INTELLIGENT VEHICLE HIGHWAY SYSTEMS: CHALLENGE FOR THE FUTURE

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Abstract

Intelligent Vehicle Highway Systems is a new paradigm for transportation in this nation. It involves the integration of technology in areas such as communications, information systems, sensors, and operation research methods with conventional transportation infrastructure to address many transportation issues that confront the nation at this time. It is a fundamentally new way of thinking about transportation.

IVHS has the potential for substantially improving our transportation systems. The goals and objectives of IVHS include improved safety, reduced congestion, increased and higher quality mobility, improved environmental quality and energy efficiency, improved economic productivity, the development of an IVHS supply industry in the United States, major changes in the transportation profession, and the development and deployment of a variety of new technologies and new partnerships between the public and private sector.

While IVHS has the potential, substantial work needs to take place if IVHS is to be successful. In this paper, we have discussed the institutional barriers that IVHS faces Further, there are important hardware and software technological challenges that must be met.

Introduction

In 1986, an informal group of academics, federal and state transportation officials, and representatives of the private sector began to meet to discuss the future of the surface transportation system in the United States. These meetings were motivated by several key factors.

First, the group was looking ahead to 1991 when a new federal transportation bill was scheduled to be enacted. It was envisioned that this 1991 transportation bill would be the first one in the post-Interstate era. The Interstate system, a $120 billion dollar program, had been the keystone of the highway system in the United States since the mid-1950s. By 1991 this project would be largely complete. A new vision for the transportation system in the United States needed to be developed.

Second, despite the advances in highway transportation in the United States brought about by the development of the Interstate, a large number of major problems remained. First, congestion had been growing dramatically over the past twenty to thirty years—leading to gridlock conditions in a number of US cities. Further, it was clear that we could no longer build our way out of these congestion problems because of economic, political and social constraints, particularly in urban areas.

From the highway passenger's viewpoint, traffic delays are substantial and growing. Rush hour conditions in many metropolitan areas often extend throughout the day. The percentage of peak hour travel on urban interstates that occurred under congested conditions reached 70% in 1989, up from 41% in 1975. Urban freeway delay is now 2 billion vehicle hours per year - about 65% of this due to non-recurring incidents.

Further, safety problems abound. Safety on our nation's highways is an important public health problem. In 1991, the US paid the extraordinary costs of 41,000 deaths and 5,000,000 injuries on our highways. Traffic accidents cost the US an estimated $70 billion in lost wages and other direct costs annually.[1] The economic loss from traffic crashes is 2% of the US gross national product. It amounts to $.05 per vehicle-mile traveled or $600 per year per motor vehicle.

Also, the US was (and is) concerned with the environmental impacts of transportation and the energy implications of various transportation policies. Any new initiatives in the surface transportation world had to explicitly consider environmental and energy issues.

The third major motivation for considering the future of surface transportation is national productivity and international competitiveness, both closely linked to the efficiency of our transportation system. In 1986, our major economic rivals in western Europe (Project Prometheus) and Japan (Project AMTICS and RACS) were advancing very quickly in areas involving the development of new technologies for use in advanced surface transportation systems. Their use of high technology concepts in the information systems and communications areas were envisioned as having the opportunity to revolutionize the world of surface transportation, improving the competitiveness of these nations and providing them with an important new set of industries and markets.

Thus, the small group saw before it an opportunity based upon:

- New transportation legislation (at that time five years in the future),
- concern for continuing transportation problems in the US despite major investment in the transportation system, and
- the development by our economic competitors in western Europe and Japan of various technologies that could enhance their industry posture and their productivity.

[1]FHWA, *Intelligent Vehicle Highway Systems — A Public/Private Partnership*, October 1991.

The essential concept was a simple one: marry the world of high technology and dramatic improvements in areas such as information systems, communications, sensors and advanced mathematical methods with the world of conventional surface transportation infrastructure; provide capacity that can no longer be provided with concrete and steel with technological advances; improve safety through technology enhancements and better understanding of human factors; and provide transportation choices and control transportation system operations through advanced operations research and systems analysis methods.

The small group became "Mobility 2000" which produced a landmark document in 1990[2], laying out a vision for what came to be called IVHS (Intelligent Vehicle Highway Systems) which was defined as "a system which applies technologies of communications, control, electronics and computer hardware and software to the surface transportation system".

In 1990, the need for a formal organization became clear and IVHS America (the Intelligent Vehicle Highway Society of America) was formed as a utilized Federal Advisory Committee for the US Department of Transportation. Currently, IVHS America has 250 organizational members.

In December 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) became law. It's purpose was "...to develop a National Intermodal Transportation System that is economically sound, provides the foundation for the Nation to compete in the global economy, and will move people and goods in an energy efficient manner."

As was envisioned in 1986, IVHS was an integral part of ISTEA with $660 million allocated for research, development and operational tests. This, together with substantial state and local government funds and private investment, suggests that IVHS will be a critical component of the US transportation landscape for the 21st century.

In June 1992, IVHS America produced a "Strategic Plan for Intelligent Vehicle Highway Systems in the US" and delivered it to DOT as a 20-year blueprint for research, development, operational testing and deployment.

The vision for IVHS was articulated as follows:

- A national system that operates consistently and efficiently across the US to promote the safe, orderly and expeditious movement of people and goods.
- An efficient mass transit system that interacts smoothly with improved highway operations.
- A vigorous US IVHS industry supplying both domestic and international needs.

Transportation & Technology

The marriage of transportation and technology is a phenomenon that has existed throughout human history. In the early part of this century, innovation in construction and manufacturing technologies made the current transportation system possible. We now have the need for a new round of technological innovation, appropriate to the transportation issues of today.

[2] *Proceedings of a National Workshop on Intelligent Vehicle/Highway Systems Sponsored by Mobility 2000*, Dallas, TX, 1990.

The US has evolved as an information and communications intensive society with extraordinary improvements in the cost and performance of computational and communications systems. These technologies have provided the basis for this evolution and they can be combined with conventional transportation infrastructure to form Intelligent Vehicle Highway Systems (IVHS). This is the transportation/information infrastructure, a new approach to surface transportation.

The transportation/information infrastructure is a paradigm shift; it is a new way of looking at, thinking about, and improving mobility. The transportation/information infrastructure creates a new range of important improvements by providing information and control assistance to the traveler through in-vehicle and hand-held devices, by improving the ability to coordinate transportation operations in metropolitan areas, and by providing travel choices and aid in selecting the best trip for a particular traveler. It can transform individual mobility into an integrated system.

Functional Areas in IVHS

It is convenient to think of IVHS in terms of six areas. This gives us a framework within which to discuss the various functions and operations of a fully deployed IVHS system.

- **Advanced Traffic Management Systems (ATMS).** ATMS will integrate management of various roadway functions. It will predict traffic congestion and provide alternative routing instructions to vehicles over regional areas to improve the efficiency of the highway network and maintain priorities for high-occupancy vehicles. Real time data will be collected, utilized, and disseminated by ATMS systems and will further alert transit operators of alternative routes to improve transit operations. Dynamic traffic control systems will respond in real time to changing conditions across different jurisdictions (for example, by routing drivers around accidents). Incident detection will be a critical function in reducing congestion on the nation's highways.
- **Advanced Traveler Information Systems (ATIS)** Advanced Traveler Information Systems involves providing data to travelers in their vehicle, in their home or at their place of work. Information will include: location of incidents, weather problems, road conditions, optimal routings, lane restrictions and in-vehicle signing. Information can be provided both to drivers and to transit users and, in fact, can provide information to people before their trip to decide what mode they should take.
- **Advanced Vehicle Control Systems (AVCS).** AVCS is viewed as an enhancement of the driver's control of the vehicle to make travel both more safe and more efficient. AVCS includes a broad range of concepts that will become operational on different time scales.

  In the near term, collision warning systems would alert the driver to a possible imminent collision. In more advanced systems, the vehicle would automatically break or steer away from a collision. Both systems are autonomous to the vehicle and can provide substantial benefits by improving safety and reducing accident induced congestion.

  In the longer term, AVCS concepts would rely more heavily on infrastructure information and control that could produce improvements in roadway throughput of two to four times. Movements of all vehicles in special lanes are automatically controlled. One could envision cars running in closely spaced (headways of less than one foot) platoons of ten or more, at normal highway speed, under automatic control.

The above three, ATMS, ATIS, and AVCS, are all technological functions of IVHS. ATMS and ATIS will have early applications in urban and suburban areas. AVCS is envisioned as a longer term program.

In addition, there are three major applications areas that are already beginning to draw upon IVHS technologies. These are:

- **Commercial Vehicle Operations (CVO).** In CVO, the private operators of trucks, vans, and taxis have already begun to adopt IVHS technologies to improve the productivity of their fleets and the efficiency of their operations. This is proving to be a leading edge application because of direct bottom-line advantages.
- **Advanced Public Transportation Systems (APTS).** APTS can use the above technologies to greatly enhance the accessibility of information to users of public transportation as well as to improve scheduling of public transportation vehicles and the utilization of bus fleets.
- **Advanced Rural Transportation Systems (ARTS).** The special economic constraints of relatively low density roads and the question of how IVHS technologies can be applied in this environment is a challenge that is being undertaken by many rural states.

Institutional Issues

While there are important technological and systems issues to work on in the IVHS area, of equal importance are various institutional issues that must be addressed if IVHS is to be successfully deployed. Several are discussed below.

Public-Private Partnerships

An important issue is the need for a public-private partnership for IVHS deployment. One can contrast IVHS with the Interstate System, the major transportation program in this nation in the twentieth century. The Interstate System could be characterized as a public works system - the funding was exclusively provided by the public sector and the fundamental decisions about the deployment of the Interstate System were made by the public sector.

IVHS, on the other hand, will require deployment of infrastructure, largely by the public sector, and in-vehicle equipment by the private sector. In the Strategic Plan, it is estimated that of the $230 billion to be spent on IVHS over the next twenty years in this country, about eighty percent of it will be private, with the remaining twenty percent of it to be expended by the public sector. Therefore, IVHS can be characterized as both a <u>public works</u> <u>and</u> a <u>consumer product</u> system. This will require unprecedented levels of cooperation between the public and private sectors if IVHS is to work effectively as a national "seamless" system. The hardware and software in the infrastructure must be compatible with the hardware and software in the privately acquired in-vehicle equipment.

While stand-alone ATMS (i.e. infrastructure) and ATIS (i.e. in-vehicle equipment) could work well, researchers are convinced that coordinated use of ATMS and ATIS will be much more effective than stand-alone systems of either type. Therefore, for optimal system operations, coordination and compatibility between ATMS and ATIS is essential. This requires close cooperation between the public and private sector. In the United States, this cooperation has not traditionally been strong. Often the public and private sector view each other in a confrontational rather than a cooperative way. So IVHS presents an important set of institutional challenges in developing an effective public/private partnership for IVHS research and development, testing, and deployment.

Organizational Change

A second institutional question is the need for organizational change brought about by IVHS. For example, our state Departments of Transportation have been based, for many decades, upon the technology of traditional civil engineering. Highway construction and maintenance have been the charter of state DOTs and, in fact, they have produced a highway system that is unrivaled in the world.

However, that world is changing with socio/political/economic constraints and with IVHS coming on the scene. Now, rather than dealing with the conventional civil engineering technologies of structures, materials, geotechnical engineering and project management, state DOTs need to be concerned with electronics, information systems, communications and sensors. DOTs will need to emphasize the operation of the transportation system rather than construction and maintenance.

This is a rather fundamental shift for these public organizations and they will have to make a difficult transition over the next several decades if IVHS is to be successfully deployed around this nation. A whole new set of professionals will need to be attracted to these public sector organizations and fundamental changes in the mission of these organizations must come about.

Academia and the Transportation Research Community

The development and deployment of IVHS imply important issues for academia, both in research and in the education of new transportation practitioners. The academic community has a major role to play and has already seen an opportunity in IVHS as a number of active programs have already been initiated (e.g., University of California, University of Michigan, University of Minnesota, University of Texas, Texas A&M, MIT and others).

The most important function of academia is the development of educational programs and the education of transportation professionals. Since the deployment of IVHS implies change for transportation organizations (such as those described above), a broader education of the transportation professional, including areas such as software systems, communications, a variety of systems analysis and operations research methodologies, information systems, and institutional studies will be required. What is needed is a "new transportation synthesis" as an educational model for the 21st century transportation professional. The development of that synthesis and the education of a new kind of transportation professional will be a critical contribution by the academic community.

Academia also has an important role to play in research activities in the IVHS arena. Academia will be a major participant, both in assessing the current state of likely technological improvements and as a major participant in basic and applied research and development.

Indeed, there is a close tie between the research programs and the new transportation synthesis noted above. IVHS research will require the talents of faculty in areas that have not traditionally been involved in transportation. The access to interesting research problems, as well as to funding, provides the pathway and motivation for new faculty to participate in transportation research in the university. It will be essential to engage those faculty members in transportation education and the new transportation synthesis. That approach has worked effectively in fields such as manufacturing and biomedical engineering and IVHS is an opportunity to make it happen in transportation more broadly as well.

Success in IVHS will require progress in three areas - the "triad" of technology, systems, and institutions and management. The development and integration of advanced technology into the transportation infrastructure are central to IVHS. Systems level activities, including network operation, economic analysis, optimization, and simulation are likewise fundamental. Finally, institutional and management issues such as public/private partnerships, intergovernmental relations and legal questions are also of prime importance.

These three areas require a breadth of capabilities not captured by many organizations. The modern research university is best suited for such broad activities. These universities, with their dual roles in education and research, have built broad faculties in engineering, management, political science, and technology policy. They often undertake mission-oriented work that requires the broad vision and expertise described above. By addressing the triad in an effective way, research universities have a unique role to play in the IVHS arena.

Summary

This paper has focused on the new paradigm for transportation, IVHS. Technological and organization challenges remain before it can be deployed, involving a wide variety of professionals. This paper serves to introduce IVHS as a concept to the microwave community.

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About the Author

The author served as the first "Distinguished University Scholar" at IVHS America while on sabbatical from MIT for the 1991/1992 academic year. During that time, he was a member of the core writing group for the "Strategic Plan for IVHS in the United States" **(Strategic Plan)**. Report No.: IVHS-AMER-92-3, Prepared by IVHS AMERICA, May 20, 1992. Parts of this article are drawn from that document.