Ten Lessons for Automated Highway System Design: A Comparable Systems Analysis

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A comparable systems analysis was performed to identify issues to be considered in the development of an automated highway system (AHS). In the analysis, many comparable systems from four main categories: highway-based systems, vehicle-driver systems, other transportation systems, and nontransportation related systems were considered. This article summarizes the results of this comprehensive analysis. Each of the comparable systems studied shares important features with AHS and is therefore relevant to different aspects of AHS. For example, some of the comparable systems are similar to AHS in that they involve the introduction of a new technology, whereas others have introduced new ways of doing old things irrespective of the technologies involved. Some involved large amounts of financing, and some introduced automation to traditionally manual tasks. The comparable systems have been analyzed to identify relevant lessons for the introduction of AHS from their own applicable perspective. The results from the analysis are synthesized within 10 overreaching issues that are relevant for AHS development. Each issue is supported by evidence from several of the comparable systems. This article presents and defends each issue based on the past experiences from comparable systems.

Our society has undergone extensive changes over the past century 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 high-occupancy vehicle (HOV) lanes], and innovative approaches for introducing new technology within preexisting systems and to old technology users (e.g., the introduction of the automobile) have had to be developed.

The objective of this comparable systems analysis was to draw relevant lessons about designing and managing technologically based change from past experience relevant to AHS. These AHS comparisons and similarities may be associated with specific aspects of AHS, or bear relevance across broad ranges of design, development, and deployment issues.

For each comparable system, an analysis was performed to identify the relevant lessons learned for AHS. This process involved review of literature, interview of subject matter experts, and application of expertise within the study team.

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DISCUSSION

The following paragraphs describe 10 of the overreaching issues identified during this comparable systems analysis. Evidence from selected comparable systems supporting each issue is also discussed.

Issue 1. The Public Must Perceive Overall Benefits

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 nonexistent or nonevident, potential users will likely be unwilling to give up the preexisting 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 from the comparable systems studied supports this conclusion. Experience has shown that people's willingness to purchase new systems and services has been enhanced when these systems and services offer clear benefits in convenience, safety, or cost effectiveness. Findings from the comparable systems studied provide the following examples.

Toll Roads

When the first toll roads were constructed, many believed that they would be unable to generate enough profits and would eventually fail. There were many local roads (already in existence) that could be utilized for no charge, which allowed drivers to travel between the same origins and destinations as the toll roads. Nonetheless, the toll roads were built as limited-access highways, intended for long-distance travel between cities. The toll roads allowed drivers to travel at faster speeds and more safely than they could travel on local roadways. After implementation, toll road use significantly surpassed expectations. Drivers found that the toll was well worth the very significant time savings and improved safety that the toll road offered (*1*).

Video Cassette Recorders (VCRs)

Similarly, people have been unwilling to pay for new systems and services that did not offer significant advantages over existing systems.

RCA discontinued work on video cassette recorders (VCR) in 1978, to concentrate on the development of the videodisk. The videodisk was released to the public in 1980, almost 5 years after the introduction of the VCR. By this time, hundreds of thousands of VCRs, which could both play and record, had been sold in the United States. The videodisk offered the same service to the public (the ability to watch movies at home), but offered fewer features than the VCR (e.g., the videodisk player could not record television programs). Few people were willing to invest in the new technology, and the videodisk has not become as successful in the marketplace as the VCR (*2*).

Our study of comparable systems provides evidence that for AHS to succeed, it must offer the public some obvious advantages and benefits over the conventional highway system. These benefits should be highlighted in the marketing of AHS.

Issue 2. Safety and Reliability Must Be Clearly Demonstrated

There are many factors that may contribute to the public acceptance of AHS. Some important factors include: cost relative to other transportation modes, convenience and ease of use, ability to match users' origins and destinations, impact on pollution, and obviousness of fail-safe features. The safety and reliability of the new technologies used by AHS must also be clearly demonstrated before public acceptance can be achieved.

Any new technology must be proven to be 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 safe operation may face a loss of users if a safety incident does occur. Systems that have a reputation for safety problems have a very difficult time achieving public acceptance.

For these reasons, the safety and reliability of AHS will need to be proven to the public before it will be accepted. The current highway system, although not perfect, is considered by the public to be relatively safe, and experience has shown that people do not completely trust computers and automation. The public is unlikely to believe that AHS is safe until they have observed it for themselves, and the public is also unlikely to accept an automated system that has experienced failures or safety problems. AHS must be demonstrated to operate as expected under all circumstances. If the initial users of AHS experience problems or delays, they will be discouraged from continuing to use the system, and are likely to be reluctant to use the system even after the problems are corrected. This has been the experience of comparable systems which share common attributes with AHS.

It is therefore necessary to demonstrate the safety and reliability of AHS before full implementation. However, public demonstrations that raise safety concerns may do more harm than good, and even prevent the system from ever being accepted. This implies that AHS developers should perform extensive testing before a prototype is demonstrated to the public. The comparable systems analysis has provided many examples to show that demonstrations of safety and reliability can help a new technology to be successful, and that demonstrations that do not accomplish this can have an opposite effect.

Elevators

Elevator-like lifting devices were used by almost all ancient societies. The primary function of these early elevators was to lift heavy objects, although they were occasionally used for transporting people. The modern elevator was developed in the late 1700s, and until 1854, was primarily used to haul freight because of serious concerns about passenger safety. In 1854, Elisha Otis demonstrated his safety elevator at the Crystal Palace Exhibition in New York City. As the public gathered, Otis stood on an elevator platform that was heavily loaded with freight and raised himself 12.2 m (40 ft) in the air. Otis' assistant then cut the rope supporting the platform. The platform jerked downward slightly, then stopped. The safety mechanism successfully engaged and stopped the elevator from falling. The public was shocked by the demonstration, but began to believe that such lifts could be safe for passengers. Soon after these demonstrations, orders began coming in for the "safety elevator," and they began to be installed in buildings worldwide for the transportation of people (*3*).

Supersonic Transport (SST)

Our comparable systems analysis also found examples of detrimental effects from unsuccessful demonstrations. When demonstrations experience problems or result in failure, a negative view of the technology or system can be created. The resulting concerns and negative image can persist even after the problems are corrected.

Advocates for the SST believed that supersonic transportation had no serious drawbacks, because supersonic flight allowed faster air travel than conventional subsonic flight. However, opposition groups identified many problems associated with supersonic flight, including the noise associated with sonic booms. In 1964, during the development phase of the SST, the FAA decided to conduct a series of supersonic tests over Oklahoma City. They wanted to prove to the public that the typical sonic boom was not overly annoying, and that it caused no physical damage on the ground. However, after the tests began, the FAA received over 15,000 complaints about the noise from the booms, and 5,000 claims for damage caused by the tests. The negative publicity resulting from the Oklahoma City tests was never really overcome (*4,5*). Public opposition to SST grew immensely, and the project was eventually canceled.

From the study of these systems, we have concluded that AHS must demonstrate its reliability and safety to the general public before the system can be fully implemented. People must believe that AHS is as safe, or safer, than the traditional highway system. The best way for them to gain this belief is to see the system in operation. However, care must be taken not to provide public demonstrations too early in the design phase, because one unsuccessful demonstration can seriously hinder eventual acceptance by the public.

Issue 3. Secure Long-Term and Continuous Financial Support Deployment

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 the additional funds at a later date. If the funds are not guaranteed, they may be cut at any time. This issue is especially important if AHS must depend on funds from the federal (or state and local) government.

If funding for AHS is derived from government sources, AHS will have to compete with many other projects. The allocation of funds must be approved by many committees, in both the Senate and the House of Representatives, and possibly even by the President of the United States. Therefore, if sufficient funding is not obtained up front, it may be a long, difficult process to obtain additional funding midway through the project. Also, if complete funding is not guaranteed, AHS may be subject to the priorities of a new administration following elections.

Evidence also supports the benefits of pay-as-you-go financing, instead of borrowing funds for a project. Under a pay-as-you-go approach revenues are raised especially for the project and used to fund the project on an as-needed, pay-as-you-go, basis. The funds may be raised from specific and dedicated taxes, private contributions, or user fees. This approach allows the project to control its own resources, and to ensure that the correct funding level is achieved. Borrowing funds for a project usually makes the project dependent on another agency (i.e., the loaning agency) for its resources and may limit the amount of available funds. There are many examples from the comparable systems analysis that provide support for this issue.

Interstate Highway System

In 1955, a bill was presented in Congress that would raise $25 billion through the sale of bonds for the development of the Interstate highway system. However, this bill was defeated because the Senate was unwilling to borrow funds for this project. The Federal Highway Act of 1956, for the construction of the Interstate highway system, promised something for everyone and established a trust fund through which highway users would pay for the Interstate system (*1,6,7*). The premise of the trust fund was that revenue raised from highway users (through gasoline taxes, user fees, etc.) would be placed in a separate account earmarked for the ongoing maintenance of the highway system. The money from this fund could not be diverted to other projects, nor could the Interstate system obtain funding above the level available in the trust fund account. The trust fund (although controversial) allowed the entire Interstate highway system to be constructed and maintained without borrowing funds, whereas the original approach of leveraged funding met with failure because of political opposition.

Downtown People Movers (DPM) Project

Because of the high level of uncertainty for eventual success, and the complexity involved in implementing (and maintaining) a public transportation system, the federal government is usually the only possible customer for the construction of a new people mover system. Unfortunately, the government is often an unstable customer for such expensive and innovative technologies. Priorities change rapidly in the federal government, and often projects must continuously request funding (e.g., annually or at the start of every project phase). At any time, the funding request may be turned down, leaving the project unfinished and with no other financial support. Local governments are reluctant to contribute to the development of these systems unless the financial risks are underwritten by the federal government (*8*). One specific example is the DPM project. The DPM project was established in 1976 to help six cities design and construct fully automated urban transportation systems. In 1981, the federal government cut off funding to the DPM Project before any of the systems could be built. Only three of the six cities (Miami, Detroit, and Jacksonville) managed to continue their projects without federal funding. Each of these cities had received firm commitments for funding from state and local governments, as well as private sources, early in the project (*9*).

To ensure the success of AHS in the United States, it is necessary to secure the necessary funding before the project has begun. This will prevent AHS from having to participate in constant battles over project financing, and will help the project to be completed according to schedule.

Issue 4. High-Level Support Enhances Success of Innovative, Infrastructure-Intensive Projects

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 project. AHS would 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 we studied. Projects without one or more strong supporters have often faced great difficulties at all stages, whereas projects with strong and influential supporters have generally been more successful. Influential supporters for such projects are important throughout all stages of project planning, development, implementation, and during initial stages of operation. Projects with such support are also more readily accepted by the American public.

Automobile Proponents

A number of organizations including lobbying groups for the automobile supply industry, the American Automobile Association, the National Association of Automobile Manufacturers, and the Automobile Club of America, were established to further the rights of motorists and the automobile industry (*10,11*). These groups were willing to spend considerable time and money convincing the government to support the automobile industry, and to provide the necessary funding to improve highways (and other services) for drivers. Although some groups were formed to oppose the automobile, these groups never wielded the power of the automobile proponents. The influence and support from these groups were important factors in the development of the highway system in the United States.

Airplane Travel

In 1932, 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. His flight gave the public confidence in flying, and helped call attention to the speed, availability, and safety of air transport as a routine mode of transportation (*12*). Similarly, when the restriction barring most American movie stars from flying was deleted from film contracts in 1935, many film stars began to fly regularly, again demonstrating to the public that flying did not pose a significant risk. In fact, some European airlines even published a monthly list of all of the celebrities who had flown on their airline that month (*12,13*). Both of these examples illustrate the influence a celebrity endorsement can have on the success of a system. The public often perceives a system to be safe if someone important or famous is willing to use it.

These experiences provide evidence that AHS will be best served if strong supporters can be found to help maintain support and enthusiasm for the project. Such support may help in obtaining funding for the project, in gaining necessary political approval, and in persuading the public to accept AHS.

Issue 5. Evolutionary Development 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 allow the public to gradually learn to use and accept AHS, building from their current experience with Interstate highways. Using this approach, the public will be able to experience AHS on a small scale and to develop confidence in its safety and reliability, before large-scale implementation is introduced.

In addition, the evolutionary approach will make it possible to begin implementation of AHS sooner than if the entire system was to be implemented all at once. A limited capability AHS, requiring fewer changes in highway infrastructure and vehicle technology, could be implemented far earlier than a fully capable system. For example, a mixed-traffic approach to AHS that uses existing highways (in which automatic and manual vehicles share the same lanes) requires less development and preparation time than a system requiring dedicated lanes for automated traffic. As AHS popularity grows, the system may then naturally evolve into a more advanced AHS system.

An evolutionary approach also provides an opportunity to incorporate user feedback into subsequent system designs. User comments and opinions about the early stages of implementation can be collected and applied to later stages. This will ensure that the latter stages of AHS design meet the needs and desires of users, and will help to ensure user acceptance of the final system. Many other technologies have taken an evolutionary approach, and have been quite successful.

High-Occupancy Vehicle (HOV) Lanes

One reason for the success of high occupancy vehicle (HOV) lanes is that they are relatively quick and inexpensive to implement, most often as retrofits into medians or by using existing lanes of congested freeways. They become an evolutionary enhancement to, and an integral part of, the larger highway system. The rules and behaviors required for HOV use differ only slightly from non-HOV lanes, and drivers have been able to adapt easily to their use and to see the immediate improvements in traffic flow resulting from HOV implementation.

Computer Technology

The rapid growth of computer technology has been realized through many small incremental steps. Each improvement has been made in a way that preserves compatibility between the newest technology and the previous generation of technology, facilitating the acceptance and improving the likelihood of success for that improvement. As each new generation of computers has been introduced, it has improved on features of the older systems, better meeting the needs of the users. Computer users have been willing to upgrade their systems to obtain the better technology. This evolutionary approach has made possible many revolutionary changes in the computer industry. Users have been able to slowly become adjusted to computer technology, and to provide feedback to hardware and software developers about what is lacking from the current generation of technology.

Based on the study of these comparable systems, arguments for an evolutionary development of AHS can be made. First, it allows people to become adjusted to the new technology at a slower pace, and prevents them from being totally overwhelmed by the implementation of a large, radically new system. An evolutionary approach also allows the AHS system to be installed in stages, which does not necessitate the system being fully developed before implementation begins. Finally, an evolutionary approach allows the AHS to be changed as necessary to meet the needs and expectations of the users based on initial experience with the system, and allows new technologies to be incorporated as they are developed.

Issue 6. AHS Must Be Designed for Integration Within the Overall Transportation System

Clearly, AHS will be one of many transportation systems available in the United States. It should, therefore, be designed as an integrated part of the overall transportation system. As an integral component of the U.S. transportation system, rather than as an independent competing mode, a large and stable user base will be encouraged.

There may be regions in which geographic or traffic conditions favor AHS, whereas other areas may be less favorable. On the one hand, this will make it possible to select locations for AHS demonstrations, 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.

To meet the goal of integration within the larger transportation system, AHS should be designed to be compatible with the existing highway system. For example, AHS should minimize the number of highway signs and markers that must be redefined. Such incompatibilities would make it difficult for people to adjust to AHS and could cause confusion on manual trips.

In addition, it is important that AHS be standardized throughout the United States and even worldwide. Standardization helps to prevent user confusion, and will support long-distance AHS trips in the future. Designing a standardized system from the early stages will prevent expensive system alterations in the future. Support for this conclusion was found from the study of several comparable systems.

Interstate Highway System

The Interstate highway system has often been implemented in urban areas without high-level system planning. In these cases, the Interstate highway system was perceived as a stand-alone system, not part of a larger interdependent roadway network. The impact of the Interstate on local roadways was not considered during the design stage and was only determined after implementation. This has led to many unforeseen problems of congestion in areas in which local roads were not capable of adequately serving the Interstate highways (*6,7*). In addition, the designers of the Interstate highway system did not anticipate the societal changes that would accompany such a system. They never imagined that the Interstate system could ever become incapable of meeting traffic demands. The highways were designed for long-distance travel, not the commuter traffic that plagues many Interstate highways today. In many areas, it is not possible to expand the highways to meet current traffic demands. Traffic planners in these areas are struggling to find alternate solutions to congestion problems. This lesson emphasizes the need to consider, in advance, the impact of AHS on non-AHS roads and facilities and on the larger transportation system.

Regional Railroads

Each regional railroad in the United States was originally built according to its own specifications for track gauge (the distance between the tracks). The trains were designed to operate only on one specific gauge and thus could not travel beyond the limits of their own system. Over time, the railroads developed methods to permit limited access of trains across a few different gauges. Eventually, all of the railroads standardized their track gauge, requiring the relocation of thousands of miles of railroad tracks to establish an efficient, national railroad system (*14*). Similarly, regional differences in AHS design could require serious rework to permit interoperability in the future.

The study of these comparable systems provides evidence that AHS should be developed using an integrated design approach that considers all aspects of the larger transportation system. To be most effective, AHS should be one integrated part of a larger system. It is also important that AHS developers consider the long-term requirements, and design the system accordingly.

Issue 7. Cost and Time Estimates Must Be Accurately Determined

It is important for the AHS project to maintain a good public image throughout the design, development, and implementation phases. Any negative publicity associated with AHS will simply make the system more difficult for the public to accept and will reduce the number of users on the system. Cost and schedule "bad news" can reduce public acceptance of the system, even when the shortfalls are because of estimation errors, rather than more serious system problems.

The public (and media) often closely monitor the progress of large-scale projects, such as the development of AHS. Projects are expected to be well managed and to be kept under tight control in terms of costs and scheduling.

For this reason, 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 when it is halfway through, or when the project takes significantly longer to complete than predicted. This is especially true for projects financed by public funds. Evidence for this issue has been found in the study of the following comparable systems.

Morgantown Personal Rapid Transit (PRT)

The PRT project was undertaken with an $18 million grant, based on a rough estimate by university officials. In addition, The Urban Mass Transportation Administration, the sponsoring agency, set unrealistic deadlines for the project, which led to incomplete analysis during the initial design phases. Because of the short deadline imposed on the project, the design team attempted to design, develop, and construct the system simultaneously, causing many system deficiencies and problems that required redesign work, increased development costs, and schedule slippage. The extensive cost overruns led to a poor public perception of the Morgantown project, and hindered support for other PRT projects.

Denver International Airport (DIA)

During the 1980s, when the idea for the construction of the new DIA was first proposed, the project was widely supported by the public in Denver. Plans for the new airport included revolutionary new technology, and the airport was supposed to be the most advanced and modern airport in the world. The scheduled opening for the airport was established as October 1994. However, because early progress on the airport was far ahead of schedule, and system promoters were trying to improve public perception of the project, the completion date for the airport was moved up to October 1993. Unfortunately, the opening date for the airport was postponed four times, and the airport did not officially open until February 1995. During the delay, public support for the project wavered. The public began to question whether Denver really needed the new airport in the first place, and whether the money spent on the project should have been spent on other, more important, social and economic programs. A more realistic schedule would have avoided at least some of the devastating negative publicity surrounding DIA.

From the study of these comparable systems, the importance of realistic and achievable budgets and schedules is reinforced. The public expects large-scale projects, such as AHS, to be well managed and to be kept under tight control. Negative publicity resulting from budget overruns or schedule slippage may help sour the public about the system. They may be less willing to accept the system or even to support future AHS projects.

Issue 8. Consortiums of Private and Public Agencies Ensure Long-Term Success

A consortium approach to AHS development can help to ensure that the AHS system is successfully implemented. The consortium approach allows the project to benefit from a wide range of expertise and perspectives, and to share the costs involved with system 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. This recommendation is based on the study of several large-scale systems developed for implementation using a common infrastructure.

It can be noted that the consortium approach differs significantly from the alternative approach of allowing many different companies to bid for the privilege of being the single system designer. This competitive approach frequently involves prototype competition in which prototype systems, designed and built by competing bidders, are judged to see which is the best. This approach has been applied for the development of many large-scale systems. The competitive environment created by this approach encourages the companies involved to invest significant fiscal and sweat equity and are thought to provide the government the best value. However, the systems developed with this approach, although often successful, are usually not oriented for public use and are not dependent on public infrastructure. Also, they do not necessarily promote compatibility across a wide range of independently developed products and services.

In contrast, under the consortium approach there is not a single winner selected on the basis of a parameter-based process. Winners and losers are sorted out in the marketplace. The motivation for investment, participation in the consortium, and diligence to the task comes from increased market share potential that results from design participation. A consortium approach to system development has proven effective in many situations similar to AHS (i.e., large, market-driven systems).

Anytime Teller Machine (ATM) Networks

To compete with Citibank's ATM network, other New York City-area banks joined in a cooperative venture to create an ATM network, which they called The New York Cash Exchange (NYCE). The network approach allowed the participating banks to share start-up and development costs, as well as operating and equipment costs. By pulling together, the member banks were able to develop a more integrated and capable system for providing banking services. This cooperative approach has been very successful. The NYCE system has grown to become a national ATM network. Also, other cooperative banking networks have been developed based on the consortium approach to system development (*15*).

International Air Transport Association (IATA)

In 1944, the airlines and associated government agencies from all nations (except Russia) joined to form the IATA. The IATA established international standards for safety, navigational controls, air maps, and even the international setting of air fares (*12*). This organization helped to make international air travel safe and efficient. These accomplishments would have been very difficult without widespread cooperation.

The consortium approach has proved successful in developing large-scale projects like AHS. The cooperation between various industries and agencies (both public and private) helps ensure that the target system will be well designed, and that the various subsystems will work together effectively. Experience has shown that the use of consortiums can reduce the total cost of system implementation.

Issue 9. Keep the General Public Educated and Informed Throughout Planning, Design, and Development

Our study of comparable systems has shown that it is important for AHS to have public support throughout the development process. Further, the best way to obtain this support is to keep the public well informed about the project, and to provide them with as much information as they require. AHS developers and supporters should make the public aware of the benefits of AHS, and immediately deal with any criticisms or concerns raised. In addition to maintaining support for the program, this will help attract users to the system by allowing them to understand how the system works and the benefits it offers.

It is possible that organized groups may oppose AHS. Our study of comparable systems has led us to conclude that it is necessary to respond immediately to opposition groups, and to address the concerns they may raise. If these groups are able to operate with no response from AHS developers, the AHS project could be hindered, possibly seriously. Public resistance to large-scale projects can be very powerful, and experience on projects similar to AHS has shown that public education can help avoid such resistance.

Ramp Metering

Some locales have rejected ramp metering because of public resistance. Often, perceptions held by some members of the public (e.g., that the metering of ramps will cause unequal access to the highways) has led to increased resistance. When programs of public education are associated with ramp-metering projects, they have been much more successful in avoiding such resistance. This approach has usually facilitated a smooth and orderly implementation of the ramp metering projects.

SST

Throughout the first half of the 1960s, important SST activities and decisions were more or less contained within government agencies. Toward the end of the 1960s, the SST slowly emerged as a matter of public concern. In 1966, the Citizens League Against the Sonic Boom was established, and eventually joined with 13 other organizations to form one unified consortium against SST. The Coalition Against the SST succeeded in lobbying Congress to vote against additional funding for the SST program. In 1971, funding was cut off for the SST, after $623 million had already been spent (*4,5*).

We have concluded, based on our study of comparable systems, that public support for large projects like AHS is critical for their success. Developers cannot expect strong public support unless the public has been involved (or at least well informed) throughout the development process. If AHS does not deal immediately with public questions as they arise, the public may develop serious concerns about the project. Concerned individuals may form organized opposition groups. Such opposition groups can be extremely powerful, especially when the project is dependent on public funding.

In addition to avoiding the potential for public opposition, our research has found that full public disclosure and education is important for avoiding liability problems. According to the definitions of the legal system in the United States, the definition of a defective product and dangerous conditions is based on the perceptions of the general public. It is necessary to inform and educate the public about AHS operation and limitations to help mitigate legal responsibility.

Issue 10. Marketability Is Influenced by Design and Economic Factors

AHS will be just one of several options for travelers. Its design and pricing approaches will affect its potential market base. Innovative approaches to AHS pricing, and the particular sales approaches used, can increase the potential achievable market. Also, the development of the AHS market can be facilitated by "piggybacking" on other markets (e.g., market AHS to those currently using ETTM systems). In planning for AHS marketing, it will also be important to consider prevailing economic conditions.

Obviously, the more people to whom AHS is marketable, the more potential users there are for the system. Limiting the potential market for AHS could exclude a large number of otherwise potential users and result in poor public perception of AHS. To maximize the potential for AHS success, it is best to open up the system to as many categories of users as possible. This approach of seeking the broadest possible market is recommended on the basis of the study of several comparable systems.

Automobiles

Initially, automobiles were marketed and sold as toys for the rich. With the introduction of the mass-produced Model-T, Henry Ford popularized the idea that owning a car was not a luxury, but was something to which every family could aspire. The Model-T was a basic car, offering few luxuries for the occupants. This concept rev-

TABLE 1 Issues Supported by Comparable Systems Analysis

	Issue	Supporting Comparable Systems Studied
1	The public must perceive overall benefits of AHS. Approach AHS design and deployment in ways that will make these benefits obvious.	• Automated teller machines • Automobiles • Commercial flight • Domestic appliances • Electric streetcars • HOV lanes • Office automation • Ramp Metering • Supersonic transport (SST) • Toll roads and limited access highways • Video cassette recorders
2	The safety and reliability of AHS must be clearly demonstrated before public acceptance can be ensured and successful commercial deployment made possible.	• Automated guide way transit systems • Automobiles • Commercial flight • Denver International Airport • Elevators • Interurbans • Maglev rail systems • Supersonic transport (SST)
3	Secure long-term and continuous financial support for AHS deployment. Funding must be sufficient, specific to the goals of AHS, and continuous. Pay-as-you-go financing is preferable to borrowing.	• Automated guideway transit systems • Interstate highway system • Interurbans • Maglev rail systems • Supersonic transport (SST)
4	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.	• Automobiles • Automated guideway transit • Commercial flight • Maglev rail systems • Supersonic transport (SST) • Toll roads and limited access highways • Typewriters
5	Evolutionary development of AHS is recommended. This will provide for incremental development and deployment, 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.	• Automated guideway transit • Automated teller machines • Air traffic control (ATC) system • Automobiles • Chunnel • Commercial flight • Domestic appliances • Elevators • HOV lanes • Personal computers • Railroads • Ramp metering

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TABLE 1 *(continued)*

	Issue	Supporting Comparable Systems Studied
6	AHS must be designed for integration within the overall transportation system in the United States and worldwide. AHS components should be standardized for all AHS applications, and should be as compatible as possible with existing conventions.	• Automated guideway transit • Domestic appliances • HOV lanes • Interstate highway system • Railroads • Ramp metering • Supersonic transport (SST) • Video cassette recorders
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.	• Automated guideway transit • Chunnel • Denver International Airport • Supersonic transport (SST)
8	Consortiums of private and public agencies can help to ensure the long-term success of AHS research, development, and implementation.	• Automated teller machines • Automobiles • Commercial flight • Railroads
9	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, and deal forthrightly with public concerns.	• Automated guideway transit • Automobiles • Commercial flight • Interstate highway system • Liability considerations for automobile systems • Ramp metering • Supersonic transport (SST)
10	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.	• Automated guideway transit • Automated teller machines • Automobiles • Domestic appliances • HOV lanes • Office automation • Typewriters • Video cassette recorders

olutionized the automobile industry and ingrained the automobile into American society. It also ultimately made the automobile industry a major part of the American economy.

Typewriters

The early typewriter was initially marketed to clergy, writers, and scholars, who were unwilling to accept the new invention. In their work, typed letters were considered offensive and raised questions of authenticity. There was, however, a growing need for such a device in the business community. Businessmen were less concerned with the social norms involved with handwritten letters, and desired a method to quickly and neatly record business activities for internal use. The typewriter was ideally suited for this purpose. It took almost 10 years after the introduction of the typewriter for the developers to recognize their market. Once the market for the typewriter was expanded to include business, the previously fledgling typewriter business became one of the fastest growing markets in the country (*16*).

The study of these comparable systems provides evidence that limitations in the market for AHS (e.g., by limiting the systems to passenger cars only) can limit the eventual success of the system. AHS developers need to assess the impact of including various segments of the transportation market within the AHS market served. Widening the market for AHS can lead to increased use of the system, which in turn will help reduce operating costs per person and allow AHS to gain more sufficient market size. This can be an important factor in long-term AHS success.

CONCLUSIONS

Significant lessons for AHS can be learned from the study of past systems that share important features with AHS. For example, insights for AHS may be provided from systems that involve new technology, new ways of doing old things, large infrastructure requirements, long development time requirements, extensive financing needs, and ideas that initially sound radical.

The study of the selected comparable systems has led to the identification of 10 issues that are highly relevant to AHS. These issues have been identified based on the experiences gained from previously implemented systems. Evidence from several of the comparable systems studied supports each issue. Table 1 describes each issue and summarizes the comparable systems from our larger study that provide supporting evidence for the issue.

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REFERENCES

1. Heppenheimer, T. A. The Rise of the Interstates. *American Heritage of Invention and Technology*, Vol. 7, No. 2, 1991, pp. 8–19.
2. Diebold, J. Audiotape, Videotape, and Videocassette Recorders: American Gifts to the Japanese. In *The Innovators: The Discoveries, Inventions, and Breakthroughs of Our Time.* Dutton, New York, 1990, pp. 203–226.
3. Ford, Barbara. *The Elevator*, Walker and Company, New York, 1982.
4. Horwitch, M. *Clipped Wings: The American SST Conflict.* Massachusetts Institute of Technology Press, Cambridge, Mass. 1982.
5. Levy, E. *The People Lobby: The SST Story.* Delacorte Press, New York, 1973.
6. Kelly, Ben. *The Pavers and the Paved.* Donald W. Brown, New York, 1971.
7. Leavitt, Helen. *Super Highway—Super Hoax.* Doubleday & Company, Garden City, N.J., 1970.
8. *Impact of Advanced Group Rapid Transit Technology*, Report OTA-T-106. Office of Technology Assessment, Washington, D.C., 1980.
9. *People Mover Profile*, Report UMTA-MA-06-0081-77-1. Urban Mass Transportation Administration, Washington, D.C., 1977.
10. Finch, Christopher. *Highways to Heaven: The AUTO Biography of America.* Harper Collins Publ., New York, 1992.
11. Rae, John B. *The American Automobile: A Brief History.* University of Chicago Press, Chicago, Ill., 1965.
12. Solberg, Carl. *Conquest of the Skies: A History of Commercial Aviation in America.* Little, Brown, Boston, Mass., 1979.
13. Hudson, Kenneth. *Air Travel: A Social History.* Rowman and Littlefield, Totowa, N.J., 1972.
14. Stover, John F. One Gauge: How Hundreds of Incompatible Railroads Became a National System. *American Heritage of Invention and Technology*, Vol. 8, No. 3, 1993, pp. 54–62.
15. Diebold, J. The Electronic Bankers: The Rise and Spread of ATMs. In *The Innovators: The Discoveries, Inventions, and Breakthroughs of Our Time.* Dutton, New York, 1990, pp. 177–202.
16. Monoco, C. The Difficult Birth of the Typewriter. *American Heritage of Invention and Technology*, Vol. 4, No. 1, 1988, pp. 10–21.

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