to safety, convenience, etc.) and these must be communicated to potential users.	All RSCs	3.2.4.3.3
DA-3	U.S. industry will be more willing to support AHS if short-term profits are possible.	U.S. industry will be more willing to invest in AHS products and technology if there is a possibility for sales in the short-term. Investments for long-term payoff carry more risk and are more difficult to realize. This has been the experience of the electronics industry. An evolutionary approach to AHS implementation will help make short-term sales more possible and facilitate private investment.	All RSCs	3.2.4.3.3
DA-3	Innovations and breakthroughs are sometimes achieved when new ways of looking at problems are applied.	Consider all possible approaches to achieving AHS goals before finalizing on one design approach. Even ideas that initially sound radical should not be dismissed out of hand. This has led to successful innovations in other industries.	All RSCs	3.2.4.3.3
DA-4	Consider providing incentives for people to upgrade their equipment as AHS evolves.	Upgrades to AHS that requires people to invest in equipment upgrades should provide clear benefits over previous equipment. Special prices for those upgrading or the acceptance of trade-ins can also be considered to help motivate people to upgrade their equipment.	All RSCs	3.2.4.3.3
DA-5	Standardization across AHS implementation will facilitate market development.	When systems are standard across all implementations, manufacturers can produce one product for a larger market. This helps market development.	All RSCs	3.2.4.3.3

Table 70. Summary and Conclusions for Automated Teller Machines

Issue No.	Issue/Risk Descriptive Title	Description/ Recommendation	RSC Impact	Where Dis-cussed
ATM-1	An initial, small scale implementation of AHS can serve to demonstrate AHS benefits and potentially lead to market-driven expansion.	The benefits of automated teller machines (ATMs) were first demonstrated with a very limited demonstration by a single bank. Dramatic market-driven improvements and growth followed. An evolutionary approach to AHS development is also recommended. Initial AHS implementations and/or demonstrations can demonstrate benefits and stimulate further evolution and growth.	All RSCs	3.2.4.4.3
ATM-2	Consider all potential markets for AHS.	AHS competitiveness will be enhanced with a large potential market. AHS should not overlook potential market segments.	All RSCs	3.2.4.4.3
ATM-3	Work out the bugs and understand customer needs before final implementation.	It will not be possible to determine all customer needs and to work out all AHS bugs during design. AHS demonstrations and initial implementations should be used to understand market requirements and to make sure that all problems are eliminated. This approach was used very successfully in the development of ATMs.	All RSCs	3.2.4.4.3
ATM-4	The perception of safety will be important in attracting AHS users.	Acceptance of new technology that carries potential risks (like AHS) will be facilitated if safety features are included and made obvious. Locating ATMs in protected enclosures and well lighted and populated areas helped to facilitate their public acceptance.	All RSCs	3.2.4.4.3
ATM-5	Cooperative consortium approaches to design and development should be considered for AHS.	The development of large scale integrated ATMs was achieved through cooperative multi-bank ventures. Start-up costs were shared and compatible approaches to integration were developed with this approach. A similar cooperative approach can be applied to benefit the development of AHS.	All RSCs	3.2.4.4.3
ATM-6	Consider the requirements of special user groups.	There may be unique requirements for accommodating particular user population groups. These may include requirements for accommodating handicapped individuals or non-English speakers. AHS must not overlook these requirements.	All RSCs	3.2.4.4.3
ATM-7	AHS design should consider personal privacy issues.	There may be concerns raised about AHS regarding its intrusion on personal privacy; and particularly the right to free, unmonitored movement. If AHS tracks and records the movement of individual vehicles, there could be individuals or groups who object on this basis. AHS designers should attempt to avoid design approaches that raise these concerns.	All RSCs	3.2.4.4.3

4.2 INTEGRATED CONCLUSIONS

Table 71 lists major issues, risks, and recommendations synthesized across all comparable systems. The specific comparable systems from which each issue was identified is noted.

Table 71. Table of Integrated Conclusions

	Issue, Risk, Concern, and Recommendations	Supporting Comparable Systems Studied	Detailed Issues
1	The public must perceive overall benefits of AHS. Approach AHS design and deployment in ways that will make these benefits obvious. This can lead to public acceptance and pressure for AHS expansion providing cost is reasonable. Demonstration of benefits can also help secure Government financial support.	• HOVs • Ramp Metering • Interstate Highway System • Aircraft Automation • Railroad • Commercial Flight • SST • Office Automation • Domestic Appliances • ATM	HOV-4 RM-6 IHS-2 AA-1 RR-3 CF-6 SST-6 OA-10 DA-2 ATM-1
2	The safety and reliability of AHS must be clearly demonstrated. Demonstration of AHS safety will be required before public acceptance can be ensured and successful commercial deployment made possible. Safety or reliability problems, especially those experienced in a sensational manner, can greatly hinder the potential for success. Make safety features obvious. Consider design redundancy and human back-up approaches to ensuring reliability.	• ETTMs • Automobile History • Automated Guideway Transt • Aircraft Automation • Commercial Flight • Elevators • Denver International Airport • Automated Teller Machines	ETTM-4 AH-5 AGT-4 AA-2 AA-6 AA-7 CF-1 CF-3 CF-4 EL-2 EL-5 DIA-2 ATM-4
3	Secure long-term and continuous financial support. Funding must be sufficient, specific to the goals of AHS, and continuous. Pay-as-you-go financing is preferable to borrowing. Financial support from private industry may help reassure the Federal Government about AHS viability.	• Interstate Highway System • Automated Guideway Transit • Railroad (Interurbans, Maglev) • Supersonic Transport (SST)	IHS-1 IHS-3 AGT-6 RR-6 SST-3
4	Support from influential persons in Government and industry is important for large programs. The success of innovative, infrastructure-intensive projects is greatly enhanced by high level support from influential persons in Government and industry. Without high level support, projects like AHS are likely to suffer failures. Lacking persons in high office, lower level persons who are persistent and convincing can make a difference.	• Interstate Highway System • Automated Guideway Transit • Railroad (Maglev) • Commercial Flight • Supersonic Transport (SST) • Office Automation (typewriter)	IHS-6 AGT-1 RR-6 CF-7 SST-1 OA-2

Table 71. Table of Integrated Conclusions (continued)

	Issue, Risk, Concern, and Recommendations	Supporting Comparable Systems Studied	Detailed Issues
5	Evolutionary development of AHS is recommended. Evolutionary deployment will provide for incremental development, allow safety and reliability to be demonstrated on a small scale before system level integration is attempted, and provide a gradual approach to achieving public acceptance. This will also allow alternative technologies and design alternatives to be compared, and the best selected. U.S. industry will be more willing to invest if short-term profits are possible. If evolution proceeds from I1 to I2 and I3, the reduced workload in I2 and I3 may produce natural evolutionary market forces.	• HOV lanes • Interstate Highway System • Automobile History • Automated Guideway Transit • Air Traffic Control • Railroads • Office Automation • Domestic Appliances • Automated Teller Machines • Highway Tunnels (The Chunnel) • Commercial flight • Elevators	HOV-2 IHS-7 AH-5 AH-6 AH-10 AGT-7 AGT-9 ATC-3 RR-2 OA-9 DA-3 DA-4 ATM-1 HT-5 CF-2 CF-3 CF-6 CF-8 CF-10 EL-3
6	AHS must be designed for integration within the overall transportation system in the United States and worldwide. The AHS market should be defined in relation to other transportation forms. The AHS network and design should be developed on the basis of this definition. AHS objectives should be clearly defined within this context. Further, AHS components should be standardized for all AHS applications, and should be as compatible as possible with existing conventions.	• HOV lanes • Ramp metering • Interstate Highway System • Automated Group Transit • Railroads • Commercial Flight • Supersonic Transport (SST) • Planning Mass Transit • Domestic appliances	HOV-5 RM-2 IHS-5 AGT-3 RR-1 CF-9 SST-5 MT-1 DA-5
7	Cost and time estimates for developing AHS must be carefully and accurately determined. System design, testing, and implementation must remain within budgetary guidelines and time constraints for the project. Serious budget overruns or schedule slippage can lead to negative publicity and poor public acceptance of the system. Also plan for schedule and cost contingencies. Despite good planning unforeseen technical problems will need to be dealt with.	• Automated Group Transit • Railroads (maglev) • Supersonic Transport (SST) • Denver International Airport • Highway Tunnels (The Chunnel)	AGT-2 RR-8 RR-11 SST-4 DIA-1 HT-5

Table 71. Table of Integrated Conclusions (continued)

	Issue, Risk, Concern, and Recommendations	Supporting Comparable Systems Studied	Detailed Issues
8	Consortiums of private and public agencies can facilitate AHS successful development. A consortium of public and private agencies and organizations can help to ensure the long-term success of AHS research, development, and implementation. Requirements that meet common goals can be identified and achieved.	• Railroads • Commercial flight • Automated teller machines	RR-1 CF-9 ATM-5
9	Community outreach and public involvement will be important to AHS success. It is wise to keep the general public educated and informed throughout the AHS planning, design, and development phases. AHS developers and promoters should build coalitions with opposition groups (or counter negative arguments), and must deal forthrightly with public concerns. If problems are encountered they should be dealt with forthrightly and openly. Environmental concerns will be important considerations.	• Ramp metering • Interstate Highway System • Electronic Toll and Traffic Management • Automobile History • Railroads • Commercial Flight • Supersonic Transport (SST) • Planning Mass Transit • Cruise Control, ABS Brakes, and Air Bags: Liability Issues	RM-5 RM-8 IHS-4 ETTM-6 AH-1 AH-8 RR-5 CF-8 SST-2 MT-2 LI-2
10	AHS may produce significant changes in society that may be difficult to predict. AHS may significantly impact the way our highways and land are used and even to societal norms, but the full impact of the changes is difficult to predict.	• Automobile History • Railroads (Interurbans) • Elevator • Office Automation (typewriter) • Domestic Appliances	AH-9 RR-10 EL-4 OA-6 DA-4
11	Do not overlook potential markets for AHS. The wider the potential market-base, the easier it will be to gain widespread acceptance of the new technology. This may also help to keep AHS operation costs low and motivate support from private industry.	• Interstate highway System • Electronic Toll and Traffic management • Automobile History • Automated Group Transit • Railroads • Office Automation (typewriter) • Mass Transit • Domestic Appliances • Automated Teller Machines	IHS-2 ETTM-2 AH-10 AH-11 AGT-10 RR-8 OA-5 MT-1 DA-1 ATM-2
12	A large return from AHS can be achieved with transit vehicles and HOVs. AHS when combined with transit and/or HOV treatments can provide very significant improvements to our highway's people moving capacity. This can be achieved through encouragement (e.g., through AHS pricing strategies) or requirement for HOV/transit use. These applications will be limited to urban centers or corridors.	• HOV lanes • Electronic Toll and Traffic Management	HOV-1 ETTM-3

Table 71. Table of Integrated Conclusions (continued)

	Issue, Risk, Concern, and Recommendations	Supporting Comparable Systems Studied	Detailed Issues
13	AHS design insights and technology foundations can be found through the study of many comparable systems. No single comparable system can provide guidance across all AHS design aspects, but many comparable systems have been found that can provide insight and potential technology to support AHS design.	• HOV Lanes • Ramp Metering • Highway Tunnels • Electronic Toll and Traffic Management • Automated Guideway Transit • Foot Races	HOV-3 RM-1 RM-2 RM-3 RM-4 RM-5 RM-7 HT-1 HT-2 HT-3 ETTM-1 AGT-8 FR-1 FR-2 FR-3
14	AHS will face liability issues. These should be anticipated and plans made to avoid or overcome legal challenges. Legal consultation should be sought, as needed. Design and programmatic approaches to limiting liability exposure should be applied.	• Cruise control, ABS Brakes, and Air Bags: Liability Issues	LI-1 LI-2 LI-3
15	AHS should be designed with maintenance and system upgrade in mind. It should be possible to accomplish maintenance functions without disrupting use patterns. It should also be possible to accomplish system upgrades and expansion with only minimal disruptions. One design consideration related to system upgrades is that it should be possible to accommodate earlier AHS users after upgrades are made.	• Automobile History • Automated Group Transit • Air Traffic Control • Elevators • Office Automation	AH-2 AGT-5 ATC-5 EL-3 OA-8
16	Public acceptance will be critical for AHS success. Many factors contribute to public acceptance. Important factors include: cost relative to other modes, convenience and ease of use, match to origins and destinations, obviousness of fail-safe features, and impact on pollution. It will be important to pay attention to public relations and privacy issues. Consideration of needs of special user groups is also important (e.g., non-English speakers). The perceived impact of AHS on job security can also impact acceptance for commercial AHS applications. Finally, even the general appearance of AHS can be a factor in AHS public acceptance.	• Electronic Toll and Traffic Management • Automobile History • Aircraft Automation • The Bicycle Railroad • Commercial Flight • Supersonic Transport (SST) • Office Automation • Automated Teller Machines	ETTM-5 ETTM-7 AH-3 AH-4 AH-7 AA-3 AA-5 RR-7 CF-4 SST-2 OA-1 OA-3 ATM-6 ATM-7

Table 71. Table of Integrated Conclusions (continued)

	Issue, Risk, Concern, and Recommendations	Supporting Comparable Systems Studied	Detailed Issues
17	The degree of centralized control and human decision making will slow system response. The degree of centralized control can slow or reduce the ability to respond to local conditions. This could affect spacing and flow achievable. Control approaches selected should consider the effect on spacing and flow. Information sent to the driver should be clear and unambiguous.	• Air Traffic Control	ATC-1 ATC-2
18	AHS exit efficiency will be critical for handling high AHS flow rates. Bottlenecks can be created at popular exits if the exits cannot handle traffic demand. This would require closing the exit to avoid vehicles from backing-up onto the AHS lane. Approaches to mitigating this problem include pro-active planning (e.g., groups of exits in a popular area put under system control and optimally managed to avoid peak variations), and the use of multiple parallel exits or buffer zones.	• Air Traffic Control • Foot Race Finishes	ATC-4 FR-1 FR-2
19	AHS marketability will be influenced by design and economic factors. AHS design and pricing approaches can affect market base. Innovative approaches to AHS pricing and sales approach can increase the potential market achievable (e.g., lease vs. buy, piggybacking on other markets). Prevailing economic conditions and the degree of competition within the AHS industry will also have an affect.	• Electronic Toll and Traffic management • Air Traffic Control • Commercial Flight • Office Automation • Domestic Appliances • Highway Tunnels	ETTM-2 ETTM-3 ATC-6 CF-5 CF-10 OA-4 OA-7 DA-4 HT-4
20	There may be regions that favor AHS implementation over others. There may be regions in which conditions and/or economics favor AHS, while other areas are less favorable. This could determine optimal demonstration sites and guide the implementation strategy. However, this could limit political support and even create opposition from areas that are not served.	• Railroads	RR-4

APPENDIX A LITERATURE REVIEW RESULTS

"A Policy on Geometric Design of Highways and Streets", American Association of State Highway and Transportation Officials, 1990.

Summary: A book intended to give guidance in the design and planning of highways.

"Automated Guideway Transit: An Assessment of PRT and Other New Systems", Office of Technology Assessment, PB 244-854, 1975.

Summary: This study is a comprehensive assessment of automated transit technology, both in the U.S. and abroad, including the potential for new systems in U.S. cities. The report is designed to provide the Congress with information needed to make informed decisions on the Federal role in new transportation systems research and development.

Supporting materials include research on the economics, social acceptability, and the operations and technology of fully automated, fixed guideway systems. Both personal rapid transit (PRT) and group rapid transit (GRT) systems are discussed.

The assessment was performed by the Office of Technology Assessment in response to a request from the Transportation Subcommittee on Appropriations, U.S. Senate.

(Included in the AHS File are selected sections of this report. The entire report is on Microfilm.)

"Cabinentaxi: A Personal Public Transport System", Transportation 1(3), pp. 321-329, 1972.

Summary: This article gives a brief overview of the Cabintaxi system, a German built PRT system.

"Denver Airport Opening Delayed Until December", Aviation Week and Space Technology, pp. 39., May 10, 1993.

Summary: News brief - the opening of the Denver International Airport will be delayed two months until Dec. 19 to allow for a seven week debugging of hundreds of systems in the $2.7-billion facility.

"Denver's Flying Baggage", New York Times, p. A26, May 5, 1994.

Summary: This ais an editorial about the Denver International Airport. It discusses the problems that the aiirport has encountered in the last year.

"Denver International Airport", Aviation Week and Space Technology, 134, pp. S1-S18, April 1, 1991.

Summary: This article describes the plans for the new Denver Airport. It describes he airport, as well as the financing plans, and overall of the new airport.It also descibes of the contractors working on the project, and the responsibilities assigned to each of them.

"Fall Guy", Inventive Genius, p. 86, 1991.

Summary: This article describes the development of Otis' safety elevator, and the introduction of the new device to the public.

"Financing Poses Unprecedented Challenge", Aviation Week and Space Technology, pp. 61-67., January 5, 1970.

Summary: This article discusses the problems encountered in obtaining funding for the US SST program. Possible funding sources include the airline manufacturers, the airlines, the government, and private financing. This article discusses why government funding for the program is probable, and various government financing alternatives available.

"Impact of Advanced Group Rapid Transit Technology", Office of Technology Assessment, Congress of the United States, OTA-T-106, January, 1980.

Summary: This report describes the advanced group rapid transit (AGRT) development program in the United States. It discusses the potential impacts of AGRT in the light of urban transportation needs and currently available transit options. Alternative patterns of Government/industry relations are explored, with particular attention paid to practices in Europe and Japan. Also included are several options for future AGT development, including a range of costs for each approach.

"Magnetic-Levitation Trains", The Economist , October 13, 1990.

Summary: This article contains a brief discussion on the OMB cancellation of maglev funding in 1975.

"Market Outlook Hinges on Concorde Sales", Aviation Week and Space Technology, pp. 51-58., January 5, 1970.

Summary: This article discusses the influence of the viability of foreign supersonic planes on future sales of the American SST. It describes factors that may influence the success of the SST. It also includes cost comparisons between the SST and existing subsonic jets, and results of Boeing's market analysis, predicting what happens when the US SST enters the market.

"New Denver Airport To Open Next March", Aviation Week and Space Technology, pp. 27., November 1, 1993.

Summary: News brief - opening day for the Denver International Airport has been delayed to March from December, 1993, as previously planned, to allow completion of construction and adequate training time for airline personnel.

"People Mover Profile", Urban Mass Transportation Administration, UMTA-MA-06-0081-77-1, 1977.

Summary: As part of its ongoing commitment to the concept of technology sharing, the U.S. Department of Transportation has initiated a series of publications on transportation topics which focus on a variety of subject areas. This report is part of such a series. People Mover Profile acquaints readers with the subject of people movers in conjunction with UMTA's Downtown People Mover (DPM) Project. The project's aim is to demonstrate the benefits of fully automated people mover systems in downtown urban areas. To date, people movers, installed in controlled environments such as airports and recreation parks, have demonstrated that they are proven operational systems. The DPM Project will demonstrate the feasibility of installing a people mover system in the harsher and more demanding environment of downtown urban areas.

This profile report is divided into three sections. The first, a narrative overview, briefly discusses the subject of people movers. The second section consists of detailed technical data and photographs of manufacturers and suppliers of existing people mover systems. The third section, the supplementary material, contains a glossary of terms used in this document in addition to the aforementioned UMTA DPM Project material. Technical data in this profile report were obtained from the people mover manufacturers and suppliers who are responsible for its accuracy.

"Report Points to Potential of Maglev Trains for United States", PR Newswire, November 2, 1993.

Summary: This article details recent government actions in support of maglev technology.

"Savings for Maglev Trains", Federal Technology Report (p.15), May 13,1993.

Summary: This article reveals that researchers in Argonne National Laboratory have found a way to cut maglev costs considerably through the simplification of guideway construction.

"SST Noise Critical to Airport Compatibility", Aviation Week and Space Technology, pp. 83-84., January 5, 1970.

Summary: This article discusses how excessive noise will be a problem for any supersonic plane. It discusses the sources of the noise problems, and various methods that could be used to reduce the noise.

Aerospace Corporation, "Personal Rapid Transit Research Conducted at the Aerospace Corporation", Aerospace Corporation, PB 256-846/AS, March, 1976.

Summary: This report summarizes extensive PRT system designs and studies done at the Aerospace Corporation in the early to mid 1970s.

Alden Self Transit Corporation, "Analysis of Short Ramps for Dual-Mode and PRT Stations", PB 272-351/AS, 1977.

Allen, Frederick, "The Letter that Changed the Way We Fly", American Heritage of Invention and Technology 4(2), pp.6-13, Fall, 1988.

Summary: This article presents the history of the earliest modern airplanes. It explains the impetus that led to the production of a line of planes that represented a “culmination of everything before them, and a breakthrough to the future.” These planes, the Douglas DC-1, DC-2, and DC-3, when first introduced made everything else in the sky obsolete, and brought commercial air travel to maturity. The new planes were safer, faster, had a greater passenger and freight capacity, were more comfortable and less expensive to operate than anything built previously.

Anderson, J. Edward, "PRT: It's A Car...It's A Train...It's PRT", Environment 16(3), pp. 6-11., April, 1974.

Summary: This paper explains the concept of personal rapid transit. It discusses automatic controls, safety and reliability, operations of large fleets, personal security, visual impact, economics, implications for society, impact on economy, and implementation.

Anderson, J. Edward, et al, (editors), "Personal Rapid Transit II: Progress, Problems, Potential", University of Minnesota, 1974.

Summary: This book is a collection of articles which were presented at the 1973 International Conference on Personal Rapid Transit. Topics for papers included are: Government Programs, Systems Presentations, Planning in Specific Cities, The Design of PRT Planning Studies, Implementation, Safe Headway and Control, Operations, System Concepts, Dual mode and Estimation of Modal Choice, and Design Aspects. Each topic area is presented as a separate section in the book, and each section begins with a short summary of all papers in that section.

Anderson, J.E., "Transit System's Theory", Lexington Books, 1978.

Summary: This is a classic book compiling some of the fundamental analyses of PRT by the greatest of the PRT enthusiasts, J. Edward Anderson.

Anderson, J.E., "Life-Cycle Costs and Reliability Allocation in Automated Transit Systems", High Speed Ground Transportation Journal 2(1), 1977.

Anderson, J.E., et al. (editors), "Personal Rapid Transit", University of Minnesota, 1972.

Summary: This book contains the proceedings of the first international conference on Personal Rapid Transit.

Andrews, Peter, "Lighter Than Air", American Heritage of Invention and Technology 9(1), pp. 9-22, Summer, 1993.

Summary: This article traces the development of lighter-than-air ships, including the introduction of manned balloon flight and maneuverable airships. Airship use in Germany and Britain is discussed, with emphasis on airship use and development in the United States. Also discussed are the problems with lighter-than-air ships, and the eventual elimination of airships from US military service.

Applied Physics Lab/JHU, "A State-Constrained Approach to Vehicle Follow Control for Short-Headway AGT Systems: Final Report", PB 272-239/AS, 1977.

Applied Physics Lab/JHU, "Point-Follower Automatic Vehicle Control: A Generic Analysis", PB 270-354, 1977.

Ardema, Mark, "Airships", McGraw Hill Encyclopedia of Science and Technology, Volume 1, 5th Edition, pp. 300-304, 1982.

Summary: This article is an encyclopedia entry which provides an overview of the history of airships, as well as possible future uses of airships.

Arnstein, K. and Ross, R.S., "Airships", McGraw Hill Encyclopedia of Science and Technology, Volume 1, 4th Edition, pp. 248-248D, 1977.

Summary: This article is an encyclopedia entry which provides an overview of the lift, hull, and aerodynamic characteristics, as well as ground handling techniques and typical uses of airships.

Aronson, Robert, "Someday We Might Be Able To Get There From Here", Machine Design, pp. 20-30., June 10, 1971.

Summary: This article discusses new concepts in transportation, including: bus-only lanes, dial-a-bus, light rail rapid transit, subways, heavy rail, people movers, and other new technologies.

Baker, Les, "Wake Up to Maglev Before It’s In Place", Travel Weekly , October 8, 1991.

Summary: This article offers suggestions for the implementation of maglev, including the recommendation that maglev systems be standardized.

Barlay, Stephen, "The Final Call: Why Airline Disasters Continue to Happen", Pantheon Books, 1990.

Summary: “There are no new types of air crashes - only people with short memories. Every accident has its own forerunners, and every one happens either because somebody did not know where to draw the vital dividing line between the unforeseen and the unforeseeable or because well-meaning people deemed the risk acceptable.

The aim of accident/incident investigation is to identify the causes of mishaps, and make the final call to prevent any repetition. Unfortunately, it is human nature to ignore the inconvenient, and forget lessons. Collective knowledge, embodied in government, ought to be a safeguard against that. It is not.”

This book attempts to explore why airplane accidents/incidents continue to occur, even though statistics tell us that air travel is amazingly safe. It presents the notion that there are now new causes for accidents, and that we must learn from our past mistakes to prevent future accidents.

Batz, Thomas M., "High Occupancy -Vehicle Treatments, Impacts, and Parameters: Procedures and Conclusions", Transportation Research Record 1181..

Summary: This paper discusses 19 specific HOV treatment types that can be implemented. Some of which produced expected impacts, some mixed, and some that produced no effect. Four types of preferences defined the 19 treatment types: economy, convenience, space and time.

Beasley, David, "The Suppression of the Automobile", Greenwood Press, 1988.

Becker, Klaus, "Cabintaxi: Technical Level, Market Situation, and Targets", Personal Rapid Transit III, pp. 69-74., 1975.

Summary: This paper describes the objectives to be carried out in 1976 by the developers of the Cabintaxi urban transport system. It describes the testing circuit to be established, and the types of tests to be performed on the system. Also included are market data for the system, as well as an outlook for future implementations of Cabintaxi.

Berger, Michael L., "The Devil Wagon in God;s Country", Archon Books, 1979.

Black, Ian, et al., "Advanced Urban Transport", Saxton House, 1975.

Summary: This book examines the role automated transport might play in British towns and cities. The authors have attempted to maintain a balance between a consideration of the new technology and an appraisal of its economic and environmental features. Concentration is on transport in the

United Kingdom, however they may be limited extrapolation to the rest of the world. Chapters of the book address the following issues: the forms of public transport that exist today, and the constraints on their development; a review of automated transit; technical details of vehicles, tracks, control techniques and stations; economic and environmental assessments, and the role of government policy in the development of automated transit.

Boeing Aerospace, "Morgantown PRT O&M Phase Operating, Availability and Maintenance History", PB 266-994/AS, 1977.

Bondada, Murthy V.A., et al., "Automated People Movers II: New Links for Land Use--APM Opportunities for Major Activity Centers", American Society of Civil Engineers, 1989.

Summary: This book is a compilation of papers that were presented at a conference in 1989. Included are papers on various topic areas, including: an overview of the APM field; planning, design and construction; financing and procurement; operations and maintenance; safety and reliability; APMs in other countries; APMs in special applications; Aerial cable people movers; and the Las Colinas APM in Texas.

Brand, Daniel, et al., "Dual Mode Transportation", Transportation Research Board: Special Report No. 170, TRB/SR-170, 1974.

Summary: The organization of this report follows generally the organization of a conference conducted by the Transportation Research Board, May 29-31, 1974. The papers address the analysis and evaluation of dual-mode transportation as a solution to urban transportation requirements.

Brenckmann, M., "Public Acceptance of the STOL Demonstration", Business Aircraft Meeting, April, 1975.

Summary: This article reviews the public reactions before and after the STOL demonstration. The results showed that it is hard to predict public reactions, since people generally generate both positive and negative responses to an issue. Also, providing information to the public generally leads to more positive responses. The study also found that public opinion is significantly affected by the perceived trustworthiness of the authority sponsoring the program, and the belief that the new service (or product) is beneficial.

Brooks, Peter W., "Chapter 17: Aeronautics", A History of Technology Volume 5: The Late Nineteenth Century c1850-c1900, 1958.

Summary: This chapter presents a history of aeronautics in the late 1800's. It discusses the early balloon flights, airships, ornithopters (flapping-wing flying machines) and early heavier-than-air air craft.. The history of flight, leading up to the Wright Brothers' first flight in 1903 is included.

Brown, David A., "Denver Aims for Global Hub Status With New Airport Construction", Aviation Week and Space Technology 134, pp. 42-45, March 11, 1991.

Summary: This article describes the plans for the new Denver International Airport, and explains the rationale behind the three billion dollar program. This article was written soon after work on the airport was begun.

Brown, S.J., "Adaptive Merging Under Car-Follower Control", APL/JHU for Contract DOT-UT-30010, 1976.

Summary: Documentation of various operational concepts used to resolve conflicts arising from merging two streams of vehicles.

Bruce-Briggs, B., "The War Against the Automobile", E.P. Dutton, 1977.

Summary: This book attempts to refute the arguments made against the automobile. It begins with a brief introduction to the evolution of the current automobile-highway transportation system. The author then presents the advantages of the automobile over other transportation systems, and refutes criticisms often attributed to the automobile. He then presents possible solutions to the transportation problem, which do not involve the elimination (or reduction) of the automobile. Instead, he encourages the development and implementation of solutions which benefit automobile owners and operators.

Buel, R.A., "Dead End", Pelican Books, 1973.

Burke, Catherine, "Innovation and Public Policy", Lexington Books, 1979.

Summary: One objective of this book is to present a theoretical framework in which the processes of technological innovation are linked with political processes. Another objective is to review the history and development or current transportation problems, along with possible alternative solutions. This book also presents and analyzes the history of personal rapid transit (PRT). Experiences with PRT at the federal level of government, experiences with PRT in four US cities, and foreign experiences with PRT are examined.

Cabon, Ph., et al., "Human Vigilance in Railway and Long-Haul Flight Operation", Ergonomics 36(9), pp. 1019-1033, 1993.

Summary: " Human operators in transport operations are often confronted with monotony, boredom, and irregular work schedules. This situation has become increasingly more acute because of the growing automation of systems. This paper presents methodology and preliminary results for two field studies on the vigilance of train drivers and long-range air crews. The aim of these studies was to identify factors that can modify vigilance and to elaborate several specific solutions for reactivation. the method is based on the collection of physiological data in the field and on task observation of the operators. the recorded physiological data (EEG, EOG, EKG) permit an evaluation of vigilance and mental workload. The rest-activity cycles are estimated by actometry. The use of EEG and EOG are discussed in relation to monotony and sleep deprivation. For pilots, results show a high occurrence of decreased vigilance, particularly during phases of low workload (i.e., when cruising). Furthermore, it was shown that these periods of lowered vigilance can occur at the same time for two crew members. A great number of incidents of decreased vigilance were also observed for train drivers. These incidents occurred even though the operators sometimes has high levels of activity. A direct relation was also noted between sleep duration and the onset of rest. These studies provide several means for maintaining vigilance during activities and improving the system of work schedule rotation."

Chant, Colin (editor), "Science, Technology and Everyday Life 1870-1950", The Open University, 1989.

Summary: This book deals with the effect of technology on society. The first two chapters raise some general issues in the study of science, technology and everyday life; the intermediate chapters deal with these issues in specific areas of technological; change, including: electrification, materials, transport, communications, food, sanitary reform, and medicine. The final two chapters consider groups of technological innovations and the social changes that they have brought about.

Congressional Budget Office, "Highway Assistance Programs, A Historical Perspective", Congress of the United States, 1978.

Cortes-Cormerer, Nhora, "Will Maglev Ever Get Off the Ground in the US?", Mechanical Engineering , October, 1988.

Summary: "Although the idea of magnetically levitated high-speed transportation originated in this country, development has been stalled for over a decade the U.S. Meanwhile, entrepreneurs have been eyeing foreign for projects in four states.'

Cowan, Ruth Schwartz, "Less Work for Mother?", American Heritage of Invention and Technology 2(3), pp. 57-63, Spring, 1987.

Summary: This article addresses the question of "what has made it possible for more than 70 percent of the wives and mothers in the American population to enter the workforce and stay there?" It examines the effects that the introduction of household technology on the amount of time spent on housework. Results from various studies show that the same amount of time is actually spent on housework today as was spent before the introduction of the new technologies. Included in the article are brief histories of the vacuum cleaner, washing machine, and automobile as they affected housework in American homes. The authors conclude that the introduction of electric appliances have reduced the amount of physical work involved with housework, thus making it feasible for a woman to work full-time and to perform household chores without destroying her health. Also discussed is the significant role of modern medical technology on allowing a woman to work full-time without endangering the health of her children.

Cowan, Ruth Schwartz, "More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave", Basic Books, Inc., 1983.

Summary: This book describes the changes in household work processes (the tasks performed and the interrelationships between the tasks) and in the technological systems (the tools used to perform the tasks) that occurred between 1860 and 1960. The book also discusses the social changes that have occurred because of, or in spite of, the changes in household work.

Crouch, Tom D., "How the Bicycle Took Wing", American Heritage of Invention and Technology 2(1), pp.10-16, Summer, 1986.

Summary: This article describes the Wright brothers recognition of the conceptual links between the bicycle and the first flying machine. It provides an overview of the rise in popularity of the bicycle during the 1890's, and gives a history of the Wright Brothers' involvement in the bicycle industry. from there, the article explains how the bicycle helped to shape the Wright brothers' approach to aircraft design.

Cumbie, Jim, "Airtrans: Problems and Potential", The New Electric Railway Journal 4, Summer, 1989.

Summary: This article discusses the AIrtrans people mover built at Dallas-Fort Worth Airport. It describes the construction of the system, as well as an overview of the operating history of the system.

d'Estaing, Valerie-Anne Giscard, "Elevator", The Second World Almanac Book of Inventions, p. 23, 1986.

Summary: This article provides a brief overview of the history of the elevator. It describes the origin of the elevator, the first mechanical eler, the hydraulic elevator, and the electric elevator.

Davies, Richard O., "The Age of Asphalt: The Automobile, the Freeway, and the Condition of Metropolitan America", J.B. Lippincott Company, 1975.

Summary: This book presents the authors personal interpretation of the sequence of events that produced the contemporary urban transportation crisis in the United States. The book explores the elements that affected the decisions made concerning the interstate highway system.

Part one consists of a narrative and historical essay which identifies the alternatives faced by the decision-makers for the nation's transportation system. The essay describes the choices made by these decision-makers, as well as the reasons why these choices have led to a modern transportation crisis. Part two consists of source documents (including journal articles, speech transcripts, government documents, and other sources) that help to illustrate the issues raised in part one.

Del Valle, Christina and Carey, John, "Will Magnetic Levitation Ever Get Off the Ground", Business Week , January 6, 1992 .

Summary: This article discusses failed maglev proposals, including the Las Vegas-Anaheim maglev fiasco.

Derry T.K., and Williams, Trevor I., "Initiation of the Conquest of the Air", A Short History of Technology: From the Earliest Times to A.D. 1900, pp. 396-402, 1961.

Summary: This chapter describes the evolution of air transportation, beginning with the earliest hot-air balloons. The development of airships, followed by gliders, and fixed-wing planes is provided as a brief overview.

Dick, Harold G. and Robinson, Douglas H., "The Golden Age of the Great Passenger Airships: Graf Zeppelin and Hindenburg", Smithsonian Institution Press, 1985.

Summary: This book presents the history of the German airships, the Graf Zeppelin and the Hindenburg. It provides information about their technologies, their construction, their service and their role in air passenger service.

Diebold, John, "The Innovators: The Discoveries, Inventions, and Breakthroughs of our Time", Truman Talley Books, 1990.

Summary: This book contains narrative histories of innovations that have arisen within organizational structures in recent times. Included in the book are chapters on the history of the automated teller machines (ATMs), the history of the videocassette recorder (VCR)., and the history of xerography. All three chapters discuss the development of the new technology as well as the process of implementing it into society.

Diebold, John, "Chapter 5: Xerography: The Revolution in Office Work", The Innovators, pp. 89-108, 1990.

Summary: This chapter traces the development of xerography, leading to the modern day copy machine.

Diebold, John, "Chapter 9: The Electronic Bankers: The Rise and Spread of ATMs", The Innovators, pp. 177-202, 1990.

Summary: This chapter describes the history of automated teller machines. It describes the technological advances which facilitated the development of the ATM, as well as the development of the ATM networks worldwide.

Diebold, John, "Chapter 10: Audiotape, Videotape, and Videocassette Recorders: American Gifts to the Japanese", The Innovators, pp. 203-226, 1990.

Summary: This chapter describes the technological development of the audio tape, videotape, and videocassette recorders. It describes how the Japanese successfully marketed the VCR to households in the United States, while the American inventors failed to do so.

Doolitle, James Rood, "The Romance of the Automobile Industry", The Klebold Press, 1916.

Doty, Laurence, "Reprogramming Bolsters 2707 in Overcoming Early Difficulties", Aviation Week and Space Technology, pp. 26-28., January 5, 1970.

Summary: This article describes the progress of the US SST development program. It includes a summary of the program up to this point, as well as plans for future work. It also describes some of the design improvements that are going to be made during the current design phase.

Dunn, John, "The Supersonic Bandwagon", The Engineer, vol. 270, May, 1990.

Elias, Samy E.G., "The West Virginia University - Morgantown Personal Rapid Transit System", Personal Rapid Transit II: Progress, Problems, Potential, pp. 15-33., 1974.

Summary: This paper describes the Morgantown People Mover, including descriptions of the technology being used on the system. Included are descriptions of the vehicle, the guideway, the stations, the communication and control, and the maintenance and control center. The paper also includes a discussion on the preliminary system economics, including operation and maintenance costs, and projected patronage and revenue.

Elias, Samy E.G., et al, "Impact of People Movers on Travel: Morgantown - A Case Study", Transportation Research Record #882, 1982.

Summary: Impact studies of the Morgantown People Mover (MPM) were conducted for two separate phases of construction. Estimates of MPM corridor travel by mode were made before and after opening of phase 1 in October 1975. Estimates of travel by mode, user group, and trip purpose were also made before and after the opening of the expanded system in August 1979. Highly similar impacts resulted both times. Several thousand person trips were diverted from the automobile to the MPM. Users, who are primarily but not exclusively students and faculty, expressed levels of satisfaction with the system nearly as high as users of private automobiles. Despite initial concern about safety before operation began, users now perceive MPM to be extremely safe.

Elms, C., et al, "Assessment of the Phase I Morgantown People Mover System", USDOT: Urban Mass Transportation Administration, UMTA-IT-06-0157-79-1, December, 1979.

Summary: *Missing most of article*
“The purpose of this study is to relate the characteristics of the Automated Guideway Transit (AGT) technology to the needs for improved forms of urban transportation and to determine the social, economic, environmental and performance factors which affect the usefulness of AGT systems”

This article describes how this AGT system is controlled, and introduces some requirements for public acceptance of the system.

Eng-Wong, Taub and Associates, "Non-Port Authority Bus Terminal Bus Survey", Eng-Wong, Taub and Associates..

European Foundation for the Improvement of Living and Working Conditions, "Office Automation: A Technological Revolution and Its Impact", 1988.

Summary: This book aims to show what technical possibilities are available with the introduction of new office technologies and what effects they have on forms of organization, the social environment and the employees themselves.

Feldman, Anthony and Ford, Peter, "Ferdinand Graf von Zeppelin", Scientists and Inventors, pp. 194-195, 1979.

Summary: This article gives a brief overview of the history of rigid airships, as developed, built and operated by Ferdinand Graf von Zeppelin.

Feldman, Elliot, "Concorde and Dissent: Explaining High Technology Failures in Britain and France", Cambridge University Press, 1985.

Fenster, J.M., "Seam Stresses", American Heritage of Invention and Technology 9(3), pp.40-52, Winter, 1994.

Summary: This article examines the problems encountered in getting society to accept a new invention, the sewing machine. Early sewing machine promoters focused on selling their machines to male factory owners, and encountered opposition from the needlewomen in the factories who expected to be replaced by the machines. On the other hand, Singer realized that women would be the ones using the machines, and marketed the idea directly to dressmakers, seamstresses and housewives. This greatly improved the popularity of the sewing machine. Despite fears, the sewing machine actually created new jobs, by reducing the price of ready-to-wear clothing and turning the garment trade into a larger and steadier industry than it had ever been before.

Ferguson, Eugene S., "How Engineers Lose Touch", American Heritage of Invention and Technology 8(3), pp.16-25, Winter, 1993.

Summary: This article deals with the necessity of providing engineering students and young engineers with hands-on experience and the ability to make rational decisions based on common sense and experience. It focuses on engineering failures that have occurred because an engineer has been too dependent on computer models and simulations that are not clearly understood. The emphasis of the article is that bad designs result from errors in engineering judgment, which is not reducible to the science or mathematics obtained from computer models.

Fichtner, D., "Individualized Automatic Transit in the City", 1965.

Summary: The earliest systematic presentation of personal sized automated transit systems.

Fidell, Sanford and Silvah, Laura, "An Assessment of the Effect of Residential Acoustic Insulation on Prevalence of Annoyance in an Airport Community", J. Acoust. Soc. Am. 89(1), pp.244-247, January, 1991.

Summary: The purpose of this study was to address the unanswered questions concerning the degree to which home insulation programs can actually render airports more compatible with communities. The results showed that there is little evidence of a reduction in long-term annoyance with aircraft noise attributable to home noise insulation.

Field, David, "U.S. Effort Urged on High-Speed Rail: Panel Endorses 300-mph “Maglev” Trains", The Washington Times , November 1, 1993.

Summary: This article discusses NMI recommendations for maglev funding and discusses the political impact of the crash at a Japanese maglev demonstration.

Fields, J. M. and Walker, J.G., "Comparing the Relationships Between Noise Level and Annoyance in Different Surveys:: A Railway Noise vs. Aircraft and Road Traffic Comparison", Journal of Sound and Vibration 81(1), pp.51-80, 1982.

Summary: The purpose of this study was to determine whether responses to various environmental noises are similar, or are they source specific. The results indicate that people’s feelings about noise may differ more between sources than do people’s perceptions as to the direct impact of the noise on behavior. The study also showed that railroad noise tends to be more regular and predictable in character than road traffic or aircraft noise, and therefore, it is generally less annoying.

Fields, Stephen, "A Test Ride for People Movers", Electronics, pp. 75-76., September 11, 1972.

Summary: This article describes the Morgantown people mover.

Finch, Christopher, "Highways to Heaven: The AUTO Biography of America", Harper Collins Publishers, 1992.

Summary: This book "chronicles the dramatic rise of the automobile and describes how it transformed the American Landscape and American psyche." It discusses the rise of the automotive industry, as well as societal changes that occurred as the automobile became widely accepted.

Fitch, L.C., "Urban Transportation and Public Policy", Chandler Publishing Company, 1964.

Flatow, Ira, "They All Laughed...From Light Bulbs to Lasers: The Fascinating Stories Behind the Great Inventions That Have Changed Our Lives", Harper Collins Publishers, 1992.

Summary: This book provides the histories of the discoveries and invention of common products. Included are chapters on the invention of: electricity, light bulbs, instant cameras, telephone, television, xerography, lasers, velcro, teflon, nylon, vaseline, synthetic sweetners, silly putty, the submarine, typewriters, video games and a few other inventions with interesting histories.

Flink, James J., "America Adopts the Automobile, 1895-1910", MIT Press, 1970.

Summary: This is a particularly good account of the early stages of the introduction of the automobile which is particularly pertinent to the introductory stages of AHS.

Ford, Barbara, "The Elevator", Walker and Company, 1982.

Summary: This book describes the history and development of the elevator. It discusses the different types of elevators, how each one operates, and how each one came into development.

Fotos, Christopher P., "Bond Sale, Federal Funds Boost New Denver Airport", Aviation Week and Space Technology, pp. 110-111., May 14, 1994.

Summary: News brief about the sale of bonds to fund the building of the new Denver International Airport.

Frederich, Fritz, "Design and Application of the Siemens/Duwag - H-Bahn, An Overhead Cabin System for AGT", Personal Rapid Transit III, pp. 59-67., 1975.

Summary: For approximately three years, Siemens and Duwag have been developing a short-haul transportation system for operation in city centers and medium-sized towns, The system in question is the SIEMENS/DUWAG - H-Bahn, an overhead cabin system for automated guideway transit (AGT). The project is receiving the support of the Federal Ministry for Research and Development of the Federal Republic of Germany.

After outlining the reasons why it was decided to proceed with the development of the H-Bahn, this paper will examine the technology of the vehicles and track, and will discuss the operation of the H-Bahn with regard to the scheduling and utilization of the vehicles.

Fuhs, Charles, "High-Occupancy Vehicle Facilities: Current Planning, Operation, and Design Practices", Parsons Brinkerhoff Quade & Douglass, Inc., October, 1990.

Summary: This report summarizes the objectives and advantages of HOV projects to improve the efficiency of the current highway systems. Current planning, operation and design practices are discussed.

Gambarani, Gary P., "Traffic Alert and Collision Avoidance System (TCAS II) Transition Program", Aviation Systems Group, ARINC Research Corporation, SAE Report No. 901970, 1990.

Summary: This is a survey paper that describes the TCAS II system. It describes the TCAS Rule of 1989, which made TCAS required on all airplanes carrying more than 30 passenger seats.

Gary, Dennis, et al. (editors), "Personal Rapid Transit III", University of Minnesota, 1975.

Summary: This book contains the proceedings of the third international conference on Personal Rapid Transit.

General Research Corporation, "Life Cycle Cost Model for Comparing AGT and Conventional Transit Alternatives", PB 259-529/AS, 1976.

Glanz, James, "Maglev: Will It Ever Really Fly", R&D 35(9)..

Summary: This article gives an overview of the common objections to maglev.

Golembeski, Dean, "Struggling to Become an Inventor", American Heritage of Invention and Technology 4(3), pp.8-15, Winter, 1989.

Summary: This article presents the history of xerox technology (xerography), and its inventor: Chester Carlson. It describes the problems Carlson encountered in developing the technology into a commercial product, and in getting the public to recognize the importance of his invention/

Gordon, Deborah, "Steering a New Course: Transportation, Energy and the Environment", Island Press, 1991.

Grenzeback, Lance R. and Woodle, Clyde E., "The True Costs of Highway Congestion", ITE Journal, March, 1992,.

Summary: A major goal of HOV lanes is to reduce congestion on the roads. This paper provides some figures of the cost of congestion. In particular, the paper addresses incidents on highways, including stalled cars, flat tires, and accidents.

Hajdu, L.P., et al, "Design and Control Considerations for Automated Ground Transportation Systems", Proceedings of IEEE 56(4), April, 1968.

Summary: The earliest source of headway and safety design considerations. Popularized the use of k-factor headway criterion.

Hamilton, W.F., and Nance, D.K., "Systems Analysis of Urban Transportation", Scientific American 221(1), July, 1969.

Summary: One of the early articles that analyses the system and operational concepts of PRT.

Hanson, C. E., "Environmental Noise Impact Assessment of the Introduction of High Speed Trains in the Northeast Corridor", Journal of Sound and Vibration, 66 (3), pp.473-476, 1979.

Summary: This study was undertaken to assess the annoyance from railroad noise expected as a result of the Northeast Corridor Improvement Program. The results of this study indicate that the noise environment from high speed trains in the Northeast Corridor will actually show improvement over existing conditions. However, there will still be some people exposed to high sound levels who will require additional noise controls.

Harris, John S., "An Airplane is Not a Bird", American Heritage of Invention and Technology 5(2), pp.18-23, Fall, 1989.

Summary: This article discusses the notion that an airplane is not a bird, and the difficulties encountered by designers, throughout the history of aircraft development, who had a hard time realizing this. Initially, designers attempted to build aircraft that would perfectly model a bird flying. Advancements in aircraft design, however, could not be made until designers accepted that their machines would fly only if they rejected the bird model.

Hebert, R., "Highways to Nowhere", Bobbs-Merril, 1972.

Henk, Russell H., et al., "Simplified Approach for Estimating the Cost-Effectiveness of HOV Facilities.", Transportation Research Record 1299..

Summary: This is a cost-effectiveness analysis of the HOV facilities in Houston, Texas. The purpose of this paper is to provide a tool to assess HOV feasibility during planning stages.

Heppenheimer, T.A., "The Jet Plane is Born", American Heritage of Invention and Technology 9(2), pp. 44-56, Fall, 1993.

Summary: This article presents the history of the turbojet engine, and thus jet planes. The technological developments are discussed, as well as the reasons why Americans were not involved in the early stages of development. The turbojet engine was invented independently by German and British researchers, although American engineers were able to eventually improve the technology to the standards known today.

Heppenheimer, T.A., "The Rise of the Interstates", American Heritage of Invention and Technology 7(2), pp.8-19, Fall, 1991.

Summary: This article presents the history of the interstate system in the United States. It discusses the political decisions that led to the original plans for the national system, as well as the financial decisions that were made to fund the interstate construction. Also discussed is the opposition and controversies that arose in the cities during the implementation of the interstate system.

Herlihy, David, "The Bicycle Story", American Heritage of Invention and Technology 7(4), pp.48-59, Spring, 1992.

Summary: This article traces the technological and social developments of the bicycle as a mode of transportation. Included also is the history of the bicycle railroad.

Hilton, George W., "The Wrong Track", American Heritage of Invention and Technology 8(4), pp.46-55, Spring, 1993.

Summary: This article provides the history of the interurbans, which were intercity electric railways operated in the early 1900's. Interurbans were basically a cross between the street-car and the railroads, and were small electric trains that ran in frequent service, with many stops, mainly between medium-sized cities. The interurbans were meant to fulfill a transportation service not adequately met by the railroads. Interurbans were built primarily between 1900-1917, and had basically disappeared by 1933. Its failure can be attributed to the convenience and popularity of automobiles.

Hilton, George W. and Due, John F., "The Electric Interurban Railways in America", Stanford University Press, 1964.

Summary: This book discusses the history of the interurbans in the U.S. The electric interurban railway played a major but short-lived role in the development of intercity passenger transport. Basically, it provided a transitional step from almost sole reliance upon the steam railroad to an almost equally complete dependence on the automobile. Interurbans offered greater convenience and flexibility for short-distance travel than the railroad, but quickly gave way to the motor vehicle, which offered still greater flexibility.

Hinman, E.J., "Command and Control Status Report", Proceedings of IEEE Conference on Control Aspects of New Forms of Guided Transport, UMTA-DOT Repot, NJTIS PB 231-681/8WT, 1974.

Hinman, E.J. and Pitts G.L., "Practical Headway Limitations for Personalized Automated Transit Systems", Proceedings of IEEE Conference on Control Aspects of New Forms of Guided Transport, 1974.

Hirschheim, R.A., "Office Automation: A Social and Organizational Perspective", 1985.

Summary: This book attempts to suggest why a social and organizational perspective is needed in the analysis of office automation, and what the result is if such a perspective is adopted. “If adopted, a number of changes become evident. First, the conception of the office changes--from one which sees the office as largely deterministic, rational, and overt to one which is largely deterministic, rational, and overt to one which is largely non-deterministic, political and covert, Secondly, the models and methodologies appropriate for office automation move from the highly formal and abstract to the less formal and participative. Third, implementation is transformed from the mechanical process of installing some particular office system/technology to a process of social and organizational change where participation is the key ingredient. Fourth, the implications of office automation become recognized as not simply the logical and rational outcome of technological use, but the product of social forces which often have little to do with any particular piece of technology. Lastly, the ability to predict the effects of any technological intervention is not one which can be undertaken with simple, empirical cause-effect models, but needs interpretive approaches.’

Hotz, Robert, "Another Major Challenge (Editorial)", Aviation Week and Space Technology, p.11., January 5, 1970.

Summary: This article is an editorial which predicts the success of the SST in the United States. It enumerates some of the issues raised by opponents to the SST program, and attempts to briefly refute them.

Hudson, Kenneth, "Air Travel: A Social History", Rowman and Littlefield, 1972.

Summary: This book traces the development of commercial flight, especially in European countries. Emphasis is on the social implications and passenger services offered

Huffman, et al., "The Law and Automated Highway Systems", January 1994.

Summary: This Working Paper contains an extensive listing of litigations involving cruise control and anti-lock brakes.

Hughes, David, "Denver Airport Still Month From Opening", Aviation Week and Space Technology, pp. 30-31., August 8, 1994.

Summary: News brief - a conventional baggage handling system with tugs, carts and conveyors will be installed while kinks in the highly automated, but balky system are worked out.

Husband, Joseph, "The Story of the Pullman Car", A.C. McClurg and Company, 1917.

Summary: This book describes the development of railroad transportation, with emphasis on the introduction of the Pullman Car. It describes why and how Pullman Cars became so widely accepted by the railroad industry, and why they found continued success.

Ingersoll, J., et al, "Report on the Panel of Social Acceptability", Automated Guideway Transit: An Assessment of PRT and Other New Systems (Pages 325-354), 1975.

Summary: The evidence of recent and current local studies on automated transit indicates that planning and decision-making at the local level on the use of automated systems is an exceptionally difficult process in automobile-dependent communities. Achieving an acceptable plan involving massive capital investment, uncertain operating cost, and educated guesses about the resulting impact on transportation, the environment, and urban form is a formidable task. The process must not only involve a complete analysis of all possible alternative approaches to transit - automated, non-automated, and mixed - but must also be responsive to a broad range of community interest groups. It must be strongly related to comprehensive regional land use planning. If the research efforts of the Federal Government are to result in actual urban use of automated systems, it must be recognized that communities need a great deal more than test track technological developments with which to judge the merits of these automated systems. They must have better answers about human engineering issues, costs, effects on land use and environmental impact. At this time, it may be appropriate to apply existing automated technology to urban and specialized settings to get some of those answers before committing the bulk of available research funds to more advanced technologies. It must be remembered that local decision-makers are more likely to be politicians than technical experts. The negative consequences of their last venture into major transportation improvement (i.e. urban freeways) has made them vary wary. This panel agreed that raising the level of confidence concerning the social acceptability of automated transit will require: (1) R&D programs directed at the process of predicting, interpreting, and communicating the social consequences of transportation improvements,; and (2) Clear indication of long-term Federal financial commitment to automated transit.

Ishii, Takemochi, et al, "CVS: Computer-Controlled Vehicle System", Personal Rapid Transit III, pp. 77-83., 1975.

Summary: CVS, which stands for computer-controlled vehicle system, is a pure personal rapid transit system. This paper describes the development of the CVS system, beginning with its inception in 1968. The technological aspects of the system are described, as well operating characteristics, and plans for system implementation.

IVHS America, "Strategic Plan for Intelligent Vehicle-Highway Systems in the United States", IVHS America, 1992.

Summary: The strategic plan provided insight into the importance of human factors in “selling” IVHS.

Jacobson, Leslie N., et al., "Public Attitude Toward the Seattle Area HOV System and Effectiveness of the HERO Hotline Program", Transportation Research Record 1299..

Summary: Positive public attitude towards HOV facilities is crucial to their effectiveness and longevity. The purpose of this paper was to determine the public attitude toward the HOV system in Seattle as well as the HERO hotline. HERO hotline allows HOV users to report violations of the HOV system.

Jakes, Andrew, "Today's People Movers", Journal of Advanced Transportation 22(2), pp. 170-181, 1988.

Summary: After two decades of people mover operations at over 50 locations worldwide and 1.1 million passengers per day, the question remains the same: does automated guideway transit hold the best promise for urban transportation needs?

Johnson, Dirk, "Denver Delays Opening of Airport Indefinitely", The New York Times, p. A16, May 3, 1994.

Summary: This article discusses the problems that are causing the delay in the opening of the Denver International Airport.

Johnson, Dirk, "Errant Luggage Delays Opening of Airport", The New York Times, p. A13, March 2, 1994.

Summary: This article discusses the problems that are causing the delay in the opening of the Denver International Airport.

Johnson, Dirk, "New Airport Keeps Denver Waiting Still", The New York Times, p. 12, April 30, 1994.

Summary: This article discusses the problems that are causing the delay in the opening of the Denver International Airport.

Jones, Alan B., et al, "Development of Obstacle Clearance Criteria And Standards for MLS and MLS/RNAV Precision Approaches and Development of an MLS Collision Risk Model", Federal Aviation Administration, SAE Report No. 8992215, 1989.

Summary: This paper is particularly relevant to AHS because it focuses on the development of obstacle clearance criteria and standards for microwave landing system (MLS) procedures development, the accuracy with which an aircraft can be flown along a defined approach path must be determined.

Kangas, Ronald, et al, "Assessment of Operational Automated Guideway Systems - Airtrans (Phase 1)", UMTA, US Department of Transportation, DOT-TSC-UMTA-76-15, 1976.

Summary: This report presents the results of an evaluation study of AIRTRANS, a unique, automated guideway system located at the Dallas/Fort Worth Airport. AIRTRANS was designed to move passengers, employees, baggage, mail, trash and supplies. The newest and largest system of its type in the world, it comprises 13 miles of single lane guideway and 68 vehicles, and serves 53 stations at different points in the airport complex. The system is e of the first intra-airport transit systems conceived, designed and constructed as an integral part of the airport development.

The study, conducted with the cooperation of the Dallas/Fort Worth Regional airport and the Vought Corporation, was intended to codify the information and experience gained in the planning, development, implementation and initial operation of the system into an integrated body of knowledge from which those concerned with any phase of future, similar system planning and implementation could profit.

The assessment team found AIRTRANS an impressive accomplishment. As a pioneering project, AIRTRANS did not have an extensive data base to build on, and consequently some problems arose attributable to insufficient system planning, analysis, organization and specification, as well as optimism about schedules and component reliability. Considering this, AIRTRANS is impressive and commendable but it could be more efficient and effective and is being constantly improved towards these goals. The report provides information useful to planners, designers, developers and operators of automated transit systems for intra-airport and other applications.

Kelly, Ben, "The Pavers and the Paved", Donald W. Brown, Inc., 1971.

Summary: This book discusses the implementation of the interstate highway system from two perspectives: government, and the general public. From the government perspective the establishment and maintenance of the highway trust fund is discussed, as well as the role of the highway lobby in the implementation of the interstate system. From the perspective of the general public, problems with the interstate system are discussed, as well as attempts

to stop highway construction and concentrating on improvements to the entire transportation system.

Kershner, D.L. and Roesler, W.J., "Models for Assessing Trip Dependability in Automated Guideway Transit Networks", APL/JHU CP 047/TPR 036, August, 1976.

Summary: This report presents various models for evaluating alternative operating strategies, equipment failure modes and reliability, and maintenance practices. Estimated are incident probabilities and distributions of the length of delays based on vehicle demand equipment reliability, guideway network structure, and maintenance policies for AGT. This is a good start at failure analysis.

Klein, Maury, "The Diesel Revolution", American Heritage of Invention and Technology 6(3), pp. 16-22, Winter, 1991.

Summary: This article presents an overview of the effects resulting from the replacement of steam engines by diesel locomotives. In only twenty years, “The diesel locomotive revolutionized the way railroads performed their work, reconfigured the physical landscape, redefined the roles of workers in this most traditional of industries, and consigned to the realm of nostalgia an entire subculture rooted in that dominant symbol of nineteenth-century America, the steam locomotive.” The article discusses each of these effects on American society.

Klein, Maury, "What Hath God Wrought?", American Heritage of Invention and Technology 8(4), pp. 34-45, Spring, 1993.

Summary: This article provides a history of the telegraph. Emphasis is made on Samuel Morse’s inventive process, but it also discusses technological contributions made by other scientists and inventors.

Kornhauser, A.L. and Dais, J.L., "Assessing Area-Wide Personal Rapid Transit", Proceedings of the International Conference on Transportation Research, 1973.

Kranzberg, Melvin and Purcell, Carroll W. Jr., "The Development of Aviation: Lighter-Than-Air Ships", Technology in Western Civilization: Volume II, pp.165-167, 1967.

Summary: This article traces the development of lighter-than-air ships as the first means of powered flight. It also discusses the disappearance of the airship as a prominent participant in air transportation. It offers the explanation that “Dirigibles offered smooth, comfortable, roomy, leisurely flying conditions. Yet these advantages did not commend them to designers, financiers, or military or civilian potential users in the third of a century that followed. Hence, dirigibles were not the object of the funds, time, engineering experience, ingenuity and persistence of purpose that have characterized the history of ocean-going vessels, railroads, or the airplane."

Lardennois, Regis, "VAL Automated Guided Transit Characteristics and Evolutions", Journal of Advanced Transportation 27(1), pp. 103-120, 1993.

Summary: VAL (Light Automated Vehicle) is a medium capacity driverless automated guideway transit system. It has demonstrated both technical feasibility and economical performance of driverless operation applied to a metro line.

It includes several advanced well proven technologies. Since the first line design, the product has been adapted to various operating requirements and enhanced by application of further technological evolutions in several areas: Automatic Train Control, Rolling Stock, Track.

Leavitt, Helen, "Super Highway--Super Hoax", Doubleday & Company, Inc., 1970.

Summary: This book presents a detailed history of the development of the interstate highway system. The author attempts to point out the shortcomings of the original highway plan, and criticizes the political system that allowed the system to be constructed. She advocates the use of mass transportation systems to help solve the continuously worsening transportation problems, instead of simply building more highways to handle the increased traffic.

Levine, Joshua, "Chunnel Vision", Forbes, February 14, 1994.

Summary: This article discusses the tunnel connecting England and France, under the English Channel. It describes the services which will be offered in the tunnel, and the marketing issues relating to it.

Levy, Elizabeth, "The People Lobby: The SST Story", Delacorte Press, 1973.

Summary: This book details the battle waged in Congress by opposing lobbyists over financing the SST, a supersonic transport plane. It describes how the SST plan was killed by Congress, due in part to lobbying for the public interest.

Levy, Gerard, "The French Aramis System", Personal Rapid Transit III, pp. 75-76., 1975.

Summary: The Aramis system, tested on a trial circuit near Orly, France from March 1973 to March 1974, is a new urban transportation system. It offers the direct origin-destination, non-stop service characteristics of personal rapid transit over a line-haul guideway system. This paper describes the characteristic features of Aramis, as well as the phases of the development process.

Lewis, David L. and Goldstein, Laurence (editors), "The Automobile and American Culture", The University of Michigan Press, 1983.

Summary: This book contains a collection of essays regarding the automobile's influence on American culture. The essays are grouped into six general topic areas: The First Decades, The Transformation of America, The Mirror of Art, Dream Machine or American Nightmare, The Future, and Historiography. Some of the essays address why the automobile became so popular, the effects of the automobile on society, and the role of the automobile in American culture.

Loomis, James P., (editor), "High Speed Commercial Flight: The Coming Era", Battelle Press, 1986.

Lutin, J. and Falls, M. , "Gambling with a Loser, The Las Vegas PRT", Transportation Research B, 1980.

Summary: This is a most interesting account of the institutional problems that proved fatal to what seemed to be a perfect implementation of PRT

Lutin, Jerome, "Integrating Personal Rapid Transit into the Urban Environment", Princeton University School of Architecture and Planning, 1975.

Summary: This paper explores the effects that implementing a PRT system will have on an urban area. It emphasizes the necessity of community involvement in the planning process, as well as the importance of designing a PRT to meet the needs and wants of a certain community.

Lyon, Peter, "To Hell in a Day Coach: An Exasperated look at American Railroads", J.B. Lippencott Company, 1968.

Summary: This book traces the history of railroads in America, with emphasis on why the railroads changed from the most popular and profitable mode of transportation to become an unsuccessful, unprofitable industry with an uncertain future.

MacKinnon, Duncan, "High Capacity Personal Rapid Transit System Developments", IEEE Transactions on Vehicular Technology, February, 1975.

Summary: High capacity personal rapid transit (HCPRT) is a system concept which utilizes small, 4 to 6 passenger, vehicles at very short headways on exclusive guideway networks. The automatic operation of small vehicles at headways of 1 second or less presents a major technical problem which is amenable to a combination of design approaches. This paper explores the effect of basic parameters such as vehicle length, reaction time, emergency and failed vehicle deceleration rates, and emergency jerk rate on potential minimum operating headway. The results of this analysis are then discussed in the context of five HCPRT programs.

Marion, Larry, "The Great West Virginia Compromise", Electronics, pp. 63-65, May 1, 1975.

Summary: This article discusses the approval for Phase 2 completion of the Morgantown People Mover. It summarizes the problems that were encountered during phase 1 development.

McGean, Thomas, "Urban Transportation Technology", Lexington Books, 1976.

Summary: This book is a “transportation systems engineering text providing both the rule of thumb performance capabilities for automobile, bus, rail, and new system technology, and some general engineering approaches suitable for estimating the performance of or for performing feasibility studies and parametric tradeoff analysis for any type of transit system.” Topics discussed include: Headway and Capacity Relationships, Typical Performance Levels for Different Transportation Systems, Station Design, Energy and Environmental Impacts, Propulsion, Braking, Ride Quality , and Steering and Switching Concepts.

McMullen, B., et al., "HOV Lane Effectiveness in Controlling Traffic Congestion", Transportation Quarterly 46(3), July, 1992.

Summary: This paper provides a history of HOV facilities, evaluations of current HOV programs-including objectives and measures, and overall objectives of HOV programs.

Mennie, Don, "People Movers", IEEE Spectrum, July, 1976.

Summary: This article describes current efforts to implement automated guideway transit into various transportation situations. Specifically, it discusses the AIRTRANS system at the Dallas/Fort Worth Airport, the Morgantown People

Mover, shuttle-loop transit systems developed by Westinghouse, as well as other AGT projects under development.

Miletich, John (compiler), "Airline Safety: An Annotated Bibliography", 1990.

Summary: This book is a bibliography of 650 references, covering the time period January 1960 to May 1990. Source publications include books, articles, conference proceedings, theses, and government publications. Subjects included in the bibliography are all related to airline safety. Emphasis is on the major airlines worldwide, there is relatively little information about general aviation and commuter airlines.

Miller and Nayer, "Build It and Hope They'll Come", Newsweek, p. 41, June 7, 1993.

Summary: This article discusses the problems that have plagued the Denver International Airport

MITRE Corporation, "Vehicle Operating Strategies for Small Automated Guideway Transit Network", PB 262-480/AS, 1976.

Monoco, Cynthia, "The Difficult Birth of the Typewriter", American Heritage of Invention and Technology 4(1), pp. 10-21, Spring/Summer, 1988.

Summary: This article presents the history of the typewriter. Focus is on the problems encountered in getting society to accept the new device. When the typewriter was first introduced, no one thought to consider business as a potential customer. Instead, they attempted to sell the machines to court reporters, lawyers, editors, authors and clergymen. however, they did not consider the strength of the social customs behind hand written correspondence. Those who predicted success for this machine felt that it would make the pen entirely obsolete, and were not able to predict the role the typewriter would actually play.

Morrison, "Accelerated Walkway Systems: Hoboken Rail Terminal Demonstration", USDOT: Urban Mass Transportation Administration, UMTA-IT-06-0126-83-2, 1983.

Summary: * Missing Most of Article*
The Accelerated Walkway System (AWS) demonstration program was designed to test the feasibility of operating such a system in an urban setting. The demonstration was designed to provide information about the mechanical performance of the system under actual operating conditions, monitor passenger usage, and evaluate public acceptance of the system. This report

describes the program of site engineering work that was planned by the Port Authority's Engineering Department in preparation for the installation and operation of the TRAX walkway system.

Moynihan, Daniel Patrick, "How To Lose: The Story of Maglev", Scientific American p.130, November, 1989.

Summary: This article contains an excellent short history of maglev.

Muller, Siegfried, "The H-Bahn System: A Fully Automatic Rapid Transit System With Its Own Segregated Right-Of-Way", Journal of Advanced Transportation 19(1), pp. 55-63., 1985.

Summary: The development of a new transit system, H-Bahn, from the manufacturer's perspective is presented in this paper. Design and operating considerations are provided. The paper goes on to describe the first application of the technology in a public setting, giving the requirements for application and what equipment the manufacturer provided to meet these requirements.

Mumford, Lewis, "The Highway and the City", Harvest Books, 1953.

Myerson, Allen, "Automation Off Course in Denver", The New York Times, pp. D1-D2, March 18, 1994.

Summary: This article discusses the problems that Denver International Airport has been hith its automated baggage transport system.

Nader, Ralph, "Unsafe at Any Speed", Grossman Publishers, 1965.

Nelson, Robert C., "Flight Stability and Automatic Control", McGraw-Hill, 1989.

Summary: A good textbook covering aerodynamics of airplanes band their control systems. This book includes a section on automatic landing and the instrument landing system.

Neumann, Edward S. and Bondada, Murthy V.A. (editors), "Automated People Movers: Engineering and Management in Major Activity Centers", American Society of Civil Engineers, 1985.

Summary: This book is a compilation of papers that were presented at a conference in 1985. The papers are grouped into nine broad topic areas: automated people movers-past, present and future; automated people mover technology, capabilities, and requirements; automated people movers in a mass transit environment; automated people movers serving special land uses; additional system concepts; financing and implementation; station design; guideway design and construction; and operations and maintenance.

New Jersey Department of Transportation, "New Jersey Statewide Long-Range Transportation Plan", Demographic and Economic Trends for New Jersey, 1993.

Summary: This provides information about the exclusive bus lanes (transit applications for HOV) that exist in New Jersey.

Nordwall, Bruce, "Delay Likely In Denver Opening", Aviation Week and Space Technology, 139, p 40, September 6, 1993.

Summary: This article discusses the general design of the Denver International Airport, anddiscusses possible opening dates for the airport.

Nordwall, Bruce, "Highly Automated System to Handle Baggage", Aviation Week and Space Technology, 139, pp. 41-45, September 6, 1993.

Summary: This article discusses the automated baggage system that was to be installed at Denver International Airport. It discusses the features of the system, and describes how the system will manage baggage.

Phillips, Edward, "Denver Airport to Open Mar. 9", Aviation Week and Space Technology, 139, p. 41, February 28, 1994.

Summary: This article describes the efforts being made to keep the Denver International Airport on track for the March 9 opening date. It also describes some of the operational plans for the airport.

Phillips, Edward, "Denver Fails to Meet Deadline for Opening", Aviation Week and Space Technology, 139, p. 32-33, March 7, 1994.

Summary: This article describes the efforts being made to keep the Denver International Airport. It describes the problems that the airport has had with the automated baggage system, and the costs associated with the delay in opening the airport.

Phillips, Edward H., "Denver, United Agree On Baggage System Fixes", Aviation Week and Space Technology, pp. 28., August 29, 1994.

Summary: News brief - fearing failure of a $225-million bond issue this week that is designed to pay for modifications to the troubled baggage handling system at Denver International Airport, officials have reached a tentative agreement calling for operation of two different systems so the new airport can open on Feb. 28.

Rae, John B., "The American Automobile: A Brief History", The University of Chicago, 1965.

Summary: This book provides a chronological overview of the evolution of the automobile in the United States. It begins with the technological developments that led to our current automobile technology. Also discussed are the growth of the US automobile industry, and the effects that the automobile has had on American society. Generally, this book contains a history of how the automobile was introduced into mainstream society, and the changes that occurred in American culture as a result.

Rae, John B., "The American Automobile Industry", Twayne Publishers, 1984.

Summary: This book presents the history of the American automobile industry. The book is divided into four sections, the period of origin and growth between 1890 and 1920, the period in which the US dominated the world Automotive scene between 1920 and 1960, the effects on the industry , in the 1960's and 1970's, of problems such as government regulation, foreign competition and the need for energy conservation, and the international operations and position of the US industry in the 1980's.

Ramsdell, Edward, "Tort Liability and IVHS Today", The Proceedings of the Annual Meeting of IVHS America, May, 1992.

Summary: IVHS is an undertaking that will significantly affect a great many members of the general population. It will in particular greatly affect the way that we have historically viewed the relationships among the owners and operators of highways, the manufacturers of equipment used on these highways and the owners, operators and lessors of the vehicles operating on them. This paper seeks to promote further discussion as to how the legal aspects of these relationships will change.

Ramsdell, Edward, "Tort Liability and IVHS: Problem or Illusion “A Transportation Industry Analyst's Perspective”", The Proceedings of the IVHS America 1993 Annual Meeting, 1993.

Summary: This paper discusses developments in tort liability case law that have been reported in the past year. The intent of this paper is to note case law changes from last year in order to provide additional insight and to encourage ongoing discussion in the area of IVHS tort liability. In the legal arena, the specter of the tort liability system and its supposed potential to stifle IVHS innovation and development continues to be of concern, There is, however, a growing body of thought that the tort liability system places no special burden on the various facets of IVHS development. The proponents of this approach believe that the real problem is of the liability system, probably coupled with limited knowledge rather than any substantial unique threat posed by IVHS. Also, the application of sovereign immunity, which seemed to have been under some attack at the state level this time last year, has been supported through a series of reversals on appeal in the higher courts of several states. Certainly the more advanced IVHS applications such as automatic vehicle control still raise liability issues that hold forth the remote possibility of catastrophic loss.

Riches, Eric, "Will Maglev Lift Off?", IEE Review, p.427-430, December, 1988.

Summary: This article provides a summary of maglev technology, along with a brief history of maglev system development worldwide. It attempts to assess the competition and provide a glimpse into the future.

Robinson, John, "Highways and Our Environment", McGraw Hill Book Company, 1971.

Summary: This book begins with a general history of roads and highways in the United States. It then focuses on the how the roadway system has impacted the environment in which we live. Litter, pollution, space encroachment, and aesthetics are a few of the issues explored.

Roy, Roger, "High-Speed Trains Could Head to Florida", Orlando Sentinel Tribune, March 20, 1993.

Summary: This article discusses maglev funding woes.

Royal Aircraft Establishment, "Cabtrack Studies", Ministry of Defense, England, 1969-1972.

Summary: These are a series of unpublished reports.

Rybczynski, Witold, "The Environment of Technology", Taming the Tiger: The Struggle to Control Technology, pp.186-194, 1983.

Summary: This article gives a brief overview of the introduction of the airship into military and commercial service, primarily after WWI. Emphasis, however, is made on the reasons why airships disappeared from all service in

1937. the author attributes the disappearance, not the disasters that occurred, or to the introduction of the passenger plane, but to the airship's failure as a weapon in a time where weapons were of the greatest concern to governments.

Saxton, Lyle, "Automated Control--Cornerstone of Future Highway Systems", March 22, 1993.

Scharchburg, Richard P., "Carriages Without Horses", Society of Automotive Engineers, 1993.

Schiffer, Michael Brian, "Postfix: The Blacksmith's Motor", American Heritage of Invention and Technology 9(3), p.64, Winter, 1994.

Summary: This article describes the development of the first electric motor, built in 1834. Its inventor, Davenport, was eventually able to build motors which could power small machines. However, there was a high cost of replenishing the zinc in the motor's batteries, and this led to the motor's commercial failure. This is an example of a situation where even though a new technology works, there is no guarantee that it will become a successful product.

Seideman, Tony, "Bar Codes Sweep the World", American Heritage of Invention and Technology 8(4), pp.56-63, Spring, 1993.

Summary: This article presents an overview of the development of bar code technology. Today, bar code technology is widely used in almost every industry; however, the original patent for bar-codes was filed in 1949, almost 20 years before the technology became widely accepted. This article describes why the technology took so long to become developed to the point where it could widely implemented in to industry.

Snow, Richard F., "They're Still There: The Oldest Otis", American Heritage of Invention and Technology 2(1), pp.6-7, Summer, 1986.

Summary: This article describes how Otis made the elevator a safe device for freight and passengers. It was not until the safety device was included on the elevator that elevators became popular, and enabled high-rise buildings to be built.

Solberg, Carl, "Conquest of the Skies: A History of Commercial Aviation in America", Little, Brown and Company, 1979.

Summary: This book presents a history of commercial aviation in the United States. It traces the development of commercial planes and airline from the 1920's to modern times. Included is a history of the technological developments as well as the emergence of flying as a popular means of transportation.

Southerland, Thomas C. Jr., and McCleery, William, "The Way to Go: The Coming Revival of US Rail Passenger Service", Simon and Schuster, 1973.

Summary: This book attempts to illustrate the necessity of upgrading, improving, and ex railroad passenger service in the US. It is directed to those who recognize the growing need for railroad service, but who have not yet become involved in the movement to revitalize the train system. The book begins with a description of train systems currently operating in Europe and Japan. It then provides a brief overview of the history of the railroads in America, and the strong political opposition that has faced the railroad movement in the past. The book concludes with a discussion of encouraging developments, like growing political support, improved train service in some locations, and the current research and plans to bring modern railroad technology to the United States in the near future.

Sproule, W.J., "Airport Development with Automated People Mover Systems", Transportation Research Record, Public Transit Research: Rail, Bus, and New Technology, 1991.

Sproule, W.J., et al, (editors), "Automated People Movers IV: Enhancing Values in Major Activity Centers", American Society of Civil Engineers, 1993.

Summary: This book is a collection of papers from the Fourth International Conference, sponsored by the Committee on Automated People Movers of the Urban Transportation Division of the American Society of Civil Engineers. Paper topics include: planning for APMs, Urban APMs, Airport APMs, PRTs, vehicles and subsystems, design and construction, and implementation and procurement.

Sproule, William J., "An Introduction to APM Systems and Applications", Automated People Movers IV: Enhancing Values in Major Activity Centers, pp. 22-34., 1993.

Summary: An automated people mover (APM) is an advanced transportation system in which automated driverless vehicles operate on fixed guideways in exclusive rights-of-way. These differ from other forms of transit in that no operators are required on board the vehicles. This feature, together with the relatively small size of vehicles, make it possible to provide a high level of service throughout the day either through more frequent service or service in direct response to passenger requests.

Currently, there are almost seventy systems of various types and configurations in the world and several systems are being planned. This paper provides an introduction to APM systems and their applications.

Starr, C., "Social Benefits versus Technological Risks", Science 165(3899PRT, personal rapid transit, people movers, AGT, APM), September 19, 1969.

Stasson, Mark and Fishbein, Martin, "The Relation Between Perceived Risk and Preventive Action: A Within-Subject Analysis of Perceived Driving Risk and Intentions to Wear Seatbelts", Journal of Applied Social Psychology, 20(19), pp.1541-1557, 1990.

Summary: “Intentions to wear seatbelts in twelve different driving situations were predicted from attitudes toward wearing seatbelts, subjective norms concerning seatbelt uses, and perceived driving risk. In a given driving situation, appropriate measures of attitudes and subjective norms both had significant effects on intentions to war a seatbelt, whereas there was little relation between risk and intentions. Intentions across the twelve driving situations were significantly related to perceived driving risk, both for aggregate data and for a substantial portion of individual subjects. However, further analysis indicated that risk seemed to affect intentions indirectly through subjective norms and attitudes associated with seatbelt use. The results suggest that attempts to increase seatbelt use should target all relevant beliefs important in determining people’s attitudes toward and subjective norms concerning seatbelt use, rather than just focusing upon making people aware of the risks associated with driving.”

Steward, Elwood C., "Economic and Environmental Aspects of STOL Transportation", Langley Research Center, 1972.

Summary: *Missing most of article*
This article provides criteria used to evaluate how well a system is meeting its objectives. The focus of the paper is the introduction of the STOL Aircraft.

Stewart, J. Richard, "Seat Belt Use and Accident Involvement: A Comparison of Driving Behavior Before and After a Seat Belt Law", Accident Analysis and Prevention 25(6), pp.757-763, 1993.

Summary: In an earlier study, researchers at the University of North Carolina Highway Safety Research Center found drivers classified as seat belt nonusers on the basis if direct observation and self-reported belt use to be over represented in prior accidents and violations. This study represents a follow-up and extension of the earlier study where accident and violation rates over a 2.5-year interval following the classification by seat belt use status are compared. Seat belt nonusers were again found to be over represented in both accidents and violations. In other analyses of these data, changes in seat belt use status were found not to be associated with changes in accident or violation rates, and seat belt use rates reported by police in accidents following the mandatory seat belt law greatly exceeded both the observed and self-reported use rates. this was especially pronounced for drivers who responded that they rarely or never used seat belts.

Stone, T.R., "Beyond the Automobile", Prentice-Hall , 1971.

Stover, John F., "One Gauge: How Hundreds of Incompatible Railroads Became a National System", American Heritage of Invention and Technology 8(3), pp.54-62 , Winter, 1993.

Summary: This article describes the development of a national railroad system. It explains how the first American railroad lines were planned and built to serve a particular city and its surrounding community, and how each line chose its own gauge (distance between the tracks), with little consideration to matching it to any other line. Once a line was built, others nearby would match it to allow for connecting service between neighboring communities. This led, however, to a system where each geographic region had its own gauge, and it was not possible to connect service between regions. Various ad-hoc solutions were developed to solve the problem, but eventually all the lines were changed over to a standard gauge. Once this was completed, the rails became a national system that permitted connecting service through any region.

Strasser, Susan, "Never Done: A History of American Housework", Pantheon Books, 1982.

Summary: This book discusses the changes in household chores that have occurred as a result of technological advances, and the social effects that have occurred because of these changes.

Strobel, Horst, "Computer Controlled Urban Transportation", John Wiley & Sons, 1982.

Summary: This book addresses the question: "What benefits can a city realistically expect to receive from solving its present and future traffic problems by technological innovations, and especially by implementing large-scale computerized traffic and transportation control systems?" Part one of the book analyzes the role of automation and computer control within the framework of general urban and transportation development policies, with special attention to the differences and similarities between the control problems occurring in the individual transport modes. Parts two through four present detailed analyses of automobile traffic control, control and monitoring of public transport systems, and new modes of urban transportation (automated guideway transit and the dual-mode concept).

Sweeney, Daniel, "Why Mohole Was No Hole", American Heritage of Invention and Technology 9(1), pp.54-63, Summer, 1993.

Summary: This article describes the 1958 plan that was announced for American geophysicists to drill a hole several miles beneath the sea floor, in order to reach the remote interior of the Earth. It also describes why this plan was originally undertaken, and all of the preliminary research that was performed to get the project underway. The project was eventually eliminated in 1966, after it was found to be much more expensive than originally believed. this article explores the reasons why the MOHOLE project failed to reach completion in an era were massive scientific projects had been undertaken and successfully completed.

Syverud, Kent, "Legal Constraints to the Research, Development, and Deployment of IVHS Technology in the United States", The Proceedings of the IVHS America 1993 Annual Meeting, 1993.

Summary: This paper discusses the legal ramifications of IVHS technology. Included are discussions on tort liability, intergovernmental cooperation, privacy law, procurement law and intellectual property, and antitrust law. The article includes a bibliography listing every published paper on legal research pertaining to IVHS technology. Also, the author makes some recommendations for further research on the legal issues surrounding IVHS and AHS.

Talley, James A. and Ernst, Pamela L., "Automated People Movers in the Family of Transit Modes", Journal of Advanced Transportation 23(2&3), pp. 165-182., 1989.

Summary: This paper describes a method of classifying existing, as well as future transit systems. The three parameters that can be used to classify transit systems are: service type (number of intermediate stops), minimum traveling unit capacity (vehicle capacity), and maximum operating velocity. Automated guideway transit systems are then classified according to these three parameters.

Ternes, J., "The Entrepreneur Who Wouldn't Give Up", The Boston Globe (June 22), 1993.

Theumer, H.A. and Elms, C.P., "Description and Technical Review of the Duke University Automated People/Cargo Transportation System", Urban Mass Transportation Administration, IT-06-0188, 1979.

Summary: This report describes and reviews the installation of the automated people/cargo transportation system at Duke University in Durham, South Carolina. Since the system is presently in the final construction phase and undergoing testing, any operational assessment will have to be accomplished after sufficient time has been allowed for maturation. For these reasons, this report is confined to a description of the technical subsystems as well as the designed operation. Beneficial use of the system is expected to begin within the near future. A subsequent report should assess the system after it has been in use for a period of time. The objectives of this study are to: 1) obtain descriptive economic system performance and public response (human factors) information which can be used for planning subsequent AGT system installations; 2) obtain factual engineering and operating data about each AGT system which can be used in planning other AGT systems; and 3) review the design, development, and implementation experience with each AGT system selected to determine what has been learned and how future urban installations of AGT can be most effectively carried out.

A description of the technical subsystems as well as the designed operation are included: specifications of performance, reliability, and maintainability are reviewed and system development and implementation are summarized. Where important, the revisions of technical subsystems includes applicability, modifications and/or improvements for application in an urban environment. Information and data presented were collected through surveys of the literature, site visits, a visit to the manufacturer, and interviews with site and manufacturer's personnel.

Thornton, Richard D., "Why the U.S. Needs a Maglev System", Technology Review, April, 1991.

Summary: This article contains an exaggerated account of the benefits and feasibility of maglev. It also details a short history of maglev.

Tillotson, Dan, "Operational Findings from a Traffic Alert and Collision Avoidance System (TCAS) Evaluation", ARINC Research Corporation, SAE Report No. 880943, 1988.

Summary: This paper provides a summary of the data and findings from a ten month evaluation of the TCAS industry prototype installed on a Piedmont Airlines' Boeing 727 aircraft..

Transportation Research Board, "In Pursuit of Speed: New Options for Intercity Passenger Transport", National Research Council, Special Report 233, 1991.

Summary: This is an excellent summary of the available HSGT technology options, complete with cost estimates and detailed policy suggestions.

Transportation Systems Center, "Proceedings of Workshop on Methodology for Evaluating the Effectiveness of Crime Reduction Measures in Automated Guideway Transit Systems: Final Report", PB 273-695/AS, July, 1977.

Summary: One of the more thorough reports on personal security issues arising in automated transit systems.

Tremong, Francois, "The Lille Underground - First Application of the VAL system", Journal of Advanced Transportation 19(1), pp. 39-53., 1985.

Summary: The VAL system was the first totally automatic transit system opened in France. This paper examines the reasons behind the development and application of the VAL technology to date. The technology is described including the vehicles, guideway and supporting equipment, as well as its operating system. The paper concludes with a review of the experimental operation of the first section of the line and the public's reaction.

Turnbull, et al., "Current Practices in Evaluating Freeway HOV Facilities", Transportation Research Record 1299...

Summary: This paper provides a history of HOV facilities, evaluations of current HOV programs- including objectives and measures, and overall objectives of HOV programs.

Turner, David B. and Wolf, William L. , "Houston Wedway People Mover Control and Propulsion System ", IEEE Vehicle Tech. Conference, 1982.

Summary: This paper describes the control and propulsion system of the PeopleMover in use at the Houston Intercontinental Airport. The Houston Wedway People Movers are passive vehicles, controlled by linear induction motors (LIM) mounted on the track. The LIM control the vehicle movements between stations, however station controls control the vehicles in and near the stations. There are system controls which oversee all of the subsystems.

Tweeney, C.F. and Shirshov, I.P., (editors), "Airships", Hutchinsons's Technical and Scientific Encyclopedia: Vol. 1, pp.55-57..

Summary: This article is an encyclopedia entry which provides an overview of the various types of airships, the construction of the hull and gas envelope, the gas used for airships, and flying and mooring considerations.

Ulberg, Cy and Jacobson, Kern, "Evaluation of the Cost-Effectiveness of HOV Lanes", Transportation Research Record 1181..

Summary: This paper describes reducing operating costs through smoother operation, ridesharing, and the ability to arrive at destinations with an evaluation of cost-effectiveness. It provides benefits of HOV lanes-travel-time savings, reduced vehicle out delays. It also provides costs associated with HOV facilities- construction and maintenance, enforcement, and subsidy to provide additional transit and other services.

Urban Mass Transportation Administration, "Dual Mode Planning Case Study, Milwaukee, Volumes 1, 2, 3", UMTA, UMTA-MA-06-0056-80-1,2,3, 1977.

Summary: A thorough study of the dual mode concept as applied to a more real orientation in Milwaukee, Wisconsin. There are three volumes; the meat of the study is contained in the second volume. the technical appendices.

Urban Mass Transportation Administration, "Transit Technology Evaluation: A Literature Capsule", US Department of Transportation, DOT-TSC-UMTA-81-65, November, 1981.

Summary: This report contains overviews and summaries of selected documents concerning automated guideway transit. The documents summarized include assessments of various AGT systems in operation, overviews of various aspects of the Transit Technology Evaluation Program, and other related documents.

URS Company, Inc., "Midtown Remedies/ Trans-Hudson Studies", URS Company, Inc., 1987.

Volti, Rudi, "Why Internal Combustion?", American Heritage of Invention and Technology 6(2), pp.42-49, Fall, 1990.

Summary: This article discusses the reasons why the internal combustion engine succeeded in becoming the most widely used engine in automobiles. It explains the advantages and disadvantages of the internal combustion engine, along with its primary competitors: the steam engine and the electric motor. The article also discusses the reasons why the internal combustion engine succeeded, while the other two engines never gained popularity.

Voorhees, A.M. and Associates, "Orange County Dual Mode Planning Case Study, Volumes 1 and 2", UMTA, UMTA-VA-0030-80-1,2, 1977.

Summary: A rather thorough study of an area-wide dual mode bus study. Buses were small, 15-25 persons, operated in a dial-a-ride collection mode and automated line-haul mode. Off-line stations were included for PRT-like service. The network was grid-like with guideway spacing of 4-6 miles. expected to attract somewhat less than 20 % of the work trips and 5% of the non-work trips. Such a system would be directly comparable to some of the transit AHS concepts.

Vranich, Joseph, "Supertrains: Solutions to America's Transportation Gridlock", St. Martin's Press, 1991.

Summary: This book presents the idea of using modern high-speed trains as a solution to the transportation problem in the United States. It recognizes that automobiles will always be required for their flexibility, and airplanes will always be needed for their speed, but high-speed rail travel may help to reduce the strain on both systems without polluting the sky or destroying much open ground.

This book describes the existing technologies , throughout the world, in the area of high-speed rail travel. It also discusses the controversies inspired by these trains, and the reasons why supertrains may be the answer to the US problems in transportation.

Vuchic, V.R., "Urban Public Transportation", Prentice Hall, Inc., 1981.

Vuchic, V.R. and Strange, R.M., "New Transit Technologies: An Objective Analysis is Overdue", Railway Gazette International, 1974.

Ward, John K., "The Future of an Explosion", American Heritage of Invention and Technology 5(1), pp.58-63, Spring/Summer, 1989.

Summary: This article examines the role of the federal government in ensuring the safety of steamboat transportation. The repeated steamboat disasters encouraged the federal government to provide funding for a private institution to conduct research on boiler safety. In addition, this was the first case where federal legislators .felt that they had an obligation to intervene in the private sector to protect American lives and property. This led to the development of the FDA, FAA, and all the other government regulatory and investigative agencies that seek to protect the American people.

Watkins, Harold, "Opposition Battles SST on Three Fronts", Aviation Week and Space Technology, pp. 84-86., January 5, 1970.

Summary: This article discusses the political, social and economic opposition that arose against the SST program. It enumerates some of the arguments, and counter-arguments raised by opposition and proponents of the program.

Weise, A.E., "A Better Idea for El Paso-Juarez Within Two Years", Mass Transit 1(1), 1974.

Weise, A.E., "The Big Oil Squeeze and Mass Transit", Mass Transit 2(2), 1975.

Wesemann, Larry, "Forecasting Use on Proposed High-Occupancy Vehicle Facilities in Orange County, California", Transportation Research Record 1181..

Wheeler, Larry, "Congress Puts Limits on Maglev Funding", Gannett News Service, October 18, 1993.

Summary: This article details maglev funding problems, with a focus on Congress.

Wheeler, Larry, "Funding for Maglev Train Axed, Research to Continue", Gannett News Service, September 23, 1992.

Summary: This article discusses maglev funding problem, and Senator Moynihan's efforts to keep maglev on the national agenda.

White, John H. Jr., "Horse Power", American Heritage of Invention and Technology 8(1), pp.40-51, Summer, 1992.

Summary: This article traces the history of the horse-drawn street railways. Although horse railways were costly and inefficient, they remained in service for fifty years. This is attributed to the ability of these railways to reliably meet their goals: to move passengers and earn their owners a decent profit. In fact, horsecar systems remained in operation until the trolley was introduced. The trolleys were the first new technology to offer significant improvements over the old system of horsecar railways. Trolleys were more powerful, relatively cheap to operate, fairly quiet, smokeless, dependable, prone to few ailments, did not cause sanitation problems in the streets, and did not require to be fed while off duty.

Williams, Trevor I., "The History of Invention: From Stone Axes to Silicon Chips", Facts on File Publications, 1987.

Summary: This section describes one of the social pressures for the development of the elevator. It discusses the introduction of the skyscraper in American cities, and the corresponding need for a means of transporting people to the upper stories.

Williams, Trevor I. (editor), "A History of Technology:-Volume 7: The Twentieth Century c1900-c1950 Part II.", Oxford University Press, 1978.

Summary: This book is a compilation of articles regarding the history of technology in the early 1900's (1900-1950). It is the second of two volumes covering this time period. Some general topics covered include: transportation (e.g. road vehicles, ships, trains, planes, and space technology), civil engineering (e.g. roads, bridges, harbors, tunnels), electricity and electronic engineering, computers, domestic appliances, medical technology, electrical communication, photography, printing, cinematography, and food technology.

Wooley, James P., "SST Keyed to Current Airline Operations", Aviation Week and Space Technology, pp. 38-44., January 5, 1970.

Summary: This article discusses how the SST has been designed to be compatible with current airline operations. It explains that the airlines will have little difficulty integrating the SST with their current system.

Zitner, A., "Ride to the Future", The Boston Globe , June 4, 1993.

APPENDIX B SUMMARY OF AUTOMOBILE LITIGATION

This appendix is extracted from The Law and Automated Highway Systems: Investigations of Cruise Control and Anti-Lock Brakes, by Bart W. Huffman, Alain Kornhauser, and Eric C. Huber (1994).

Included in this section, in summary form, are the outcomes of litigation involving cruise control, anti-lock brake, computer, and air bag systems. The outcomes are divided into decisions for the plaintiff and for the defendant. The presentation is for illustrative purposes only but it should provide a reasonable overview of how relatively sophisticated automobile components have fared in the legal system as of this writing. In keeping with the licensing requirements of the research tools which were used by the author to procure this information, it is emphasized that the information is presented solely for the promotion of scholarly research.

1.0 CRUISE CONTROL CASES

1.1 FOR PLAINTIFFS

Patty and Neal v. Toyota Motor Co., Nos. 4:91-CV-62 and 4:91-CV-63 (U.S.D.C. Ga. Sept. 10, 1992) (LEXIS, Verdct library, Gajury file).
Driver and passenger recovered $1,000,000 for injuries sustained when the vehicle in which they were traveling accelerated into a stopped tractor-trailer. Multiple bases of recovery were alleged, including a defective cruise control system and a loose floor mat which allegedly caused the accelerator to be depressed when the brake pedal was pushed down. Counsel and the jury concentrated on the floor mat problem, because the cruise control issue would have been "very technical and hard to prove."

Party names withheld, Tri-service ref. No. 59-16 (Ventura, Cal. settled on Feb. 1, 1992) (LEXIS, Verdct library, Cajury file).
An experienced motorcycle driver received $21,000 in settlement of a claim for injuries sustained when the cruise control device allegedly locked and the driver fell down because he was unable to slow down. The plaintiff driver alleged defective design and/or manufacture of the cruise control system. Of the $21,000, the manufacturer of the cruise control system contributed $11,000, and the retail distributor contributed $10,000.

Party names withheld, Tri-service ref. No. S91-06-17 (Riverside, Cal. settled on May 3, 1991) (LEXIS, Verdct library, JVR file).
The plaintiff received $250,000 from the defendant car manufacturer in settlement of a claim for injuries sustained when his car accelerated off an embankment. The car was traveling 80 m.p.h. when it left the road. Plaintiff alleged that an electric malfunction was triggered by the cruise control, resulting in sudden acceleration. The defendant contended that the plaintiff should have turned the car off, put it in neutral, or tried the emergency brake.

Pavill v. Sloane Chevrolet, et al., No. 89-5189, 1990 WL 466311 (U.S.D.C. Pa. Oct. 1990).

A jury awarded the plaintiff, a 35-year-old, $60,000 for soft tissue injuries which allegedly were caused by a defective cruise control system. The plaintiff claimed that the cruise control locked and he was forced to jump from his car. The verdict was rendered only against the dealership and installer defendants, as the manufacturer and designer defendants had contended that the cruise control was improperly installed, and not defectively designed. The installer unsuccessfully argued that the plaintiff should not have jumped from the car, but rather should have turned it off or placed it in neutral.

Party names withheld, Tri-service ref. No. 33-2 (Van Nuys, Cal. settled on Feb. 20, 1990) (LEXIS, Verdct library, Cajury file).

The plaintiff received $37,000 in settlement from the defendant driver of a vehicle which collided into the rear of plaintiff's vehicle. The defendant blamed the accident on sudden acceleration due to a defective cruise control system, and admitted that a malfunction had occurred 20 minutes earlier. The plaintiff alleged that the defendant was negligent in not pulling over before the accident, because the condition.

Taylor v. Diagnostic Technical Sys., Inc., No. 882-2412, 1990 WL 460915 (St. Louis County Cir. Ct. Mar. 1990).

A jury awarded the plaintiff $20,000 against the defendant company whose driver had rear-ended the plaintiff. The plaintiff claimed that the defendant's driver had blamed the accident on a jammed cruise control immediately after the accident.

Estate of Weisser v. Preston and CTL Dist., Inc., No. CA 89-1138, 1990 WL 463165 (Pasco County Cir. Ct. June 1990).

The plaintiff's estate was awarded $483,230 against the defendant driver. The plaintiff had been driving at 55 m.p.h. on cruise control and saw the lights of defendant's truck, but did not expect the truck to back into the intersection. The defendant claimed that the plaintiff had been intoxicated and should have slowed down to avoid the collision.

Fraley v. Stecher, Docket No. withheld, 1990 WL 465396 (Outagamie County Cir. Ct. Sept. 1990).

The defendant driver could not stop in time to avoid hitting the plaintiff's vehicle as it turned into a driveway because the defendant was driving with the cruise control unit on. The plaintiff was awarded $120,500 against the defendant driver.

Binenstock v. General Motors Corp., 3 Prod. Liab. L. Rep. 136 (ATLA) (Los Angeles County Super. Ct. July 2, 1984).

The plaintiff, an elderly man, recovered $301,514 for back injuries caused by a sequence of accidents in which his car lurched backward into a neighbor's tree and then forward through plaintiff's garage. His allegations were that the cruise control "stuck" and caused high idling of the engine.

Fisher v. General Motors Corp., 3 Prod. Liab. L. Rep. 20 (ATLA) (Los Angeles County Super. Ct. Nov. 3, 1983) (also reported in LEXIS, Verdct library, Cajury and CRA files).

The plaintiff recovered $600,000 in a wrongful death action, alleging that the cruise control self-activated, overrode the brake system, and caused the decedent's vehicle to drive off a cliff. The vehicle left 180 feet of skid marks on the road, 208 feet of skid marks on the shoulder, and another 76 feet of skid marks to the edge of the cliff. The defendant offered evidence that the cruise control unit worked perfectly even after the accident. The trial lasted 3-4 weeks and the jury was out for more than a day.

Lewis v. General Motors Corp., 3 Prod. Liab. L. Rep. 57 (ATLA) (Pulaski County Cir. Ct. June 22, 1983).

A secretary and her four children recovered $86,700 for a minor knee injury to the secretary and minor bruises on the children. The plaintiffs alleged that the cruise control system was defective in that it suddenly accelerated, causing the secretary's son, who was the driver, to lose control of the vehicle, which subsequently crossed the median and rolled over.

1.2 FOR DEFENDANTS

Ardoin v. General Motors Corp., No. 90-0503, 1992 WL 506244 (U.S.D.C. La. May 1992).

Plaintiff contended that the defective design and manufacture of her vehicle's cruise control system caused her car to accelerate out of control, resulting in an accident where her car left the road and overturned. The defendant prevailed at trial.

Parker v. General Motors Corp., No. 86-01-03213 (C.P. Philadelphia Apr. 1992) (LEXIS, Verdct library, JVR file).

A verdict was returned for defendants in a trial involving alleged defects in plaintiff's vehicle's acceleration components. Two witnesses who pulled the plaintiff from her vehicle testified that the accelerator was stuck and the engine was racing even after the accident, but defendant's expert testified that the cruise control's servo cable was stretched as a result of the accident, causing the throttle to open.

Robertson V. Nissan Motor Corp., No. C-666,570 (Los Angeles County Ct. Aug. 9, 1991) (LEXIS, Verdct library, Cajury file).

Plaintiff alleged that a cruise control defect caused unintentional acceleration (a fully open throttle) and the brakes were ineffective to stop her vehicle, resulting in a loss of control and collision. The court directed a verdict for defendants because the plaintiff's case was insufficient to state a reasonable basis for recovery.

Red v. General Motors Corp., et al., No. 360768-6 (Fresno County Super. Ct. July 1991) (LEXIS, Verdct library, Cajury file).

A verdict was returned in favor of defendants, who contended that plaintiff's acceleration problem was a result of mistakenly pushing the gas pedal instead of the brake pedal. The plaintiff had alleged loss of control resulting from the unexpected activation of the cruise control system.

Ammel v. Nissan Motor Corp., No. 577,345 (San Diego County Ct. Jan. 1, 1991) (LEXIS, Verdct library, Cajury file).

Plaintiff, a middle-aged insurance executive, was injured when the vehicle which she was driving accelerated 179 feet to a ramp and vaulted 54 feet through the air into (and through) the side of a wood frame structure. She alleged a defect in the speed sensor of the cruise control unit. Defendant showed that the vehicle had to have been operating at full throttle to reach a speed sufficient for a 54 foot vault, the cruise control system was incapable of the malfunction alleged by plaintiff, the brakes would have stopped the car at full throttle, and the only possible cause was plaintiff's mistaken depression of the accelerator pedal. A verdict was returned for defendant.

Deadwyler, et al. v. General Motors Corp. and Avery Greene Motors, No. 640337-4, 1990 WL 461615 (Alameda County Super. Ct. Apr. 1990).

Plaintiffs, an elderly female driver and passengers, were injured when the driver hit a guardrail at a rest stop. Defendants prevailed over plaintiffs claims for bruises, an eye injury, and emotional distress despite an expert's testimony that either the cruise control was defectively designed and situated, causing reactivation, or that the gas and accelerator pedals were too close together.

Boivin v. Transit Homes, Inc., No. 88-1877C, 1990 WL 459927 (U.S.D.C. Mo. Feb. 1990).

Plaintiff was injured in multiple collisions as she attempted to pass a wide-load trailer with her cruise control set at 65 m.p.h. The defendant denied that a collision with the trailer took place and alleged that plaintiff was driving at an unsafe speed. A verdict was returned for defendant.

Rudd v. General Motors Corp., et al., No. 202327, 1989 WL 392955 (Kern County Super. Ct. July 1989).

Defendant prevailed in a suit brought by an elderly woman plaintiff whose car struck a tree. The woman alleged a malfunction in the cruise control had caused sudden acceleration.

Cole v. General Motors Corp., 852 F.2d 568 (6th Cir. 1988).

Summary judgment was granted for the defendant (the court ruled that the plaintiff had no cognizable cause of action) where the plaintiff concocted an intricate series of alleged malfunctions and defects which resulted in inadvertent activation of the cruise control system in plaintiff's vehicle at a low speed. Specifically, the plaintiff's expert described the following scenario: inadvertent engagement of the cruise control at the same moment when "whipping" of the speedometer cables produced a false indication of a speed above the 25 m.p.h. "low limit" on the cruise control system, in conjunction with defective electric and manual cut-off switches on the brake pedal and a defective condition of the brakes which should have stopped the vehicle anyway.

Bradosky v. Volkswagen of America, 17 Prod. Liab. Advisory 5 (N.D. Ohio 1988).

Plaintiff sued on behalf of young boy who was killed by a vehicle with an allegedly defective cruise control system which caused unintended acceleration. The defendant prevailed, noting that the driver had stated shortly after the accident that her foot had slipped off the brake.

Raines v. Ron Hite Chevrolet Co., Prod. Liab. Rep. (CCH) ¶ 11474 (Tenn. App. 1987).

Judgment was affirmed for defendant, whose experts provided undisputed testimony that there were no mechanical defects in the cruise control system and that no foreign particles had entered it.

Babb v. Ford Motor Co., Inc., 535 N.E.2d 676 (Ohio Ct. App. 1987).

The jury found a negligent failure to warn of a defect in the cruise control system, and defective design of the cruise control system. The defendant's cruise control system had only an electrical disengage device with no mechanical back-up, and could fail even when the brake stop-light failed. Nonetheless, the plaintiff could not recover because the jury also found that neither the negligent failure to warn or defective design was the cause of the accident.

Strotman v. K.C. Summers Buick, Inc., 489 N.E.2d 1148 (Ill. App. Ct. 1986).
Plaintiffs alleged an "unknown defect" which caused their car to overturn while being driven on cruise control at 55 m.p.h. This allegation was dismissed by the court in favor of defendant, because the plaintiff failed to state a cause of action. The plaintiffs had failed to eliminate any components which might not have caused the accident and could not point to any facts from which an inference of defect might be drawn.

2.0 ANTI-LOCK BRAKE CASES

2.1 FOR DEFENDANTS

Chavez v. General Motors Corp., No. VC-001250 (Los Angeles County Ct. May 22, 1992) (LEXIS, Verdct library, Cajury file).
The jury returned an unanimous verdict in favor of defendant, who was sued for statutory breach of warranty with respect to the anti-lock brake system in plaintiff's newly purchased vehicle. The plaintiff alleged that a malfunction in the anti-lock brake caused the vehicle to skid. Despite several inspections and test drives, no defect in material or workmanship was revealed.

Myrick, et al. v. Fruehauf Corp. et al., 795 F. Supp. 1139 (N.D. Ga. 1992).
The plaintiff truck driver brought state tort law claims against the defendant truck and trailer manufacturers for injuries resulting from a collision. The plaintiff alleged defective design in the failure to install an anti-lock brake system in the truck or in the trailer. Such claims were not tenable; the Federal motor vehicle safety standards (stating that anti-lock systems were optional) preempted state tort law recovery, because such recovery would effectively establish standards higher than those imposed in the Federal regulatory scheme.

Champeau v. Fruehauf Corp., et al., 814 F.2d 1271 (8th Cir. 1987).
Plaintiffs recovered $1,000,000 at the first trial against defendant truck and anti-lock component manufacturers. A new trial was granted, however, because of judicial misconduct and because the first verdict was clearly against the weight of the evidence. The plaintiff had presented evidence of a brake failure and evidence of a potential specific defect in the anti-lock brake system, but had not presented any evidence connecting the two, i.e., there was no evidence of causation. At the second trial, a verdict was returned for the defendants.

Scott v. Whit Trucks, 699 F.2d 714 (5th Cir. 1983).
The plaintiff driver brought an action against the defendant truck manufacturer, alleging that when the brakes were lightly applied, the left front wheel "grabbed" and the truck "jackknifed," resulting in an accident which injured plaintiff. The jury's verdict in favor of the plaintiff was overturned by the trial judge in favor of the defendant because the plaintiff had not shown that either the anti-lock brakes in particular or the brake system in general were defectively designed or manufactured when the truck was relinquished from the manufacturer's control.

3.0 AIR BAG CASES

3.1 FOR PLAINTIFFS

Burge v. American Honda Motor Co., et al., No. 41,74,45 (Orange County Ct. settlement date withheld) (LEXIS, Verdct library, Cajury file).

The defendant settled with the plaintiff for a confidential amount just prior to trial. The plaintiff alleged that the vehicle in which she was a passenger was uncrashworthy, that its seat belt was inadequate and that it was not equipped with a passenger-side air bag when such would have been a reasonable inclusion.

Wright v. General Motors Corp., et al., No. 82-20212, 1987 WL 233632 (Orleans County Dist. Ct. October 1987).

Plaintiffs sued on behalf of driver who was killed in a head-on collision, naming as defendants the automobile manufacturer, the city with jurisdiction over the roadway, and the engineering firm which designed the roadway. Several causes of action were advanced, including that the car should have been equipped with some form of passive restraint, such as an air bag. Defendants settled with plaintiffs for $997, 500.

3.2 FOR DEFENDANTS

Perry v. Mercedes Benz of North America, Inc., 761 F. Supp. 437 (M.D. La. 1991).

Plaintiff sued for injuries sustained when she drove her car into a ditch after running a stop sign. She was not wearing her seat belt, but claimed that the air bag system in her car was defective in that it did not inflate on impact. A summary judgment was granted for defendants because no reasonable juror would conclude that the car's speed on impact was above the limit at which air bags are required to deploy according to federal regulations.

Steenberg, et al. v. Ford Motor Co., JVR No. 50659, 1989 WL 392202 (Dallas County Dist. Ct. June, 1989).

Plaintiffs sued on behalf of driver who was killed in an accident, alleging that the car's design was faulty in that it did not contain air bags or passive seat belts, and it had a steering column which was inferior in shock-absorbing capacity. The defendant contended that the accident arose from the driver's negligence and poor highway design. A verdict was returned for the defendants.

4.0 COMPUTER SYSTEM CASE

Peterson v. General Motors Corp., 904 F.2d 436 (8th Cir. 1990).

The defendant manufacturer prevailed in a suit brought by plaintiff pedestrians who were injured when a vehicle manufactured by defendant accelerated and struck them in a parking lot. The plaintiffs alleged that the vehicle's computer system allowed a burst of electromagnetic energy to corrupt its memory, causing the idle air control valve to fully open such that the vehicle surged backward when put in reverse with so much G-force pressure that the elderly driver could not apply sufficient pressure to the brake pedal to stop. The manufacturer contended that the only possible explanation was that the accelerator pedal had been depressed instead of the brake pedal, and then the accelerator pedal had been depressed even more as the driver remained convinced that she was depressing the brake.

APPENDIX C AGT SYSTEM DATA

Table C1. AGT System Summary Sheet — Airtrans

AGT System	Airtrans				
Type of Service	GRT, shared vehicle, scheduled				
Manufacturer	LTV Corporation				
System Location	Dallas/Fort Worth International Airport				
Vehicle Size and Capacity	Length (m) 6.3	Width (m) 2.1	Height (m) 3	Weight (kgs) 6,300	Capacity (persons) 40
Vehicle Specifications	Suspension	Axles are attached to the vehicle through an air-bag suspension. Tires are foam-filled rubber tires.			
	Propulsion	Rotary electric DC motor.			
	Brakes	Pneumatically actuated automotive type mechanical brakes. Mechanical force is transmitted to each brake by a dual chamber brake actuator.			
System Performance Specifications	Vehicles/Hour (each direction) 225	Persons/Hour (each direction) 9,000	Vehicle Speed (mph) 15	Minimum Headway (seconds) 18	
System Design Specifications	Lateral Control	Vehicle is guided by contact with the side walls of the guideway, through four on-board guide wheels. Guidance wheels are attached to the steering wheels by a mechanical linkage which provides steering input to all four wheels. The front and rear wheels steer in opposite directions to provide for a short turning radius.			
	Switching	A four inch wheel is attached to the top of each vehicle guidance wheel. Entrapment rails are mounted on top of the guideway side wall and are used to trap the vehicle steering bar switch wheels. The entrapment rails can be pivoted to direct the vehicle in the desired direction.			
	Longitudinal Control	Point Follower			
	Headway Protection	Fixed five-block system. At normal operating speeds, vehicles must maintain a safe separation. As the separation is closed, the vehicle is instructed to slow. For separations of less than two blocks, the vehicle is instructed to stop.			

References:

Black, Ian et al. (1975). *Advanced Urban Transport.* Westmead: Saxton House, pp. 198-199.

Cumbie, Jim. (1989). “Airtrans: Problems and Potential,” *The New Electric Railway Journal*, v. 4, pp. 4-10.

Cuncliffe, J. Peter. (1975). "Progress Reports on System Development," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, pp. 84.

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People Mover Profile. (1977). USDOT, UMTA-MA-06-0081-77-1. May. pp. 20-21.

Strobel, Horst. (1982). *Computer Controlled Urban Transportation.* Chichester: John Wiley & Sons, pp. 418-430.

Table C2. AGT System Summary Sheet — Aramis

AGT System	Aramis						
Type of Service	PRT, personal or shared vehicle, on-demand						
Manufacturer	Matra						
System Location	Orly International Airport, Paris, France						
Vehicle Size and Capacity	Length (m) 2.3	Width (m) 1.3	Height (m) 1.9	Weight (kgs) 643.5	Capacity (persons) 4/10		
Vehicle Specifications	Suspension	Vehicles run on air-filled rubber tires.					
	Propulsion	Two rotary electric DC motors drive each rear wheel separately.					
	Brakes	Propulsion thrust reversal.					
System Performance Specifications	Vehicles/Hour (each direction) 500 - 3,750	Persons/Hour (each direction) 2,000 - 15,000	Vehicle Speed (mph) 30	Minimum Headway (seconds) .2			
System Design Specifications	Lateral Control	On-board horizontal wheels roll on two lateral guide rails.					
	Switching	Vehicle-borne arm embraces the left or right guiderail.					
	Longitudinal Control	Vehicle Follower					
	Headway Protection	Fixed Block. Vehicles are platooned through electronic coupling.					

References:

Black, Ian et al., (1975). *Advanced Urban Transport.* Westmead: Saxton House, p. 195.

Cuncliffe, J. Peter. (1975). "Progress Reports on System Development," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, p.68.

Levy, Gerard. (1976). "The French Aramis System," In *Personal rapid Transit III.* Minneapolis: University of Minnesota, pp. 75-76.

MacKinnon, Duncan. (1975). "High Capacity Personal Rapid Transit System Developments," *IEEE Transactions on Vehicular Technology,* VT-24(1).

Strobel, Horst. (1982). *Computer Controlled Urban Transportation.* Chichester: John Wiley & Sons, p. 471.

Table C3. AGT System Summary Sheet — Bendix-Dashaveyor

<table>
<tr><td>AGT System</td><td colspan="5">Bendix-Dashaveyor</td></tr>
<tr><td>Type of Service</td><td colspan="5">GRT, shared vehicle, scheduled or on-demand</td></tr>
<tr><td>Manufacturer</td><td colspan="5">The Dashaveyor Company, subsidiary of The Bendix Corporation</td></tr>
<tr><td>System Location</td><td colspan="5">Metro Toronto Zoo</td></tr>
<tr><td>Vehicle Size and Capacity</td><td>Length (m)
6.9</td><td>Width (m)
2.1</td><td>Height (m)
3.24</td><td>Weight (kgs)
8,100</td><td>Capacity (persons)
32</td></tr>
<tr><td rowspan="3">Vehicle Specifications</td><td>Suspension</td><td colspan="4">Vehicle runs on air-filled rubber tires.</td></tr>
<tr><td>Propulsion</td><td colspan="4">Two 25 hp rotary DC motors.</td></tr>
<tr><td>Brakes</td><td colspan="4">Mechanical friction brakes.</td></tr>
<tr><td>System Performance Specifications</td><td>Vehicles/Hour (each direction)
240</td><td>Persons/Hour (each direction)
7,680</td><td>Vehicle Speed (mph)
30</td><td colspan="2">Minimum Headway (seconds)
15</td></tr>
<tr><td>System Design Specifications</td><td>Lateral Control</td><td colspan="4">On-board rubber guide wheels roll along side guide rails.</td></tr>
<tr><td></td><td>Switching</td><td colspan="4">Off-board guide wheels.</td></tr>
<tr><td></td><td>Longitudinal Control</td><td colspan="4">Vehicle Follower</td></tr>
<tr><td></td><td>Headway Protection</td><td colspan="4">Fixed Block</td></tr>
</table>

References:

Cuncliffe, J. Peter. (1975). "Progress Reports on System Development," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, pp. 80-81.

MacKinnon, Duncan. (1974). "Personal Rapid Transit Systems at Transpo 72," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis, University of Minnesota, pp. 35-45.

Strobel, Horst. (1982). *Computer Controlled Urban Transportation.* Chichester: John Wiley & Sons, p. 446.

Table C4. AGT System Summary Sheet — Cabinentaxi

AGT System	Cabinentaxi					
Type of Service	PRT, personal vehicle, on-demand					
Manufacturer	Demag and MBB					
System Location	Ziegenhain Hospital, Ziegenhain, Germany					
Vehicle Size and Capacity	Length (m) 2.25	Width (m) 1.56	Height (m) 1.47	Weight (kgs) 693	Capacity (persons) 3	
Vehicle Specifications	Suspension	Vehicles either run along rail or are top suspended.				
	Propulsion	Two linear induction three-phase AC motors.				
	Brakes	Linear induction motor provides braking forces. Hydraulically operated wheel brakes.				
System Performance Specifications	Vehicles/Hour (each direction) 3,000 - 5,000	Persons/Hour (each direction) 9,000 - 15,000	Vehicle Speed (mph) 22.5	Minimum Headway (seconds) .7		
System Design Specifications	Lateral Control	On-board horizontal wheels bear on a central spine.				
	Switching	Vehicle-borne arm embraces the left or right guiderail.				
	Longitudinal Control	Vehicle Follower				
	Headway Protection	Spacing controlled by three separate non-fail safe systems.				

References:

Becker, Klaus. (1976). "Cabintaxi: Technical Level, Market Situation, and Targets," In *Personal Rapid Transit III.* Minneapolis: University of Minnesota, pp. 69-74.

Black, Ian, et al., (1975). *Advanced Urban Transport.* Westmead: Saxton House, pp. 196-197.

Cunliffe, J. Peter. (1975). "Progress reports on System Development," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, pp. 66-67.

MacKinnon, Duncan. (1975). "High Capacity Personal Rapid Transit System Developments," *IEEE Transactions on Vehicular Technology,* VT-24(1).

Strobel, Horst. (1982). *Computer Controlled Urban Transportation.* Chichester: John Wiley & Sons, p. 471.

Table C5. AGT System Summary Sheet — CVS

AGT System	CVS				
Type of Service	PRT, personal vehicle, on-demand				
Manufacturer	Japan Society for the Promotion of Machine Industry				
System Location	Demonstration system in Higashimurayama City, Japan				
Vehicle Size and Capacity	Length (m) 3.24	Width (m) 1.74	Height (m) 2.07	Weight (kgs) 990	Capacity (persons) 4
Vehicle Specifications	Suspension	Vehicle runs on air-filled rubber tires and has a mechanical spring suspension.			
	Propulsion	Rotary electric DC motor.			
	Brakes	Propulsion thrust reversal.			
System Performance Specifications	Vehicles/Hour (each direction) 3,750	Persons/Hour (each direction) 15,000	Vehicle Speed (mph) 25	Minimum Headway (seconds) 1	
System Design Specifications	Lateral Control	Mechanical, vehicle-borne front arm is attached to the front steering mechanism of the vehicle. The other end of the arm is inserted into the guide groove in the center of the guideway. this end of the front arm has two small wheels which run along the horizontal guide rail, located within the guide groove.			
	Switching	Mechanical, on-board switching. At a switching point, if the front arm moves to the right, the vehicle's steering mechanism turns the vehicle to the right. For a turn to the left, the front arm must move to the left..			
	Longitudinal Control	Point Follower			
	Headway Protection	Moving Block			

References:

Black, Ian, et al., (1975). *Advanced Urban Transport.* Westmead: Saxton House, pp. 197-198.

Cunliffe, J. Peter. (1975). "Progress reports on System Development," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, pp. 72-73.

Ishii, Takemochi, et al. (1976). "CVS: Computer-Controlled Vehicle System," In *Personal rapid Transit III.* Minneapolis: University of Minnesota, pp. 77-83.

MacKinnon, Duncan. (1975). "High Capacity Personal Rapid Transit System Developments," *IEEE Transactions on Vehicular Technology,* VT-24(1).

Strobel, Horst. (1982). *Computer Controlled Urban Transportation.* Chichester: John Wiley & Sons, p. 471.

Table C6. AGT System Summary Sheet — Ford ACT

<table>
<tr><td>AGT System</td><td colspan="5">Ford ACT</td></tr>
<tr><td>Type of Service</td><td colspan="5">GRT, shared vehicle, scheduled or on-demand</td></tr>
<tr><td>Manufacturer</td><td colspan="5">Ford Motor Company</td></tr>
<tr><td>System Location</td><td colspan="5">Fairlane Shopping Center, Dearborn, Michigan
Bradley International Airport, Hartford, Connecticut</td></tr>
<tr><td>Vehicle Size and Capacity</td><td>Length (m)
7.5</td><td>Width (m)
2.0</td><td>Height (m)
2.64</td><td>Weight (lbs)
6,750</td><td>Capacity (persons)
24</td></tr>
<tr><td rowspan="3">Vehicle Specifications</td><td>Suspension</td><td colspan="4">Vehicle runs on foam filled rubber tires. Coil spring suspension.</td></tr>
<tr><td>Propulsion</td><td colspan="4">Two 60 hp rotary DC motors.</td></tr>
<tr><td>Brakes</td><td colspan="4">Friction drums.</td></tr>
<tr><td>System Performance Specifications</td><td>Vehicles/Hour (each direction)
450</td><td colspan="2">Persons/Hour (each direction)
10,800</td><td>Vehicle Speed (mph)
30</td><td>Minimum Headway (seconds)
150</td></tr>
<tr><td>System Design Specifications</td><td>Lateral Control</td><td colspan="4">Mechanical, on-board rubber guide wheels roll along side guide rails.</td></tr>
<tr><td></td><td>Switching</td><td colspan="4">Mechanical, on-board guide wheels steer vehicle through passive guideway switch sections.</td></tr>
<tr><td></td><td>Longitudinal Control</td><td colspan="4">Point Follower</td></tr>
<tr><td></td><td>Headway Protection</td><td colspan="4">Moving Block</td></tr>
</table>

References:

Cunliffe, J. Peter. (1975). "Progress reports on System Development," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, pp. 82-83.

MacKinnon, Duncan. (1974). "Personal Rapid Transit Systems at Transpo 72," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis, University of Minnesota, pp. 35-45.

People Mover Profile. (1977). USDOT, UMTA-MA-06-0081-77-1, May, pp. 14-15.

Strobel, Horst. (1982). *Computer Controlled Urban Transportation.* Chichester: John Wiley & Sons, p. 446.

Table C7. AGT System Summary Sheet — H-Bahn

AGT System	H-Bahn				
Type of Service	GRT, shared vehicle, scheduled or on-demand				
Manufacturer	Siemans and Duwag				
System Location	Dortmund University, Dortmund, Germany				
Vehicle Size and Capacity	Length (m) 3.42**	Width (m) 2.28**	Height (m) 2.28**	Weight (lbs) 2,475**	Capacity (persons) 16**
Vehicle Specifications	Suspension	Suspended from overhead guideway by steel wheels (with composite facing) which run on the inside bottom of a box beam.			
	Propulsion	Two linear synchronous electric motors.			
	Brakes	Linear motors run asynchronously, aided by caliper brakes on the track rail.			
System Performance Specifications	Vehicles/Hour (each direction) 113**	Persons/Hour (each direction) 1,800 **	Vehicle Speed (mph) 30	Minimum Headway (seconds) 40	
System Design Specifications	Lateral Control	Mechanical. Horizontal rubber wheels roll on the vertical upper inside surface of the box-beam guideway.			
	Switching	Magnetic. The two motors generate magnetic forces to bias the vehicle in the desired direction, or supporting wheels both pass to one side of a switching point, with lateral guidance rollers taking over for guidance.			
	Longitudinal Control	Point Follower			
	Headway Protection	Moving Block			

References:

Black, Ian, et al. (1975). *Advanced Urban Transport.* Westmead; Saxton House, pp. 199-200.

Frederich. (1976). "Design and Application of the Siemans/Duwag H-Bahn: An Overhead Cabin System," In *Personal Rapid Transit III.* Minneapolis: University of Minnesota, pp. 59-67.

Table C8. AGT System Summary Sheet — Horvair

<table>
<tr><td>AGT System</td><td colspan="5">Horvair</td></tr>
<tr><td>Type of Service</td><td colspan="5">PRT/GRT, shared vehicle, scheduled or on-demand</td></tr>
<tr><td>Manufacturer</td><td colspan="5">Transportation Technology, Inc. (TTI), a subsidiary of Otis Elevator Company</td></tr>
<tr><td>System Location</td><td colspan="5">Duke University, Durham, North Carolina
Harbour Island, Tampa, Florida
Sun City, South Africa
Serfaus, Austria</td></tr>
<tr><td>Vehicle Size and Capacity</td><td>Length (m)
4.65</td><td>Width (m)
2.25</td><td>Height (m)
2.4</td><td>Weight (kgs)
4,590</td><td>Capacity (persons)
6/10</td></tr>
<tr><td rowspan="3">Vehicle Specifications</td><td>Suspension</td><td colspan="4">Blowers on-board the vehicle supply compressed air to a series of pods beneath the vehicle.</td></tr>
<tr><td>Propulsion</td><td colspan="4">Linear induction motor.</td></tr>
<tr><td>Brakes</td><td colspan="4">Propulsion thrust reversal.</td></tr>
<tr><td>System Performance Specifications</td><td>Vehicles/Hour (each direction)
300</td><td>Persons/Hour (each direction)
1,800/3,000</td><td>Vehicle Speed (mph)
30</td><td colspan="2">Minimum Headway (seconds)
12</td></tr>
<tr><td>System Design Specifications</td><td>Lateral Control</td><td colspan="4">Mechanical. An angle iron rail is attached to the parapet wall of the guideway. Lateral guidance wheels roll against the side of the guideway.</td></tr>
<tr><td></td><td>Switching</td><td colspan="4">Magnetic. Electromagnets draw the vehicle into the proper channel on the guideway.</td></tr>
<tr><td></td><td>Longitudinal Control</td><td colspan="4">Vehicle Follower</td></tr>
<tr><td></td><td>Headway Protection</td><td colspan="4">Fixed Block</td></tr>
</table>

References:

Black, Ian et al. (1975). *Advance Urban Transport.* Westmead: Saxton House, pp. 200-201.

Cuncliffe, J. Peter. (1975). "Progress Reports on System Development," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, pp. 88-89.

MacKinnon, Duncan. (1974). "Personal Rapid Transit Systems at Transpo 72," *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, pp. 35-45.

Strobel, Horst. (1982). *Computer Controlled Urban Transportation.* Chichester: John Wiley & Sons, p. 446.

Table C9. AGT System Summary Sheet — Monocab

AGT System	Monocab				
Type of Service	PRT/GRT, personal vehicle, on-demand				
Manufacturer	Monocab Incorporated, subsidiary of Rohr Industries				
System Location	Demonstration track at Transpo 72				
Vehicle Size and Capacity	Length (m) 3.9	Width (m) 1.65	Height (m) 2.01	Weight (lbs) 1.845	Capacity (persons) 6
Vehicle Specifications	Suspension	Vehicle suspended from monorail. Air filled rubber tires.			
	Propulsion	40 hp rotary DC motor.			
	Brakes	Friction disks.			
System Performance Specifications	Vehicles/Hour (each direction) 350	Persons/Hour (each direction) 2,700	Vehicle Speed (mph) 35	Minimum Headway (seconds) 10	
System Design Specifications	Lateral Control	Mechanical. On-board rubber guide wheels roll along a suspended monorail.			
	Switching	Mechanical.. Off-board actuation of on-board guide wheels.			
	Longitudinal Control	Vehicle Follower			
	Headway Protection	Moving Block			

References:

Cunliffe, J. Peter. (1975). "Progress reports on System Development," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, pp. 86-87.

MacKinnon, Duncan. (1974). "Personal Rapid Transit Systems at Transpo 72," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis, University of Minnesota, pp. 35-45.

Strobel, Horst. (1982). *Computer Controlled Urban Transportation.* Chichester: John Wiley & Sons, p. 446.

Table C10. AGT System Summary Sheet — Morgantown

AGT System	Morgantown				
Type of Service	GRT, shared vehicle, scheduled or on-demand				
Manufacturer	Boeing Aerospace Company				
System Location	University of West Virginia, Morgantown, West Virginia				
Vehicle Size and Capacity	Length (m) 4.65	Width (m) 1.8	Height (m) 2.61	Weight (kgs) 3,893	Capacity (persons) 21
Vehicle Specifications	Suspension	Vehicle runs on air-filled rubber tires and has a air bag damped suspension.			
	Propulsion	60 hp rotary DC motor.			
	Brakes	Redundant four wheel hydraulically operated disk braking system.			
System Performance Specifications	Vehicles/Hour (each direction) 240	Persons/Hour (each direction) 5,040	Vehicle Speed (mph) 30	Minimum Headway (seconds) 15	
System Design Specifications	Lateral Control	Mechanical. Support wheels are biased left or right. An on-board control arm senses a trough wall and alters the steering to permit the vehicle to follow it.			
	Switching	Mechanical. Vehicle steering is biased to the left or right wall of the trough at a divergent switch.			
	Longitudinal Control	Point Follower			
	Headway Protection	Moving Block			

References:

Black, Ian, et al. (1975). *Advanced Urban Transport.* Westmead: Saxton House, pp. 202-203.

Cunliffe, J. Peter. (1975). "Progress Reports on System Development," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, pp. 76-77.

Elias, S. (1975). "The West Virginia University-Morgantown PRT System," In *Personal Rapid Transit III.* Minneapolis: University of Minnesota, pp. 15-33.

Elias, S., et al. (1982). *Impact of People Movers on Travel: Morgantown, A Case Study.* Transportation Research Record # 882, pp. 7-12.

MacKinnon, Duncan. (1974). "Personal Rapid Transit Systems at Transpo 72," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis, University of Minnesota, pp. 35-45.

People Mover Profile. (1977). USDOT, UMTA-MA-06-0081-77-1, May, pp. 10-11.

Table C11. AGT System Summary Sheet — Skybus

AGT System	Skybus					
Type of Service	GRT, shared vehicle, scheduled					
Manufacturer	Westinghouse					
System Location	Tampa International Airport Seattle/Tacoma International Airport					
Vehicle Size and Capacity	Length (m) 11.1	Width (m) 2.79	Height (m) 3.3	Weight (kgs) 8,550	Capacity (persons) 70	
Vehicle Specifications	Suspension	Vehicles run on air filled rubber tires and have air/taper leaf spring suspensions.				
	Propulsion	Two 60 hp rotary DC motors.				
	Brakes	Mechanical friction disks.				
System Performance Specifications	Vehicles/Hour (each direction) 30	Persons/Hour (each direction) 2,100	Vehicle Speed (mph) 35	Minimum Headway (seconds) 120		
System Design Specifications	Lateral Control	Mechanical. On-board rubber guide wheels roll on a central guide rail.				
	Switching	Mechanical. An off-board guide rail must move to the desired path.				
	Longitudinal Control	Vehicle Follower				
	Headway Protection	Fixed Block				

References:

MacKinnon, Duncan. (1974). "Personal Rapid Transit Systems at Transpo 72," *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, pp. 35-45.

People Mover Profile. (1977). USDOT, UMTA-MA-06-0081-77-1, May, pp. 24-25.

Table C12. AGT System Summary Sheet — Transurban

AGT System	Transurban				
Type of Service	GRT, shared vehicle, scheduled				
Manufacturer	Krauss-Maffei				
System Location	Demonstration Track in Munich, Germany				
Vehicle Size and Capacity	Length (m) 5.91	Width (m) 1.98	Height (m) 2.79	Weight (kgs) 5,400	Capacity (persons) 20
Vehicle Specifications	Suspension	Electromagnets on vehicles are attracted to armature rails on the guideway. The current through the magnets is regulated to maintain a constant air gap.			
	Propulsion	Linear AC three-phase induction motor.			
	Brakes	Linear induction motor aided by friction brakes bearing on a track rail.			
System Performance Specifications	Vehicles/Hour (each direction) 50 - 1,000	Persons/Hour (each direction) 1,000 - 20,000	Vehicle Speed (mph) 50	Minimum Headway (seconds) 10	
System Design Specifications	Lateral Control	Support magnets.			
	Switching	Magnetic. A set of electromagnets on-board the vehicle selects the path when switched in the correct sequence.			
	Longitudinal Control	Vehicle Follower			
	Headway Protection	Fixed Block			

References:

Black, Ian et al. (1975). *Advance Urban Transport.* Westmead: Saxton House, pp. 203-204.

Cuncliffe, J. Peter. (1975). "Progress Reports on System Development," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, pp. 70-71.

Table C13. AGT System Summary Sheet — Uniflo

AGT System	Uniflo					
Type of Service	PRT/GRT, shared vehicle, on-demand					
Manufacturer	Uniflo Systems Company					
System Location	Demonstration track in Minneapolis, Minnesota					
Vehicle Size and Capacity	Length (m) *	Width (m) *	Height (m) *	Weight (kgs) 675	Capacity (persons) 8	
Vehicle Specifications	Suspension	Levitated by air blowing beneath the vehicle.				
	Propulsion	Track based pneumatic control regulates the flow of air from valves in the guideway. Air is forced under levitation pads into forward thrusters.				
	Brakes	Air flows under levitation pads into reverse thrusters.				
System Performance Specifications	Vehicles/Hour (each direction) 625 - 2,500	Persons/Hour (each direction) 5,000 - 20,000	Vehicle Speed (mph) 20	Minimum Headway (seconds) 3		
System Design Specifications	Lateral Control	Mechanical. Guideway is totally enclosed.				
	Switching	Mechanical, with magnetic control. A channel at the side of the track 'traps' the guide wheels, and then the channel moves to guide the vehicle to the desired route. A set of ferrous tabs are magnetized in a particular sequence indicating the designation of the vehicle, and sensors on the guideway read the tabs and cause switching as necessary.				
	Longitudinal Control	Sensors along the guideway control speed by regulating the number of air valves in the propulsion system that open.				
	Headway Protection	No valves open if vehicles become too close together, which cuts off the air supply to the propulsion system.				

References:

Black, Ian et al. (1975). *Advance Urban Transport.* Westmead: Saxton House, pp. 67-68.

Cuncliffe, J. Peter. (1975). "Progress Reports on System Development," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, pp. 90-91.

Table C14. AGT System Summary Sheet — VAL

AGT System	VAL				
Type of Service	GRT, shared vehicle, on-demand				
Manufacturer	Matra				
System Location	Lille, France				
Vehicle Size and Capacity	Length (m) 13	Width (m) 2.01	Height (m) 3.21	Weight (kgs) 14,652	Capacity (persons) 64
Vehicle Specifications	Suspension	Aircushions (four per vehicle) are used to support the vehicles. Vehicles also have an elastometric series suspension with four pneumatic tires.			
	Propulsion	Two 120 kW DC motors.			
	Brakes	Conjugative regenerative braking and pneumatic friction disks.			
System Performance Specifications	Vehicles/Hour (each direction) 31 - 234	Persons/Hour (each direction) 2,000 - 15,000	Vehicle Speed (mph) 37.5	Minimum Headway (seconds) 60	
System Design Specifications	Lateral Control	Eight pneumatic tires are mounted horizontally on the vehicles, and run along the side of the guideway.			
	Switching	Mechanical. Two metal rollers are located in the axes of the vehicle. When the rollers come over points in the track, the rollers engage in a groove formed by two rails. This sends the vehicle in the desired direction.			
	Longitudinal Control	Vehicle Follower			
	Headway Protection	Fixed Block			

References:

Cuncliffe, J. Peter. (1975). "Progress Reports on System Development," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, p. 68.

Lardennois, R. (1993). "VAL Automated Guideway Transit Characteristics and Evolution," *Journal of Advanced Transportation,* 27(1), pp. 103-120.

Mimoun. (1985). "Lille DPM System - VAL Family," In *Automated People Movers.* New York: American Society of Civil Engineers, pp. 256-287.

Tremong, Francois. (1985). "The Lille Underground - First Application of the VAL System," *Journal of Advanced Transportation,* 19(1), pp. 39-53.

Table C15. AGT System Summary Sheet — VEC

AGT System	VEC				
Type of Service	PRT, personal, on-demand				
Manufacturer	Cytec Development, Inc.				
System Location	Demonstration track in Paris, France				
Vehicle Size and Capacity	Length (m) 1.8	Width (m) 1.05	Height (m) 1.74	Weight (kgs) *	Capacity (persons) 2 - 6
Vehicle Specifications	Suspension	Vehicles run on air-filled rubber tires.			
	Propulsion	Linear induction motor drives a conveyor belt.			
	Brakes	Speed of conveyor belt is slowed until it is stopped.			
System Performance Specifications	Vehicles/Hour (each direction) 1,670	Persons/Hour (each direction) 10,000	Vehicle Speed (mph) 10 - 20	Minimum Headway (seconds) 2	
System Design Specifications	Lateral Control	Mechanical. On-board wheels ride along a guide rail.			
	Switching	*			
	Longitudinal Control	Controlled by the conveyor, no computers are used.			
	Headway Protection	The conveyor locks vehicles together mechanically. Separation is maintained by contact with the conveyor.			

References:

Cuncliffe, J. Peter. (1975). "Progress Reports on System Development," In *Personal Rapid Transit II: Progress, Problems, Potential.* Minneapolis: University of Minnesota, pp. 78-79.

Table C16. Operating Automated People Movers — 1993

(Source: Sproule, William J., " An Introduction to APM Systems and Applications," In *Automated People Movers IV: Enhancing Values in Major Activity Centers.* New York: American Society of Civil Engineers

Type	Location	Description	Start of Service	Length of Guide-way	System Supplier
Airport	Atlanta, Georgia	System links two landside buildings with four remote airside buildings.	1980/ 1991	5.7 km	AEG Westinghouse
Airport	Birmingham, U.K.	Shuttle between terminal and train station.	1984	.6 km	People Mover Group
Airport	Chicago (O'Hare), Illinois	System links terminal buildings with remote parking.	1993	4.3 km	Matra
Airport	Cincinnati, Ohio	Shuttle serves new terminal expansion.	under const.	.4 km	Otis
Airport	Dallas-Fort Worth, Texas	System connects five terminals, hotel, and remote parking areas.	1974/ 1991	22.4 km	Vought
Airport	Denver, Colorado	System links landside terminal with three remote airside buildings.	under const.	3.9 km	AEG Westinghouse
Airport	Frankfurt, Germany	Pinched loop connects two terminals.	under const.	3.8 km	AEG Westinghouse
Airport	Hartford, Connecticut	Shuttle connects main terminal with a remote parking lot.	1974		Ford
Airport	Houston, Texas	Closed loop connects three terminals, hotel, and remote parking area.	1972/ 1990	2.6 km	WEDway
Airport	Las Vegas, Nevada	Shuttle between landside terminal and airside building.	1985	.8 km	AEG Westinghouse
Airport	London (Gatwick), U.K.	Shuttle between landside terminal and airside building. Another shuttle links terminals with train station.	1983/ 1988	3.0 km	AEG Westinghouse
Airport	London (Stansed), U.K.	Shuttle between main terminal and airside building.	1991	2.7 km	AEG Westinghouse
Airport	Miami, Florida	Shuttle between landside terminal and airside building.	1980	.8 km	AEG Westinghouse
Airport	Newark, New Jersey	Monorail line links remote parking and terminals.	under const.	3.8 km	AEG Von Roll
Airport	Orlando, Florida	Shuttles connect landside terminal and airside buildings.	1981/ 1989	3.5 km	AEG Westinghouse
Airport	Paris (Orly), France	Shuttle between terminals and regional rail system.	1991	7.2 km	Matra
Airport	Pittsburgh, Pennsylvania	Shuttle between landside terminal and an airside terminal in midfield.	1992	1.5 km	AEG Westinghouse
Airport	Seattle-Tacoma, Washington	Two loops link central terminal with satellites. Loops are connected by a shuttle service.	1973	2.7 km	AEG Westinghouse

Table C16. Operating Automated People Movers — 1993 (continued)

Type	Location	Description	Start of Service	Length of Guide-way	System Supplier
Airport	Singapore	Shuttles link landside and airside stations in two terminals.	1989	1.3 km	AEG Westinghouse
Airport	Tampa, Florida	Shuttle connects landside terminal to five airside buildings. Monorail links parking garage with central landside terminal.	1971/ 1987/ 1991	3.9 km	AEG Westinghouse/ TGI Bombardier
Airport	Tokyo, Japan	Two elevated shuttles, linking new landside and airside terminals.	1992	.5 km	Otis
Institutional	Broadbeach Gold Coast, Australia	Monorail loop linking shopping center, hotel, and casino.	1989	1.3 km	AEG Von Roll
Institutional	Bull-La Defense, Paris, France	Shuttle between two stations. Suspended monorail, propelled by cables.	1990	.1 km	Pomagalski
Institutional	Circus-Circus Hotel/Casino, Las Vegas, Nevada	Two shuttles between two hotel towers and casino.	1981/ 1986	.6 km	VSL
Institutional	Circus-Circus Hotel/Casino, Reno, Nevada	Two shuttles between hotel tower and casino.	1985	.4 km	VSL
Institutional	Docklands, London, U.K.	Automated light rail transit linking London financial district to Docklands area.	1987/ 1991	13.6 km	GEC/Mowlem
Institutional	Dortmund University, Dortmund, Germany	Vehicles are suspended from guideway, linking two parts of the campus.	1984	1.0 km	Siemens/ Duewag
Institutional	Duke University Hospital, Durham, North Carolina	Shuttle connects two buildings of the Duke University medical school and remote parking.	1980	1.0 km	Otis
Institutional	Fairlane Shopping Center, Dearborn, Michigan	Single lane shuttle, with double lane bypasses connect a shopping center with a hotel.	1976	1.0 km	Ford
Institutional	Harbour Island, Tampa, Florida	Shuttle between new Harbour Island development and downtown Tampa.	1985	.7 km	Otis
Institutional	Hyatt Regency Resort, Waikoloa, Hawaii	Monorail operates throughout the resort.	1987	1.5 km	VSL
Institutional	Las Colinas, Dallas, Texas	PRT system provides service in the urban center of the Los Colinas community.	1989	4.9 km	AEG Westinghouse
Institutional	Merry Hill Shopping Complex, Birmingham, U.K.	Low speed monorail.	1991	3.6 km	AEG Von Roll

Table C16. Operating Automated People Movers — 1993 (continued)

Type	Location	Description	Start of Service	Length of Guide-way	System Supplier
Institutional	Mirage Hotel and Casino, Las Vegas, Nevada	Monorail to connect two casinos/resorts.	under const.	.3 km	VSL
Institutional	Mud Island, Memphis, Tennessee	Suspended vehicles shuttle between a public park, Mud Island, and the Memphis Civic Center.	1982	.5 km	VSL
Institutional	Noisy Le Grand, France	Shuttles between an office complex and a regional rail station.	under const.	.5 km	Soule
Institutional	Pearlridge Shopping Center, Honolulu, Hawaii	Monorail links two buildings of the complex across a parking area.	1978	.4 km	AEG Westinghouse (Rohr)
Institutional	Primadonna, Stateline, Nevada	Shuttles between two casinos over an interstate highway.	1991	.5 km	VSL
Institutional	Sertaus, Austria	Shuttle operates underground in the downtown of a small ski resort town, linking remote parking areas to the ski area.	1985	1.3 km	Otis
Institutional	Sun City Resort, South Africa	Shuttles between remote parking, hotel/casino, and entertainment center.	1986	1.7 km	Otis
Institutional	U.S. Senate	Underground system to link U.S. Capital with two Senate office buildings.	under const.	1.0 km	TGI/ Bombardier
Institutional	West Virginia University, Morgantown, West Virginia	Links downtown Morgantown with downtown and suburban college campuses. Provides non-stop origin destination service.	1975/ 1979	14.0 km	Boeing
Institutional	Ziegenhain Hospital, Ziegenhain, Germany	Suspended vehicles shuttle between main complex and an extended care facility.	1976	.6 km	Cabinentaxi
Urban Mass Transit	Berlin, Germany	Maglev shuttle linking two metros..	1989	3.0 km	AEG/M-Bahn
Urban Mass Transit	Chiba, Japan, “Yamanote Line”	Monorail utilized as urban transportation in CBD.	1988	15.5 km	Chiba Urban Monorail Corp., Ltd.
Urban Mass Transit	Detroit, Michigan, “Detroit People Mover”	One-way loop in downtown Detroit.	1987	4.7 km	UTDC
Urban Mass Transit	Hiroshima, Japan	Line Haul Service to connect a new town with Hiroshima.	under const.	12.7 km	
Urban Mass Transit	Jacksonville, Florida, “Automated Skyway Express”	Links convention center and remote parking area to downtown.	1989	1.1 km	Marta

Table C16. Operating Automated People Movers — 1993 (continued)

Type	Location	Description	Start of Service	Length of Guide-way	System Supplier
Urban Mass Transit	Kita Kyushu, Japan, “Kokura Line”	Monorail utilized as urban transportation in CBD.	1985	8.4	Kitakyushu Urban Monorail Corp., Ltd.
Urban Mass Transit	Kobe, Japan, “Portliner”	Loop connecting Kobe Port Island development to mainland railway station.	1981	6.4 km	Kobe/ Kawasaki
Urban Mass Transit	Kobe, Japan, “Rokko Island Line”	Shuttle connecting Kobe Rokko Island development to mainland railway station.	1990	4.5 km	Kobe/ Kawasaki
Urban Mass Transit	Komaki, Japan, “Tokadai Line”	Line connects newly developed area to regional rail network.	1990	7.4 km	Nippon/Mitsui
Urban Mass Transit	Laon, France	Cable driven system links upper city with upper city and railway station.	1984	1.5 km	Pomagalski
Urban Mass Transit	Lille, France, “VAL”	An automated system in line haul service, connects the suburb of Villeneuve d’Aseq with Lille CBD.	1983/ 1989	25.2 km	Marta
Urban Mass Transit	Lyon, France	Automated vehicles on Line D of the rail rapid transit system.	1991	12.0 km	Marta/Alsthom
Urban Mass Transit	Miami, Florida, “Metromover”	Two-way loop in downtown, linked to the regional rail rapid transit system.	1986/ 1994	7.0 km	AEG Westinghouse
Urban Mass Transit	Omiya, Japan,“Ina Line”	Line serves newly developed area, feeder to the regional rail network.	1983	11.6 km	Niigata/ Kawasaki
Urban Mass Transit	Osaka, Japan, “Port Town”	Tram system connecting Nakko Port area to the Osaka subway system.	1981	6.6 km	Niigata/ Vought
Urban Mass Transit	Sakura, Japan, “Yukarigaoka Line”	Line serves newly developed area, feeder to the regional rail network.	1983	4.1 km	Nippon VONA/Mitsui
Urban Mass Transit	Scarborough, Ontario, Canada, “Scarborough RT”	Feeder service from Scarborough Town Center to the Toronto subway system.	1985	7.1 km	UTDC
Urban Mass Transit	Sydney, Australia, “Darling Harbourlink”	One-way loop monorail linking harbour redevelopment area with downtown.	1989	3.5 km	AEG Von Roll
Urban Mass Transit	Taipei, Taiwan	Line haul service.	under const.	10.8 km	Marta
Urban Mass Transit	Toulouse, France	Line haul service.	under const.	10.3 km	Marta

Table C16. Operating Automated People Movers — 1993 (continued)

Type	Location	Description	Start of Service	Length of Guide-way	System Supplier
Urban Mass Transit	Toyonaka, Japan, "Osaka Monorail"	Monorail connecting airport and surrounding residential areas.	1990	13.4	
Urban Mass Transit	Vancouver, British Columbia, Canada "Skytrain"	Line haul service for region, originally opened for Expo '86.	1986/ 1989/ 1994	29.0 km	UTDC/ Bombardier
Urban Mass Transit	Yokohama, Japan, "Kanazawa Seaside Line"	Line serves residential and industrial areas and a seaside park, feeder to the rail rapid transit system.	1990	10.8 km	Niigat/ Mitsubishi
Recreation	Bronx Zoo, Bronx, New York	Low speed monorail, one way loop.	1977	3.0 km	Rohr (AEG Westinghouse)
Recreation	Busch Gardens, Williamsburg, Virginia	One way loop linking brewery, amusement park and hospitality center.	1975	2.1 km	AEG Westinghouse
Recreation	California Exposition, Sacramento, California	Low speed monorail, one way loop.	1969	2.3 km	UMI (Bombardier)
Recreation	Carowinds, Charlotte, North Carolina	Low speed monorail, one way loop.	1973	3.2 km	UMI (Bombardier)
Recreation	Chester Zoo, Liverpool, U.K.	One way monorail loop.	1991	1.5 km	CPM
Recreation	Dallas Zoo, Dallas, Texas	Low speed monorail, one way loop.	1989	2.1 km	VSL
Recreation	Disneyland, Anaheim, California	One way loop.	1967	1.8 km	WEDway (Bombardier)
Recreation	Disney World, Orlando, Florida	One way loop through "Tomorrowland"	1973	1.5 km	WEDway
Recreation	HersheyPark, Hershey, Pennsylvania	Low speed monorail, one way loop.	1969	1.3 km	UMI (Bombardier)
Recreation	Jakarta Cultural Park, Jakarta, Indonesia	One way loop in park.	1989	3.2 km	Sur Coester Aeromovel
Recreation	Jurong Birdpark, Singapore	Low speed monorail, one way loop.	1991	2.0 km	AEG Von Roll
Recreation	King's Dominion, Richmond, Virginia	Low speed monorail, one way loop through "Lion Country Safari."	1975	3.2 km	UMI (Bombardier)
Recreation	King's Island, Cincinnati, Ohio	Low speed monorail, one way loop.	1974	3.2 km	UMI (Bombardier)
Recreation	Magic Mountain, Los Angeles, California	Low speed monorail, one way loop.	1971	1.3 km	UMI (Bombardier)
Recreation	Metro Toronto Zoo, Toronto, Ontario, Canada	One way loop.	1975	5.1 km	Bendix

Table C16. Operating Automated People Movers — 1993 (continued)

Type	Location	Description	Start of Service	Length of Guide-way	System Supplier
Recreation	Miami Metrozoo, Miami, Florida	Low speed monorail, one way loop.	1982	3.2 km	UMI (Bombardier)
Recreation	Minneapolis Zoological Gardens, Apple Valley, Minnesota	Low speed monorail, one way loop.	1979	2.0 km	UMI (Bombardier)
Recreation	Paris Nord Exhibition, Villepinte, Paris, France	Shuttle link from parking to exhibition halls.	1987	.3 km	Soule
Recreation	Sea World Australia, Surfers paradise, Australia	Low speed monorail, one way loop.	1987	2.0 km	AEG Von Roll
Recreation	Seibu Amusement Park, Saitama, Japan	Shuttle link connecting amusement park and baseball stadium.	1985	2.8 km	Niigata

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